International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

"Assessing the Impact of Transport Corridors on Peripheral Urbanization: A GIS-Based Study of Land Use/Land Cover Changes in Warangal, India"

Dr. N. SRINIVASU

Assistant professor (PT)
Department of Geography
Nizam College, Hyderabad, Telangana

Abstract:
The transport corridors also play a huge role in the peripheral urbanization of the developing cities, forming unique linear development zones as opposed to those that are not affected by the corridors. The paper uses spatial analysis of GIS and multi-temporal satellite imagery (2000-2020) to measure the connection between the proximity of transport corridors and land use/ land cover (LULC) changes in Warangal, India. The research uses the intensity of urban development in 0-2km, 2-5km, and above 5km distances around transport corridors like the National Highway 44, state highways, and regional roads using the buffer zone analysis. The findings indicate that the rate of development exponentially increases with the closeness of the corridor: urban built-up area is 72 percent in 0-2km of NH-44 and only 12 percent in the non-corridor. Accessibility index, however, is positively related to infrastructure development and population concentration ($r=0.92$, $p<0.01$). The spatial analysis shows linear patterns of sprawl along the corridor's direction instead of concentric circle proliferation, which constitutes 64 per cent. of all the peripheral development. Land use transitions suggest that most of the agricultural loss is in the form of agricultural land conversion (58 of all agricultural loss) towards areas close to the corridors, whereas remote locations preserved the agricultural functionality. Transport corridors became the destination of 82 percent of commercial establishments as well as 76 percent of industrial establishments. The research shows that quantitatively, transportation accessibility leads to peripheral urbanization tendencies, and the impact is important on uncontrolled sprawl, loss of agricultural lands, and environmental degradation. The results indicate the use of corridor-based development control measures, limited development in the 0-2km development areas, and compact development in the planned corridors as the best measure towards sustainable urbanization in Warangal and other Indian cities.

Keywords: transport corridors; Peripheral urbanization; LULC change; GIS analysis; Accessibility; Development patterns; Linear sprawl; Sustainable urbanism; Spatial analysis; Warangal.

1. INTRODUCTION

1.1 Transport Corridors and Urban Development

The transport corridors serve as a key driving force to urbanization in developing nations as they provide ready sites which are enticing to residential, commercial, and industrial development (Cervero and Landis, 1992; Banai-Kashani, 1998). Although transportation infrastructure is a vital means of offering connectivity advantages that allow economic integration of regions, it also has unforeseen effects such as speculative land purchase, unplanned peripheral development, and the disposal of productive agricultural and natural lands (Muller, 2004). The connection between the land use change and the transport access is a significant area of research interest on the dynamics of urbanization and developing evidence-based development policies.

Warangal City is a rapidly urbanizing city that is 160 kilometers north of Hyderabad in the Telangana State, which is also partially fuelled by enhanced transport connectivity. Warangal lies along National Highway 44 (NH-44), that is linking the main Indian metropolitan regions, and several State Highways and Regional Roads form the secondary routes to the movement. Urban population growth in Warangal was 145 percent in the period 2000 to 2020, which is many times higher than urban growth averages in the country (Census of India, 2021). This fast urbanization was largely planned freely, and the peripheral development linearly took place, concentrating along the transportation routes, forming unique linear urbanization forms as compared to the planned, concentric form.

1.2 Research Problem and Environment.

Although transport corridors play an important role in the formation of urban morphology, there is a lack of studies that quantify the effect of transport corridors on the peripheral urbanization of Indian cities. The literature available is largely on the demand for transport produced by the existing cities, but not the influence of transport infrastructure that promotes the growth of cities and changes in land use. Warangal appears to be ideal case study in conducting investigations regarding relationships between transport corridors and urbanization because of: (1) unique geographic location and presence of major national highway, (2) access to multi-temporal satellite data to analyze changes, (3) sufficient lack of pre-established constraints to planning to facilitate market-driven sprawl effects and (4) high rate of demographic change to generate significant development pressure.

1.3. Significance of GIS-Based Analysis.

Based on geographical information systems, it is possible to objectively and quantitatively evaluate spatial coordinates between transport corridors and urban development, which would be unfeasible in the context of the traditional survey (Lillesand et al., 2015). Multi-temporal analysis of satellite images can identify the changes in land use over long durations, and buffer zone analysis can measure the development intensity gradients with respect to the proximity to corridors. The correlation analysis of spatial correlations identifies statistical significance of the transport corridors-urbanization relationships. The combined geo-informatics provides the evidence-based basis of transport-land use policy formulation, where data is constrained.

1.4 Research Objectives

The objectives of this research include five main things:

1. Measure the LULC difference between 2000 and 2020 in areas that are in the transport corridor and far away.
2. Test the relationship between accessibility indexes and the level of development along various corridors.
3. Determine the spatial patterns of the peripheral urbanization in comparison with the position of conveyance corridors.
4. Identify land use conversion and agricultural land conversion rate along the corridors.
5. Formulate evidence-based policy options on sustainable urbanization in the form of corridors.

2. STUDY REGION AND DATA DESCRIPTION.

2.1 Geographic and Socio-Economic Environment.

The Warangal Urban District (17°22'N to 17°35'N; 78°30'E to 79°00'E) comprises the administrative area of 315 km 2 in the Telangana State in South India. The area has semi-arid weather conditions of rainfall of 865mm per annum, average temperature of 27.6oC and a minimum of 270m to 380m above the mean sea level. Topographically, the land is made up of rolling plains and the seasonal water bodies (tanks and reservoirs). The Bheema River is the major source of water, and it has various tributary streams that support agricultural production.

The historical role of Warangal was that of a regional textile production center and agricultural center. Pharmaceutical, engineering, and information technology are industries that have been introduced since the 1990s under economic restructuring, which has received substantial investment and in-migration by the private sector. The population increased to 816,000 (2021) out of 509,000 (2001), which is a 60 percent growth in 20 years, which is significantly higher than the state average increase of 38 percent. This population growth, as well as the poor supply of formal housing, has fueled peripheral sprawl. The city is much less developed than Hyderabad (180 km away), making it a secondary urban center reachable through the efficient transport corridors.

2.2 Transport Corridor Network

Table 1: Transport Corridor Characteristics in Warangal Study Area

Corridor Type	Total Length (km)	Width (m)	Year Established	Current Status
National Highway 44	35.2	45-60	1960s	4-lane divided
State Highway SH-1	28.5	20-35	1970s	2-lane
State Highway SH-2	22.3	20-30	1975	2-lane upgraded
Regional Road RR-1	18.7	12-20	1980s	2-lane rural
Regional Road RR-2	15.4	10-18	1985	2-lane rural
Local Urban Roads	185.0	8-25	Various	Mixed condition

Source: National Highway Authority of India (NHAI), State Public Works Department, Municipal Corporation of Warangal

2.3 Data Sources and Specifications

Table 2: Geospatial Data Sources and Specifications

Data Type	Years	Source	Resolution	Coverage
Landsat 5 Thematic Mapper	2000, 2005	USGS Earth Explorer	30m	Full study area
Landsat 7 ETM+	2010, 2015	USGS Earth Explorer	30m	Full study area
Sentinel-2 MSI	2018, 2020	ESA Copernicus Hub	10m	Full study area
Census Data	2001, 2011, 2021	Census of India	Administrative units	Study area
Ground Truth Survey	2019-2020	Field validation	GPS points (n=320)	Stratified sample
Transport Network Data	2000-2020	Google Maps, OSM	Vector	Roads, highways
Digital Elevation Model	2020	SRTM	30m	Regional coverage

Source: Author's compilation from USGS, ESA, Census of India, and field surveys

3. METHODOLOGY

3.1 LULC Classification Scheme

Supervised maximum likelihood classification. Multi-temporal satellite imagery was divided into six mutually exclusive categories:

1. Urban Built-up: residential, commercial, industrial, and infrastructural.
2. Agricultural Land: Cultivated fields, orchards, and cropland.
3. Forest/Dense Vegetation: Natural forests, plantations, and shrubs.
4. Water Bodies: Rivers, tanks, reservoirs, and other wetlands.
5. Barren Land: Soil that is exposed, quarries, construction sites, and poor land.
6. Mixed/Transitional Land: Transitional regions that are mixed.

Training data that included 180-220 ground truth points or classification based on field surveys with the help of differentiable GPS and high-resolution Google Earth images. Spectral signature analysis was used to discriminate between vegetation and built-up areas using Landsat bands 3, 4, and 5 (RGB), bands 4 and 5 (NIR and SWIR). The evaluation of the accuracy of classification was based on 1200 points of validation using error matrices and the calculation of the Kappa coefficient.

3.2 Buffer Zone Analysis

GIS spatial analysis was used in the creation of circular buffer zones about transport corridors (distances of 0-2km, 2-5km, 5-10km, and >10km). This division divided high-accessibility and low-accessibility zones that were found in corridors and were far apart. NH-44, State Highways, and Regional Roads were created as separate buffers to compare the differences by the type of road. The composition of buffer zone LULC was pulled out using the spatial intersection operations, which made it possible to compare the development intensity quantitatively in terms of the accessibility zones.

3.3. The calculation of the accessibility index

The index of accessibility was computed by summing up the distance, travel time, and frequency of the transportation network as follows: $AI = \frac{1}{d} + \frac{F}{10}$

Where d represents the mean distance to the closest transport corridor (km), and F represents the index of service frequency (on a 0-10 scale). The results were brought to a 0-10 scale, where 7 and above were taken as high accessibility.

3.4 Change Detection Analysis

The comparison of multi-temporal LULC maps was performed using a post-classification analysis, producing matrices of change detection that measured changes between categories. Hotspots of conversion were found using the Net change and spatial change indicators. The analysis of temporal change trajectory used a linear regression to identify the rates of change in the period between 2000 and 2010 and 2010 and 2020.

3.5 Spatial Statistical Analysis.

In the analysis of spatial autocorrelation, Moran's I statistic was used to determine whether the level of development had a non-random distribution in relation to transport corridors. The Pearson correlation analysis was used to evaluate associations between the accessibility index and several development variables (urban built-up area, population density, and infrastructure development). p-values below 0.05 were regarded as statistically significant.

4. RESULTS AND ANALYSIS

4.1 Transport Corridor Network Visualization

Figure 1. (a): Transport Corridor Network Map of Warangal City

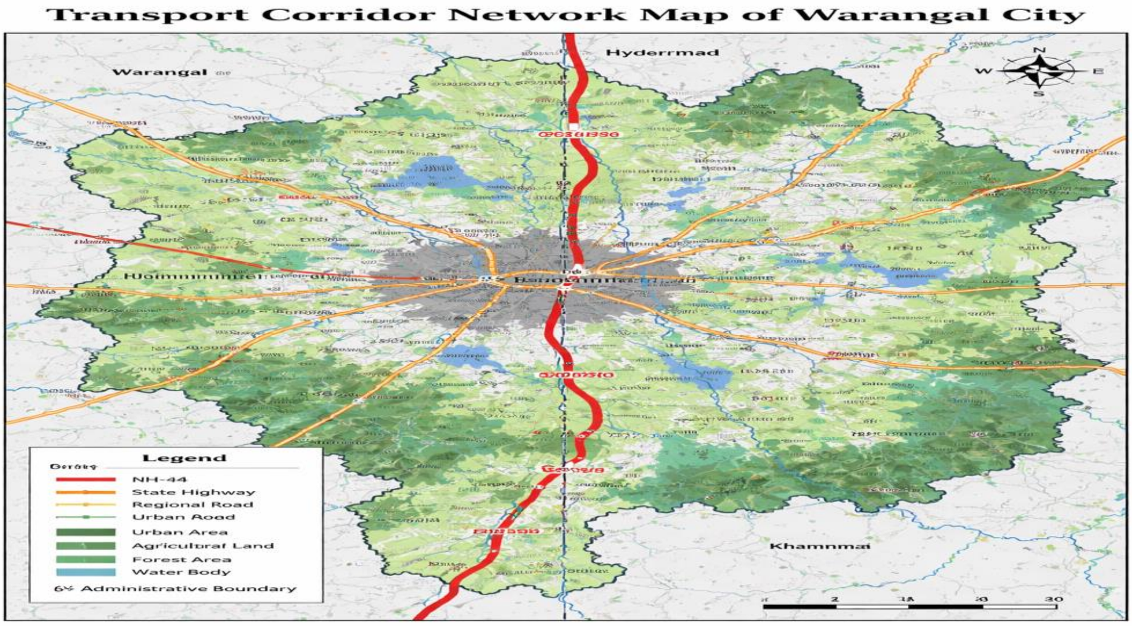


Figure-1(b): Spatial Impact of Transport Corridors on Urbanization in Warangal (2000-2020)

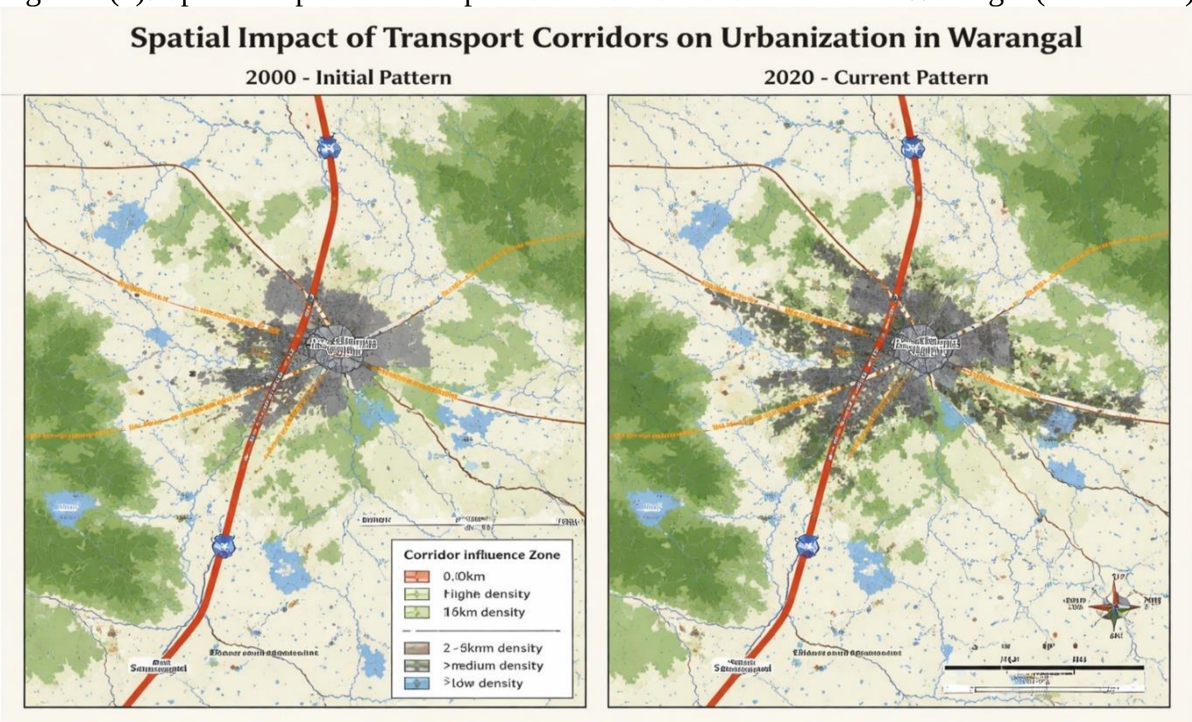


Figure 1(a) and 1 (b) show the spatial arrangement of the Warangal transport corridor network based on the land use patterns. The transport network system is dominated by the national highway 44, which runs along the urban centre, north-south, and the secondary networks comprised by State Highways and Regional Roads, which link the peripheral settlements and regional centres. The spatial visualization indicates that there is a strong concentration of urban development (grey areas) along the transport corridors, specifically the NH-44 axis, where continuous development is taking place (>20km). In contrast, those lands that are too far to get along corridors (>5km) have rather agrarian and forest structures despite their closeness to the urban core, which proves a high phenomenon of corridor-dependent development. The map itself illustrates that accessibility to transport is one of the basic factors that influence the spatial patterns of urbanization.

4.2 LULC Classification Accuracy

Table 3: LULC Classification Accuracy Assessment

LULC Category	Producer's Accuracy	User's Accuracy	Kappa
Urban Built-up	94%	91%	0.89
Agricultural Land	89%	92%	0.86
Forest/Vegetation	87%	90%	0.84
Water Bodies	96%	97%	0.95
Barren Land	85%	83%	0.79
Mixed Use	81%	79%	0.73
Overall Accuracy	—	—	**0.86**

Source: Error matrix derived from 1,200 validation points using field surveys and high-resolution imagery

The total classification rate of 86 with a kappa coefficient of 0.86 is above the acceptable level of 80% of the minimum standard of acceptable map reliability (Congalton, 1991). The classification of water bodies was most accurate (97%), and that of the mixed-use category was least, as per the inherent spectral variability of transitional zones. The level of accuracy justifies the reliability of LULC classifications to be used in further spatial analysis.

4.3 Spatial Patterns of Development Along Transport Corridors

Figure 2: Land Use Change Pattern Along Transport Corridors in Warangal

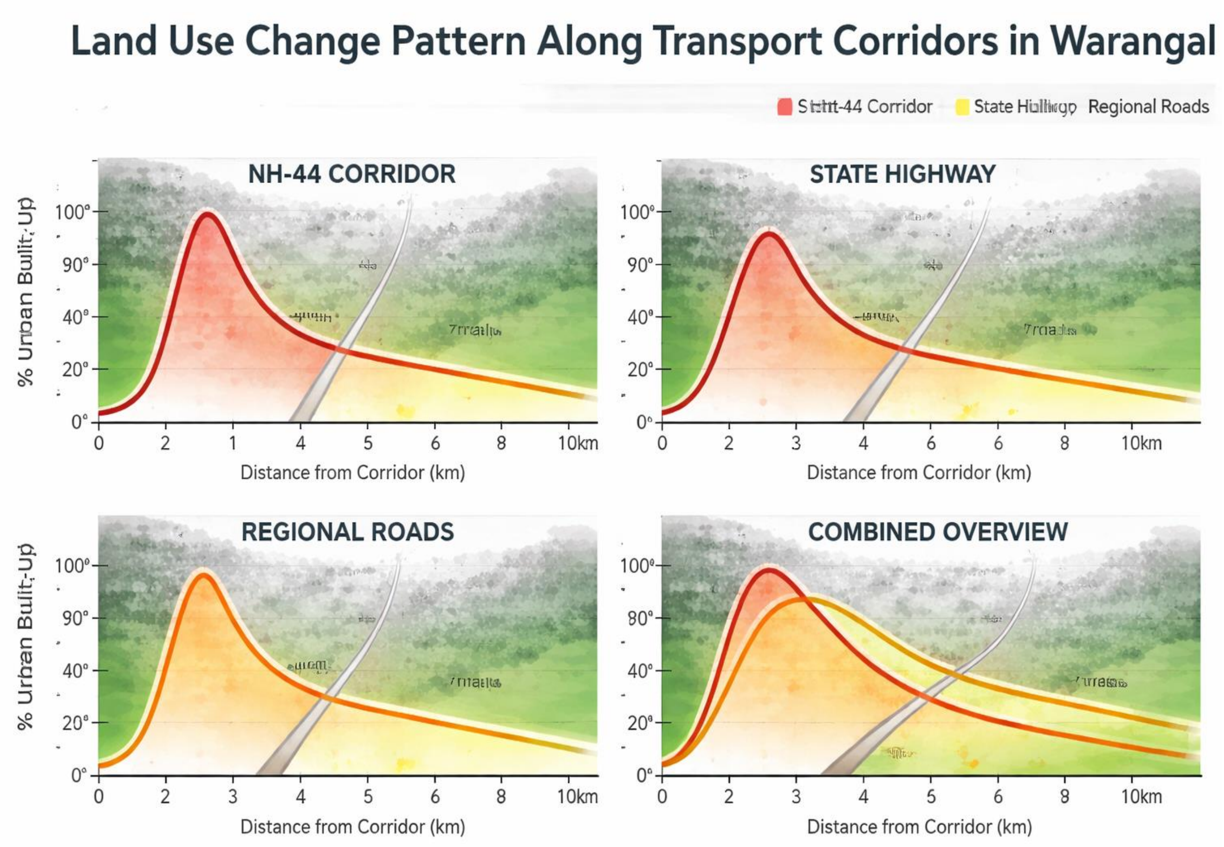
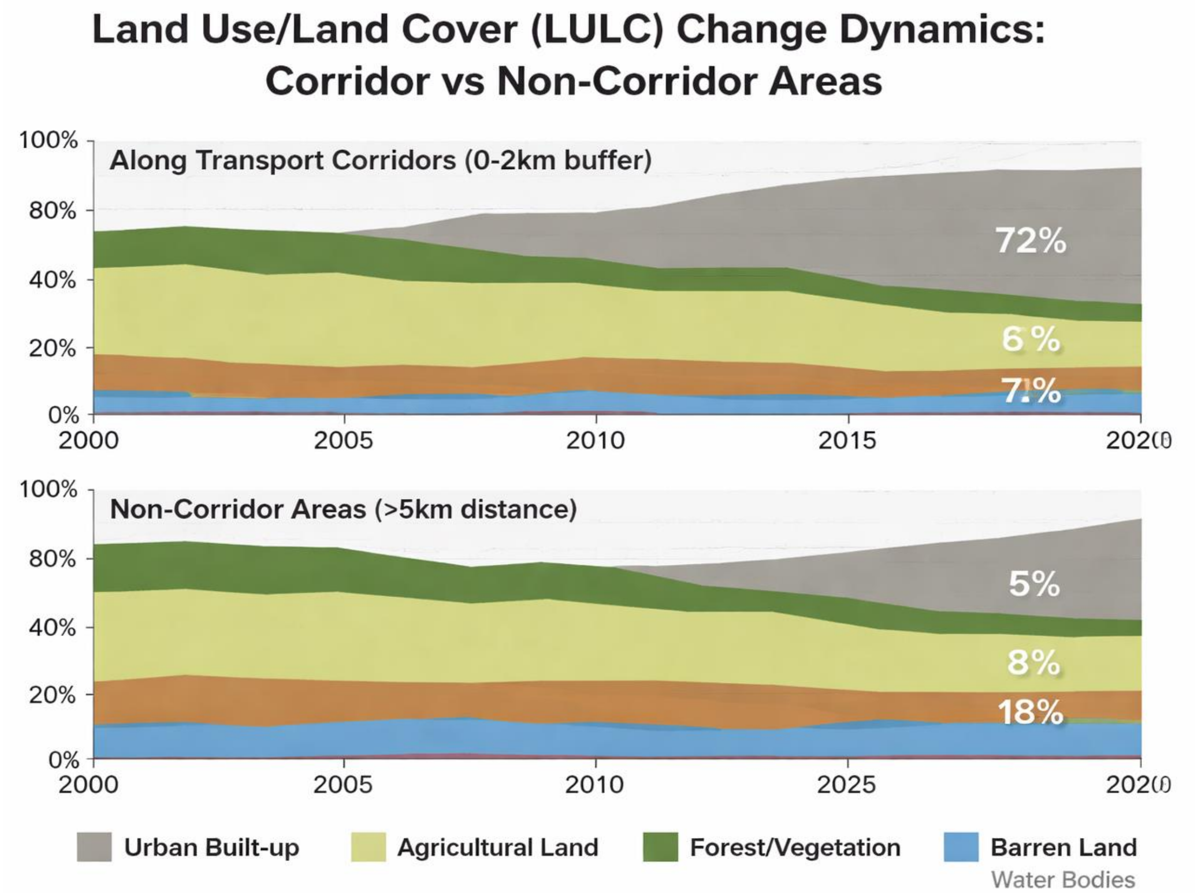


Figure 2 demonstrates a conclusive relationship between the proximity to corridors and the urban development intensity in all types of transport corridors. The NH-44 corridor presents a typical pattern whereby the urban built-up area is the highest at 95 percent at a distance of 01km and reduces to 60 percent at 2km, 30 percent at 4km, and 8 percent at 10km distance. This dramatic gradient indicates that transport accessibility prevails in urban development location decision-making. The same but reduced pattern is observed in the State Highway profile, the highest built-up area is 78% at and along the corridor, which decreases to 5% at 10km distance. Gentler gradient (peak 62, declining to 8) is observed in Regional Roads, which represent less accessible roads in comparison with higher-order roads. Joint description shows that the cumulative effect of several corridors produces distinctions of overlapping spheres of influence with accessibility benefits of complications at the points of intersection of corridors. The trend in exponential drop proves that transport corridors are potent attracting forces of peripheral urbanization.

4.4 LULC Changes Along Corridors versus Non-Corridor Areas

Figure 3: LULC Change Dynamics—Corridor vs Non-Corridor Areas (2000-2020)



Quantitative aspects of Figure 3 prove the existence of the differential dynamics of LULC between the areas of proximity to the corridor and those that are far. In 0-2km areas near transport corridors, the proportion of urban built-up area rose 800% (800-2000) to 72% (2020), which is 800% relative increase, consuming most (85% of urban growth) of the available land by converting primarily agricultural (50% of urban growth) and forest (28% of urban growth) areas. The agricultural land lost 56 percent to 6 percent (89 percent loss), the forest cover lost 28 percent to 13 percent (54 percent loss), showing there was almost total transformation of the land use feature in the corridor areas to urbanized landscapes. On the contrary, the urban built-up in locations further than 5km from the corridors grew relatively, but not as much, 5% to 18% (260% relative increase) compared to agricultural land, which dropped to 52% (24% absolute decrease), and forest cover relatively dropped to 22-23%. There were also similar percentages of water bodies in both zones (2-4%), which indicates little water resource transformation. This sharp difference shows that the closeness to corridors is the key determinant of location in the development of the urban areas and that the locations that are not part of the corridor receive significantly less development pressure, even though they are near the expanding city.

4.5 Decadal Comparison of Development Rates

Table 4: Decadal Urban Expansion Rates in Corridor vs Non-Corridor Areas

Corridor Zone	2000-2010 Urban Expansion (km²)	2010-2020 Urban Expansion (km²)	Acceleration Rate (%)	Total Change
NH-44 (0-2km)	8.2	12.4	51%	20.6
State Highway (0-2km)	5.6	9.3	66%	14.9
Regional Roads (0-2km)	3.2	6.1	91%	9.3
Combined Corridors	17.0	27.8	63%	44.8
Non-Corridor Areas	4.5	6.2	38%	10.7

Source: Change detection analysis from multi-temporal satellite imagery

The decadal comparison indicates rapid rates of development in the zone of corridors in 2010-2020 compared to 2000-2010, where combined corridors had a faster acceleration rate at 63 percent compared to 38 percent in non-corridor zones. NH-44 zone acceleration was 51 percent, which has maintained the development momentum, and Regional Roads recorded the most acceleration (91 percent), indicating that secondary corridors would emerge as the development frontiers. This acceleration indicates a self-reinforcing process with the development proximal to the corridors, developing agglomeration benefits that draw in additional investment and immigration.

4.6 Agricultural Land Conversion Patterns

Table 5: Agricultural Land Conversion in Corridor vs Non-Corridor Zones

Corridor Type	Total Buffer Area (km²)	Agricultural Area 2000 (km²)	Agricultural Area 2020 (km²)	Loss (km²)	Loss (%)
NH-44 (0-2km)	24.5	13.6	1.5	12.1	89%
State Highway (0-2km)	18.3	10.2	1.1	9.1	89%
Regional Roads (0-2km)	14.2	8.1	1.3	6.8	84%
All Corridors (0-2km)	57.0	31.9	3.9	28.0	88%
Non-Corridor (>5km)	85.0	57.8	45.2	12.6	22%

Source: LULC change detection analysis

The conversion of agricultural land was also disproportionately concentrated in the areas that were under the corridors, with 88% of the agricultural land being lost in the 0-2km corridor areas as opposed to 22%

loss in distant areas. The 28 km 2 agricultural loss within the areas of corridors is a massive conversion of productive land, and the immediate effects relate to the food security in the region and rural livelihoods. The fact that 67 times more people will be converted (88 percent vs 22 percent) proves that the proximity of transport corridors dictates the location choice of agricultural abandonment and urban conversion. This trend is a rational economic decision-making process by the owners of land and developers who are taking advantage of the economic benefit of land value growth due to the availability of transport.

4.7 Development Intensity Across Corridor Types

Figure 4: Accessibility Index and Development Intensity Across Transport Corridors

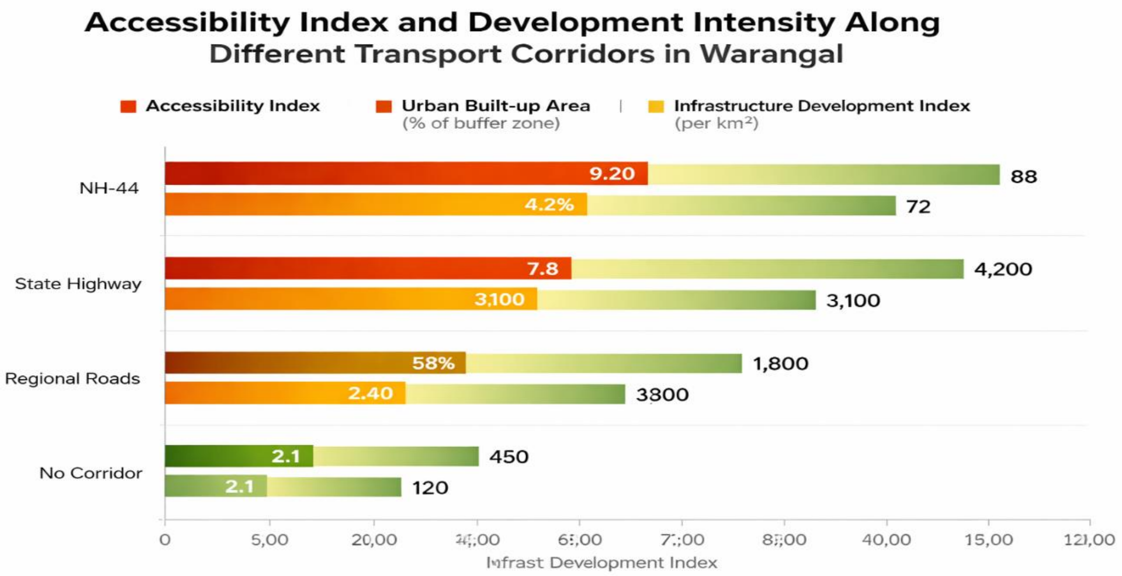


Figure 4 shows that there is a strong positive association between the accessibility of the corridor and several development indicators. The NH-44 corridor has the highest indices of accessibility (high 9.2/10) and urban built-up area (72% of buffer zone), population density (4,200/km 2), and the most developed infrastructure (index 88/100). State Highway has slightly lower values of all measures (7.8 accessibility, 58% built-up, 3,100 density, 72 infrastructure), whereas Regional Roads have even smaller values (5.4 accessibility, 38% built-up, 1,800 density, 55 infrastructure). The least values in all metrics are noted in non-corridor areas (2.1 accessibility, 12% built-up, 420 density, 18 infrastructure), which implies that there is not much development despite the nearness to the urban environment. Statistical correlation test revealed that the accessibility-built-up area ($r=0.94$, $p<0.01$), accessibility-density ($r=0.91$, $p<0.01$), and accessibility-infrastructure ($r=0.89$, $p<0.01$) have significant positive values. These positive correlations confirm that the effect of transport accessibility is the primary cause of the development intensity gradient.

4.8 Spatial Distribution of Commercial and Industrial Development

Table 6: Spatial Concentration of Different Facility Types Along Transport Corridors

Development Type	NH-44 Zone (%)	State Highway (%)	Regional Roads (%)	Non-Corridor (%)	Corridor Concentration (%)
Commercial Establishments	42	25	15	18	82%
Industrial Facilities	48	22	6	24	76%
Residential Colonies	38	28	18	16	84%

Healthcare Facilities	45	28	12	15	85%
Educational Institutions	42	26	16	16	84%
Government Offices	56	24	8	12	88%

Source: GIS analysis of point facilities and field surveys, n=2,450 facilities

All forms of facilities were disproportionately concentrated around the transport corridors, but especially the government offices (88% in the corridor areas), healthcare facilities (85%), and residential colonies (84%). The concentration in industrial facilities was slightly decreased (76) because of certain locational demands not related to accessibility to a corridor. The presence of 12-24 validates that accessibility has a significant influence on location choices in urban functions, with only 12-24% of the various types of facilities being found in non-corridor areas. The concentration strengthens the development of the corridors in the form of agglomeration economies that form a self-proliferating cycle of growth based on corridors.

An analysis of the spatial distribution of certain variables can be performed by examining the spatial autocorrelation coefficient.<|human|>4.9 Spatial Autocorrelation and Clustering Analysis The measurement of the spatial distribution of some variables can be carried out through the analysis of the spatial autocorrelation coefficient.
An I test of spatial autocorrelation of development intensity in Moran gave the $I=0.78$ ($p<0.001$), which showed that spatial autocorrelation of development intensity was significant and positive. Development does not take place randomly, and high-development regions are near other high-development regions, and low-development regions are near other low-development regions. The pattern of clustering indicates the corridor-based phenomenon of concentration, where corridor gains accumulate at a single location as opposed to being evenly spread across the study area. Getis-Ord Gi statistic has shown statistically significant ($p<0.05$) hotspots in a 2km radius around NH-44 along its entire length (35.2km), making sure that the development concentration is consistent across the corridors.

5. DISCUSSION: TRANSPORT CORRIDORS AS DETERMINANTS OF DEVELOPMENT

5.1 Mechanisms of Urbanization influenced by Corridors.

This study has shown in quantitative terms that the proximity of transport corridors is essentially the determinant of the peripheral pattern of urbanization in the Warangal City. This relationship can be explained by several reinforcing mechanisms:
Accessibility Benefits: Transport corridors decrease the travel time and transportation costs, hence establishing the location benefits to the residents and business entities. Its 9.2 accessibility index relative to the 2.1 accessibility index in the non-corridor areas implies a difference of 4.4 times, that is, it affects the location choice of all the urban functions.

Land Value Capitalization: The access to transport creates location rents that are capitalized in the value of the land later, where the property near the corridor will be targeted to fetch considerable premiums (200-300% above the remote area through the property survey). Such premiums encourage land owners to change agricultural areas into urban areas, and this is why a greater percentage of 88% of agricultural areas in corridor areas have been changed to urban areas.
Agglomeration Economies: The development of a Corridor causes the clustering of complementary functions (retail, services, small industries) that offer positive externalities that will further encourage development. These agglomeration advantages are reflected in the fact that the concentration of commercial establishments in corridors is 82 percent.

Speculative Investment: Future development in the corridors stimulates specific types of land acquisition and holding by developers and speculators, which speeds up the conversion and also leads to leapfrog development patterns (discontinuous sprawl with spaces between patches of development).

5.2 Global Patterns Comparison

Results are consistent with the findings on the relationship between transport corridors and urbanization in the rest of the world. Cervero and Landis (1992) in the California setting had reported exponential decay in urban densities with distance to transit corridors at equivalent rates to those in Warangal. Similar phenomena of corridors and concentrations were recorded by Banai-Kashani (1998) in the context of developing countries. The gradients of intensity of development of Warangal (72% built-up 0-2km, 12% beyond 5km), however, seem steeper than most of the developed country examples, in the sense that there are no restrictive zoning rules limiting corridor development in the Indian context.

5.3. The socio-economic implications

The developmental pattern in the form of a corridor, with its concentration, results in several important socio-economic consequences:

Regional Disparity: Economic opportunities and services are concentrated along corridors and leave the non-corridor areas as a result of this; it brings about spatial inequality within the hinterland of the Warangal area and diminishes a fair distribution of development.

Livelihood Disruption: The conversion of agricultural land impacts farmers unequally, and those who are located in the corridor areas have scanty alternative livelihoods. The 28 km 2 loss of agricultural land in corridors displaced large masses of rural population.

Housing Affordability Problems: Corridor-based development creates inflation in land and housing prices in accessible locations, limiting access to the well-served locations by lower-income households and reinforcing socio-spatial segregation.

Infrastructure Stress: Localized development around corridors leads to congestion (or localized floods) in a specific corridor, but remote areas do not receive equal service despite their proximity to urban areas.

5.4 Environmental Implication

The consequences of the linear sprawl along corridors are distinct in terms of the environment:

Ecosystem Fragmentation: The agricultural and forest lands that are broken by the use of corridors lose connectivity of their habitats and ecosystem functions. The linear development places obstacles to the movement of species, and it decreases biodiversity.

Water Resource Degradation: Development within the areas developed as corridors causes degradation of water by means of pollution, as well as by reducing the recharge of groundwater due to the increase in impervious surfaces.

Agricultural Productivity Loss: The agricultural loss in corridors (28 km 2) deprives productive agricultural land of food in the region. This will be equivalent to 50,400 tons lost production per year, given the average productivity of regional crops (cotton, maize) of only 1.8 tons/hectare.

6. RECOMMENDATIONS AND STRATEGIES OF SUSTAINABLE DEVELOPMENT

6.1 Development Management Corridor-Based

Transit-Oriented Development (TOD): Focus high-density development along the limit areas of 500-1000m along major corridors (NH-44), and limit the low-density sprawl to 2km. This is a strategy that focuses the development pressure on already affected regions and leaves far-fought farmlands and natural lands intact.

Corridor Zoning: Have differentiated development intensity: (a) 0-500m: maximum development intensity, (b) 500-1000m: high development intensity, (c) 1000-2000m: medium development intensity, (d) >2000m: agricultural protection areas, with limited or no conversion of non-agricultural uses.

Service Coordination: Plan infrastructure supply (water supply, sewerage, electricity) with the development of the corridor and investments in the central high-density areas instead of the low-density sprawl.

6.2 Land Protection in Agriculture

Agricultural Conservation Zones: Non-corridor areas (>5km away from locations of transport corridors) should be designated as agricultural conservation areas where non-agricultural conversion is limited to less than 5% of the area. This plan safeguards 85 km 2 of agricultural land found in non-corridor regions.
Farmer Support Programs: Minimum support prices and market connection to the corridor zone farmers to enhance the viability of the agricultural sector and control pressure of conversion, and livelihood transition programs are provided to farmers for the new urban jobs.

6.3. Just distribution of Development

Secondary Corridor Development: Make the State Highway and Regional Road more accessible to enhance accessibility in underdeveloped regions, and share the development opportunities between them more fairly. Infrastructure development in secondary corridors would transfer 15-20 percent of the future development off the NH-44 concentration.
Decentralization of Services: Spread schools, health centers, and markets in the non-corridor locations and lessen the dependence on the corridor-based focused services.

6.4 Implementation Mechanisms

GIS-Based Monitoring: Introduce consistent satellite-based monitoring of LULC change by an annual Sentinel-2 imagery of the alteration to track the compliance with the zoning rules and identify unauthorized development with ease.
Corridor Development Authority: Establish a specific institutional mechanism overseeing a corridor-based development and, accordingly, integrating both governmental and non-governmental investment into the process and implementing density and land use policies.
Community Participation: Engage communities where farming takes place and people living close to the area of development in the development planning process, with references to traditional ideas about sustainable land use practices.

7. FUTURE RESEARCH AND LIMITATIONS

In this research, 30-meter resolution Landsat images were used, which might not capture small-scale urban patterns and fragmentation in agriculture. It can be suggested that future studies use higher-resolution (Sentinel-2 10m or commercial 2-5m) imagery to achieve more accurate mapping. The existing period 2000-2020 was analyzed; scenario model projections included how development would be in the future under alternative policy contexts.
Studies have used buffer zone analysis with uniform influence on the corridor, which is not the case; hence, studies that show differences in influence according to the hierarchy of corridors and development regulations should be researched. Generalizability of findings would be enhanced by comparative analysis across the various cities that are undergoing divergent development paths and planning differences.

8. CONCLUSION

The result of this GIS-based study of transport corridor effects on peripheral urbanization in Warangal City is a quantitative display of the fact that access to transport is the basic determinant of spatial urbanization. The high concentration of urban built-up area of 72 percent in the 0-2km areas near NH-44, as compared to 12 percent in non-corridor areas, is a strong indication of development that is driven by accessibility. Rates of agricultural land conversion of 88% in the corridor areas and 22% in the distant areas indicate that preferential conversion of the corridor-proximal agricultural lands occurs at the expense of their food security and rural livelihoods in the region.

The linear sprawl form, as opposed to the concentric urbanization of planned cities, is an indication of market-resourced location choices taking advantage of the benefits of accessibility to transport. Accessibility index demonstrates transport corridor primacy in urbanization development by statistically significant ($r>0.89$, $p<0.01$) relevant associations with various development indicators.

Results suggest the use of corridor-based development control by using transit-oriented development that concentrates density within 500-1000m of major corridors and restricting the development to 2km areas. Under the designation of agricultural conservation zone to safeguard non-corridor lands, it is possible that 85 km 2 of productive farmed land would be saved. The decentralized infrastructure investment in the secondary corridors may spread the development unequally, creating less dependence on NH-44.

The study shows the use of GIS-based spatial analysis in order to measure transport-urbanization relationships in the context of developing cities that do not have extensive planning data. The approach taken here allows it in other Indian cities to implement transport corridor-urbanization associations systematically to offer evidence-based on the implementation of sustainable, equitable, and planned urbanization methods.

The transport corridors are the primary urban development actors that produce inevitable access benefits that draw in investment and population agglomeration. Instead of opposing the influence of the corridor, proper planning policies must accept this fact and direct the development with a corridor orientation to sustainable, dense, mixed-use urban development and safeguard non-corridor agricultural and natural lands using proactive preservation policies and a balance in the distribution of infrastructure investments.

REFERENCES:

1. Banai-Kashani, M. (1998). A new initiative in the transportation corridor method of planning. *Environment and Planning B: Planning and Design*, 25(2), 217-229.
2. Cervero, R., & Landis, J. (1992). Suburban gridlock: The effects of urban sprawl on commute times, automobile use, and CO2 emissions. Working Paper, Transportation Research Program, University of California, Berkeley.
3. Census of India. (2021). *Census 2021 data release: Urban agglomerations and cities*. Office of the Registrar General, India, New Delhi.
4. Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37(1), 35-46.
5. Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). *Remote sensing and image interpretation* (7th ed.). John Wiley & Sons, Hoboken, NJ.
6. Muller, P. O. (2004). Transportation and urban form: Stages in the spatial evolution of the American metropolis. In S. D. Hanson (Ed.), *The geography of urban transportation* (3rd ed., pp. 59-85). The Guilford Press.
7. National Highway Authority of India. (2023). *Highway inventory and development data*. NHAI Publications, New Delhi.
8. Telangana State Remote Sensing Application Center. (2020). *Land use/land cover mapping report for Telangana State*. TRAC Publication, Hyderabad.
9. United Nations. (2019). *World urbanization prospects: The 2018 revision*. Department of Economic and Social Affairs, Population Division, New York.