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A Hybrid CRITIC-TOPSIS Model for Robust Assessment of Urban Environmental Quality: A Case Study of Bengaluru City

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ABSTRACT: Urban Environmental Quality (UEQ) reflects the balance between human activities and environmental sustainability within a city. Rapid urbanization in Bengaluru has led to issues such as rising air and water pollution, reduced green cover, and increasing waste generation, all affecting residents' quality of life. This study aims to assess the environmental quality of Bengaluru city using an integrated Multi-Criteria Decision-Making (MCDM) framework based on the CRITIC (Criteria Importance Through Inter-criteria Correlation) and TOPSIS(Technique for Order Preference by Similarity to Ideal Solution) method.Environmental indicators including air quality, green cover, water quality,traffic congestion, waste generation, and population density were analyzed across different city zones. The CRITIC (CRiteria Importance Through Intercriteria Correlation) method was employed to derive objective weights for each criterion, and TOPSIS method for ranking to evaluate the Urban Environmental Quality of Bengaluru's central, outer, and industrial zones. The final environmental quality scores were computed and visualized using GIS mapping to identify areas of high and low environmental performance. Findings reveal spatial disparities in environmental quality — central and industrial areas show poor air conditions, while peripheral zones maintain better ecological balance. The study highlights the importance of integrating objective weighting techniques with geospatial analysis for effective and sustainable urban planning in rapidly growing cities like Bangalore.

Keywords: Multi Criteria Decision Making (MCDM), Urban Environmental Quantity (UEQ), Air Quality index (AQI), green space, Geographic Information System (GIS).

Contents

1. Introduction

The concept of Urban Environmental Quality (UEQ) encompasses the physical, ecological, and social conditions that define the livability of urban spaces. Urbanization has emerged as a dominant trend in developing nations [1] .The global trend of rapid industrialization, infrastructural expansion, and concomitant population growth places an unprecedented strain on environmental resources, particularly in major Indian metropolitan cities [2]. UEQ assessment has transitioned from an academic exercise to an essential component of effective, sustainable urban planning and resource management [3] .It serves as a comprehensive metric, evaluating how the relentless process of urbanization impacts essential environmental parameters [4] .With Indian cities witnessing rapid population growth and infrastructure expansion and With the expansion of metropolitan regions, maintaining environmental balance has become a growing challenge [5]. Bengaluru, known as India's "Silicon Valley" has undergone a profound transformation, evolving into a major industrial and technological hub over the past decades [6]. Although this growth has driven economic advancement, it has simultaneously resulted in deteriorating environmental quality , the consequences are visibly manifested through a series of environmental degradations,

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including heightened air and noise pollution, widespread water contamination, a significant reduction in natural vegetation cover, and increasingly inefficient solid waste management [7]. Bengaluru, once renowned for its pleasant climate and abundant green spaces, now confronts environmental degradation that threatens both its ecological resilience and the overall quality of life for its residents. [8] Urban sustainability assessment is inherently complex due to the multiple, often conflicting, indicators that define environmental performance [9] . For example, while green cover and air quality reflect ecological health, parameters like waste generation and population density highlight anthropogenic pressures. Assessing UEQ thus requires a method capable of integrating diverse quantitative indicators into a single decision framework. Traditional assessment models often rely on subjective expert judgment, which introduces bias and inconsistency . To overcome this, Multi-Criteria Decision-Making (MCDM) techniques have emerged as robust analytical tools [10] that integrate multiple indicators systematically and produce objective, comparable evaluations of environmental performance across regions [11] [12] [13] [14] [15]. Among various MCDM methods, the CRITIC (Criteria Importance Through Intercriteria Correlation) technique provides a data-driven mechanism for deriving the objective weights [16] . Unlike expert-based methods such as AHP, which depend on subjective preferences, CRITIC determines criterion weights using statistical parameters like standard deviation (to measure contrast intensity) and correlation (to assess interdependence among indicators) [23] [24] [25]. This ensures that indicators contributing more unique and informative variability to the dataset receive higher importance [17] [18]. Once the weights are determined, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is applied to rank different zones of Bengaluru based on their relative proximity to an ideal environmental condition [19] [20]. The combined CRITIC–TOPSIS framework offers a powerful hybrid model for evaluating UEQ because it merges objective data-based weighting with a rational ranking process that measures how each urban region performance relative to both the best and worst possible environmental scenarios.

Several global studies have used multi-criteria decision-making (MCDM) frameworks to evaluate urban environmental conditions [21]. The integration of remote sensing (RS), GIS, and statistical tools enables a comprehensive and spatially explicit understanding of environmental quality [22].This study applies the CRITIC–TOPSIS integrated MCDM approach to evaluate the environmental quality of Bengaluru's major zones — Central, Industrial, and Outer regions. This research aims to identify and quantify the key environmental indicators that precisely define the Urban Environmental Quality (UEQ) within Bengaluru, and to derive objective weights for each identified indicator using the statistical-based CRITIC method. The study's subsequent objectives are to utilize the TOPSIS method to rank the different functional regions based on their overall environmental performance, and to visualize and interpret the spatial disparities in UEQ through GIS-based mapping, thereby providing a clear spatial context for necessary intervention.

2. Methodology

2.1. Study Area

Bengaluru, also known as Bangalore, is situated in the southern part of India on the Deccan Plateau. It lies at an elevation of about 920 meters above sea level, making it one of the highest major cities in the country. The city is located at approximately 12.97° N latitude and 77.56° E longitude, in the southeastern part of the state of Karnataka. Bengaluru is positioned nearly equidistant from the eastern and western coasts of India, giving it a moderate and pleasant climate throughout the year. It is surrounded by a gently undulating terrain with numerous small hills and valleys, and its landscape is interspersed with several lakes and tanks that contribute to its ecological balance. The city's elevated position and plateau climate have played a significant role in its development as a major technological and educational hub, often referred to as the "Silicon Valley of India."

Bengaluru, the capital city of Karnataka, is a vibrant metropolitan region composed of diverse administrative, economic, and residential zones. The city is divided into eight major zones under the Bruhat Bengaluru Mahanagara Palike (BBMP) — East, West, South, Bommanahalli, Mahadevapura, Dasarahalli, Yelahanka, and Rajarajeshwari Nagar — which together encompass 243 wards.

The assessment of Urban Environmental Quality (UEQ) in Bengaluru is conducted by delineating the vast metropolitan area into three distinct functional regions, each representing a unique blend of land use, environmental pressure, and demographic concentration. These regions The Central Region(East zone-inner part ,West zone, South zone - inner part) ;The Industrial Region(North-west,South-west) and the Outer Region(Yelhanka zone-north,Mahadevapura (outer) zone - east , Bommanahalli - Anekal - south zone, Rajarajeshwari Nagar-outer Zones) ;The administrative zones are categorized to represent varying degrees of urbanization that serve as the fundamental alternatives in the Multi-Criteria Decision-Making (MCDM) analysis.

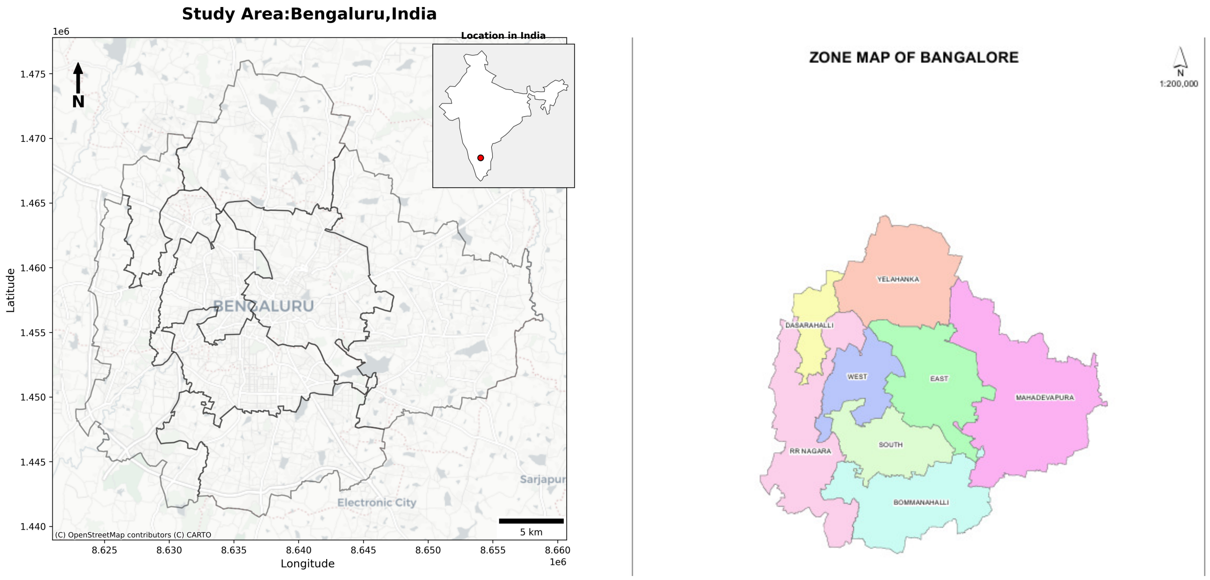

Figure a: Location Map of Bengaluru City

Figure b: Zone map of Bengaluru City

Figure 1: Location map of the study area

Central Region: Representing the historical and commercial heart of the city, the Central Region encompasses the densely built core and its immediate surroundings. This zone is currently characterized by intense, long-established urban land use, marked by a mixture of governmental, financial, and high-density residential buildings. Its inclusion is essential for comparative analysis, as it generally exhibits the highest population density and the lowest proportion of natural green cover compared to the outlying regions. **Industrial Region**: Defined by specialized economic activity, the Industrial Region encompasses areas primarily designated for manufacturing, processing, and large-scale logistics. This zone is currently characterized by expansive non-residential land use, marked by the concentration of factories, warehouses, and related infrastructure. Its inclusion is essential for comparative analysis, as it generally exhibits a moderate to low residential population density (relative to the Central Region) and often contains unique environmental characteristics resulting from its focus on heavy industrial development. **The Outer Region**: Represents the transition from rural to urban land use, this region encompasses the outlying suburban and semi-urban areas. This zone is currently undergoing rapid urbanization, marked by the proliferation of residential developments and commercial hubs. Its inclusion is essential for comparative analysis, as it generally exhibits a lower population density and a higher proportion of natural green cover compared to the core areas.

The differentiation into these three regions allows the integrated CRITIC–TOPSIS methodology to provide a robust and nuanced spatial analysis of UEQ, highlighting the distinct environmental burdens and performance levels across the city's diverse functional zones and providing policymakers with a clear roadmap for geographically targeted, evidence-based interventions.

2.2. Selection of Key Indicators

The study evaluates the Urban Environmental Quality (UEQ) of Bengaluru using five key indicators—Air Quality Index (AQI), Water Quality Index (WQI), Green Cover, Waste Generation, and Population Density. AQI represents air pollution brought on by vehicular and industrial emissions. While WQI assesses the health of water bodies impacted by domestic and industrial discharge. While waste creation emphasizes environmental stress and municipal efficiency, green cover, which represents the extent of plant life, indicates ecological health and resilience. Human demand on land and urban resources is captured by population density. When taken as a whole, these indicators offer a thorough, data-driven view of Bengaluru's Central, Industrial, and Outer regions' environmental conditions.

Bengaluru's Urban Environmental Quality (UEQ) evaluation necessitated the development of an extensive database that integrated environmental and socio-demographic parameters. This database was prepared by methodically gathering, organizing, and cleaning data from numerous governmental and scientific sources. The Karnataka State Pollution Control Board (KSPCB), the Bangalore Water Supply and Sewerage Board (BWSSB), the Bruhat Bengaluru Mahanagara Palike (BBMP), and the Census of India were among the organizations from which raw data was first collected. After that, these data were pre-processed to guarantee accuracy and consistency between areas. The indicators were standardized to a common range between 0 and 1 to facilitate comparison and integration in the MCDM framework because separate datasets were given in different scales and units. Beneficial indicators (e.g., green cover, water quality) were normalized such that higher values represented better environmental performance, while non-beneficial indicators(e.g., AQI, noise, waste, population density) were transformed so that higher values indicated poorer quality. Following normalization, the CRITIC method computes objective weights based on each indicator's variability and correlation. These weights are then applied in the TOPSIS method to calculate each zone's proximity to ideal (best) and anti-ideal (worst) environmental conditions. The resulting UEQ scores are used to rank Bengaluru's zones, and Python-based GIS libraries are utilized to create spatial maps that visualize the disparities in environmental quality across the city. An objective, verifiable, and policy-relevant evaluation of spatial environmental disparities is made possible by their incorporation into the CRITIC–TOPSIS framework, providing insightful information for sustainable urban management.

Table 1: Urban Environmental Quality (UEQ) indicators and their values across regions

Indicator	**Central**	**Outer**	**Industrial**	**Type**
Air Quality (AQI)	91.90	80.74	114.00	Cost
Green Space (sq. m)	5,306,463.44	5,302,480.45	738,896.17	Benefit
Population Density (person/km^2)	12,992	10,379	11,032	Cost
Waste Generation (ton/day)	1,528.75	2,446.00	2,540.50	Cost
Traffic Congestion Index	86.74	74.89	96.84	Cost
Water Quality (Score)	2	1	3	Cost

Table 1 summarises the Urban Environmental Quality (UEQ) indicators used in this study for the Central, Outer, and Industrial regions of Bengaluru. The indicators were selected based on their environmental relevance and categorized as benefit or cost criteria according to their directional influence on urban quality. While most indicators constituted single-parameter measurements (e.g., AQI, traffic congestion, population density), water quantity comprised multiple underlying sub-parameters. Consequently, water quantity was evaluated independently using the CRITIC–TOPSIS method to derive a composite score, which was subsequently integrated into the final decision matrix. This complete matrix—including air quality, green space, population density, waste generation, traffic congestion, water quality, and the computed water quantity—was then processed through the CRITIC–TOPSIS framework to determine criterion weights and compute UEQ scores for each region.

2.3. Criteria Importance Through Intercriteria Correlation (CRITIC)

The. CRiteria Importance Through Intercriteria Correlation (CRITIC) method is an objective weighting technique that relies exclusively on the inherent information contained within the decision matrix to calculate attribute weights. This approach determines importance by assessing both the contrast intensity (variability) of the data and the contradictory nature (correlation) among the evaluation criteria . By factoring in the standard deviation to measure information quantity and using the correlation coefficient to quantify the conflict between criteria, CRITIC ensures that criteria with greater differentiation and lower correlation with others are assigned higher significance, thereby providing a robust and data-driven foundation for subsequent Multi-Criteria Decision Making (MCDM) analysis. Let $X = (x_{ij})_{m\times n}$, $i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n$ be the initial decision matrix, where m is the number of alternatives and n is the number of criteria. The steps of this method are described as follows:

1. **Normalization of the Decision Matrix:**

   To ensure commensurability among criteria, the initial matrix X is normalized to obtain the normalized matrix $R = [r_{ij}]$ with $r_{ij} \in [0, 1]$. In this paper, we use range (min–max) normalization (commonly used with CRITIC) or z-score due to mixed cost/benefit types and interpretability.

   - For benefit-type criteria:

   $$r_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{2.1}$$

   - For cost-type criteria:

   $$r_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \tag{2.2}$$

2. **Normalization of the Decision Matrix:** The standard deviation of each normalized criterion vector measures its contrast intensity. Criteria with higher variability are considered more informative. The standard deviation for criterion j is:

   $$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2}{m-1}} \tag{2.3}$$

   where the mean of criterion j is:

   $$\bar{r}_j = \frac{1}{m}\sum_{i=1}^{m} r_{ij} \tag{2.4}$$

3. **Calculation of Inter-criteria Correlation Matrix:** The Pearson correlation coefficient between criteria j and k is:

   $$\rho_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)(r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 \sum_{i=1}^{m}(r_{ik} - \bar{r}_k)^2}} \tag{2.5}$$

   This yields the $n \times n$ correlation matrix $P = [\rho_{jk}]$.

4. **Determination of Information Content (C_j):** The information content combines contrast intensity (σ_j) and the conflict measure across criteria. The degree of conflict is given by $\sum_{k=1}^{n}(1 - \rho_{jk})$.

   $$C_j = \sigma_j \times \sum_{k=1}^{n}(1 - \rho_{jk}) \tag{2.6}$$

   Criteria with high variability and low correlation (high conflict) obtain larger C_j values.

5. **Calculation of Objective Weights (W_j):** The final CRITIC weight for criterion j is:

   $$W_j = \frac{C_j}{\sum_{i=1}^{n} C_i} \tag{2.7}$$

The resulting weight vector is:

$$W = (w_1, w_2, \dots, w_n),$$

which is used as input for the TOPSIS method.

2.4. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method ranks alternatives based on their geometric distance from an ideal solution. It involves the following steps:

1. **Normalization of the Decision Matrix:** The initial matrix X is normalized using the standard vector normalization method to create the dimensionless Normalized Decision Matrix $R = (r_{ij})_{m\times n}$:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{2.8}$$

2. **Compute the Weighted Normalized Decision Matrix:** The weights W_j of the criteria are applied to the normalized matrix R to form the Weighted Normalized Decision Matrix $V = (v_{ij})_{m\times n}$:

$$v_{ij} = W_j \cdot r_{ij} \tag{2.9}$$

3. **Determination of Positive Ideal Solution (A^+) and Negative Ideal Solution (A^-):** The Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) are identified for each criterion from the weighted normalized matrix V. Let J_{benefit} denote the set of benefit criteria and J_{cost} denote the set of cost criteria.

   - **Positive Ideal Solution (PIS):**

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+), \quad v_j^+ = \begin{cases} \max_i(v_{ij}) & \text{if } j \in J_{\text{benefit}} \\ \min_i(v_{ij}) & \text{if } j \in J_{\text{cost}} \end{cases} \tag{2.10}$$

   - **Negative Ideal Solution (NIS):**

$$A^- = (v_1^-, v_2^-, \dots, v_n^-), \quad v_j^- = \begin{cases} \min_i(v_{ij}) & \text{if } j \in J_{\text{benefit}} \\ \max_i(v_{ij}) & \text{if } j \in J_{\text{cost}} \end{cases} \tag{2.11}$$

4. **Calculate the Separation Distances (D_i^+ and D_i^-):** The Euclidean distances of each alternative i from the PIS and NIS are computed.

   - **Separation from PIS:**

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, \qquad i = 1, \dots, m \tag{2.12}$$

   - **Separation from NIS:**

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \qquad i = 1, \dots, m \tag{2.13}$$

5. **Determine the Closeness Coefficient (CC_i):** The relative closeness of each alternative to the ideal solution is:

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{2.14}$$

Higher CC_i values indicate better environmental quality. Alternatives are ranked in descending order of CC_i, and the one with the highest value is considered the optimal option.

3. Results and Discussion

A hybrid Multi-Criteria Decision-Making (MCDM) framework that combines the CRITIC (CRiteria Importance Through Intercriteria Correlation) method and the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was used to evaluate Bengaluru's urban environmental quality (UEQ). Both the objective weighting of indicators and the logical ranking of regions according to how close they are to an ideal environmental condition are guaranteed by this integrated approach. By taking into account both the contrast intensity (standard deviation) and the conflict between criteria (inter-criteria correlations), the CRITIC technique objectively establishes the weight of each environmental criterion. The alternatives (in this case, the Bengaluru regions) are then assessed and ranked by the TOPSIS approach based on how close they are to the ideal (best) and anti-ideal (worst) circumstances. For this study, five major indicators representing the environmental quality of Bengaluru were selected.These criteria collectively capture the major environmental and urban factors that influence the city's livability and ecological sustainability.

Table 2: CRITIC Method Results

Criterion	**Standard Deviation (σ_j)**	**Information Content (C_j)**	**Final Weight (W_j)**
Air Quality	0.508936	0.904455	0.093942
Green Space	0.577099	1.185886	0.123174
Population Density	0.520432	2.938261	0.305186
Waste Generation	0.552365	2.752308	0.285872
Traffic Congestion	0.500529	0.932689	0.096875
Water Quality	0.500000	0.914164	0.094951

Based on each criterion's variability and independence from other indicators, the CRITIC technique was used to determine the objective weights of each criterion. Green space (0.577), population density (0.520), and waste generation (0.552) exhibit substantial variability between regions, according to the standard deviation (σ_j) values, indicating that these factors are crucial in differentiating the city's environmental circumstances. On the other hand, Water Quality (0.500), Air Quality (0.509), and Traffic Congestion (0.501) showed moderate variation, suggesting that these metrics are still reasonably consistent across the urban landscape but still contribute to total environmental quality inequalities. The correlation matrix revealed that Air Quality, Traffic Congestion, and Water Quality were highly interrelated (correlation coefficients exceeding 0.97), emphasizing that vehicular emissions and poor transport management directly influence both atmospheric and water pollution in Bengaluru. Conversely, Population Density and Waste Generation displayed a strong negative correlation (r = –0.95), indicating that areas with high population density tend to experience more waste-related stress and reduced ecological balance.

Using the computed weights, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was applied to evaluate the closeness of each region to the ideal environmental condition. The resulting TOPSIS scores and rankings are presented below:

Table 3: TOPSIS Method Results

Region	**TOPSIS score**	**Rank**
Outer	0.587	1
Central	0.507	2
Industrial	0.388	3

The results highlight distinct spatial variations in environmental quality across Bengaluru's regions. The Outer Region exhibits better performance primarily due to lower population density, moderate air quality, and relatively less waste generation compared to central and industrial zones. The availability of open and green spaces in the periphery also enhances its environmental condition. The Central Region, despite having good green space coverage and established urban infrastructure, suffers from higher air pollution, traffic congestion, and waste generation owing to its dense population and concentration of commercial activities. Nevertheless, it performs moderately due to better service infrastructure and partial green cover. The Industrial Region shows the lowest environmental quality, which can be attributed to elevated pollution levels (particularly air and solid waste), limited green space, and high traffic. The high correlation between poor air quality and industrial activities reinforces the impact of rapid industrialization on environmental degradation.

The CRITIC–TOPSIS results provide actionable insights for urban planners and policymakers. The high weightage assigned to population density and waste generation suggests that managing these two aspects should be prioritized to improve Bengaluru's overall environmental quality. Strategies such as promoting decentralized waste management systems, balanced urban expansion, and enhancing green infrastructure can help mitigate the environmental stress in the Central and Industrial regions. Additionally, the Outer Region's relatively favourable environmental performance should be preserved through controlled urban growth, eco-sensitive zoning, and maintenance of green buffers to prevent future environmental degradation as the city continues to expand.

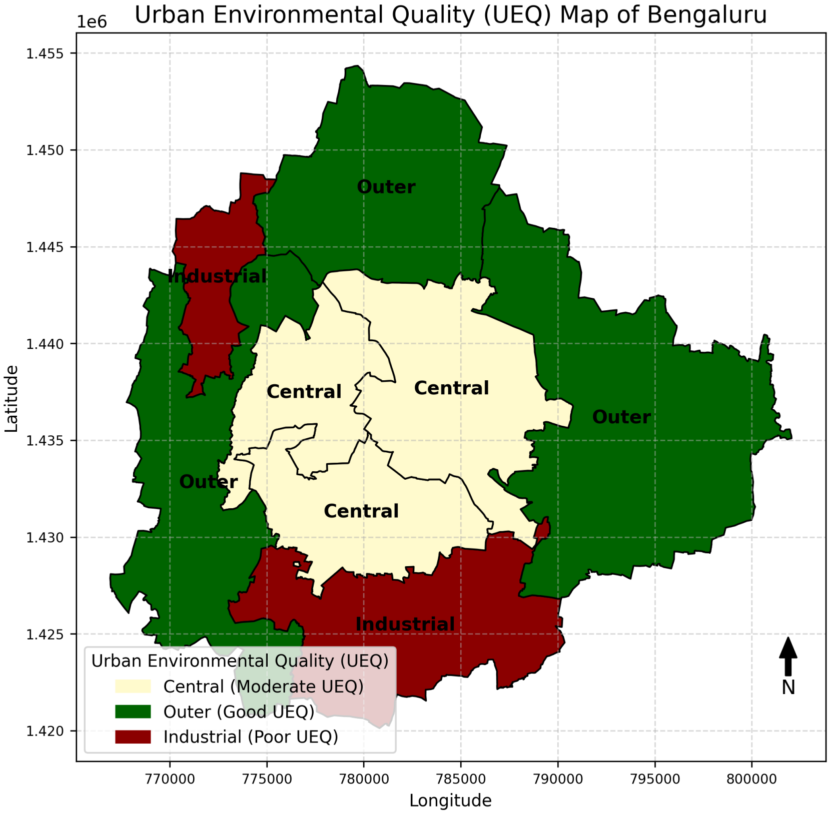

Figure 2: UEQ map of Bengaluru

4. Conclusion

This study successfully leveraged the integrated CRITIC-TOPSIS model to provide a robust, objective, and comparative assessment of Urban Environmental Quality (UEQ) across the diverse functional regions of Bengaluru City. The integration of CRITIC ensured that the subsequent ranking was based on empirically determined weights, thereby enhancing the objectivity and reliability of the final results. The TOPSIS ranking revealed significant intra-city disparities in UEQ. Consistent with the initial hypothesis, the Outer Region exhibited the best overall environmental conditions, largely benefiting from its lower development intensity and greater natural cover. Conversely, the Industrial Region was identified as the most environmentally strained area, followed closely by the Central Region, underscoring the compounding challenges of dense urbanization and concentrated economic activity. The CRITIC weighted data provided crucial insights into the determinants of environmental degradation. The most important factors influencing Bengaluru's UEQ were identified as waste generation and population density. These criteria not only directly contribute to acute issues in sanitation and waste management but also exert significant indirect pressure on air and water quality through increased pollution loads and infrastructural strain. Furthermore, the inclusion of Water Quality as an integrated indicator was instrumental, demonstrating a strong correlation with decentralized waste discharge patterns and vehicular pollution within the city's denser zones.

This paper's key contribution lies in the effective integration of the CRITIC and TOPSIS methods. Using CRITIC ensured that the subsequent TOPSIS ranking was based on data-driven objective weights, thereby minimizing the potential subjectivity inherent in many Multi-Criteria Decision Making (MCDM) applications. This established an empirically validated framework for complex urban evaluations. The resulting neighbourhood ranking serves as a powerful decision-support tool for municipal authorities to prioritize environmental interventions and resource allocation.

To enhance the Urban Environmental Quality (UEQ) of Bengaluru, a multi-dimensional strategy integrating technology, policy, and sustainability is essential. The city should implement a real-time environmental monitoring system, promote cleaner industrial production with emission controls, and expand green infrastructure to mitigate pollution and heat. Strengthening waste management through circular economy principles and improving water quality via lake restoration and wastewater reuse are crucial. Encouraging public and non-motorized transport can reduce vehicular emissions, while developing green industrial parks and renewable microgrids can make industrial areas more sustainable. Incorporating AI-driven predictive models for planning and establishing an empowered environmental authority with green financing mechanisms will ensure accountability and long-term resilience. These combined actions will reduce pollution, enhance ecological balance, and promote sustainable growth across Central, Industrial, and Outer Bengaluru. The CRITIC–TOPSIS framework proved to be an effective and replicable model for evaluating urban environmental quality and can guide sustainable urban development across other metropolitan regions.

Future work can build upon this foundation through temporal analysis using the established CRITIC-TOPSIS model to monitor the dynamic effectiveness of environmental policies. Additionally, integrating these results with Geographic Information Systems (GIS) would allow for a finer spatial disaggregation of the UEQ assessment, enabling highly localized and targeted planning interventions.

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References

1. X. Bai, T. McPhearson, H. Cleugh, H. Nagendra, X. Tong, T. Zhu, and Y.-G. Zhu, *Linking urbanization and the environment: Conceptual and empirical advances,* Annual Review of Environment and Resources, **42**(1) (2017) 215–240.
2. R. Mahtta, M. Fragkias, B. Güneralp, A. Mahendra, M. Reba, E. A. Wentz, and K. C. Seto, *Urban land expansion: the role of population and economic growth for 300+ cities,* npj Urban Sustainability, **2**, Article 5 (2022).
3. A. S. Raghubanshi, *Sustainable urban planning: A comparative study of green city initiatives around the world,* Journal of Sustainable Solutions, **1**(3) (2024) 18–23.
4. V. S. Krishnan and C. Mohammed Firoz, *Regional urban environmental quality assessment and spatial analysis,* Journal of Urban Management, **9**(2) (2020) 191–204.
5. C. Punyamurthy and R. S. Bheenaveni, *Urbanization in India: An overview of trends, causes, and challenges,* JETIR, **9**(5) (2022) a812–a819.
6. M. R. Narayana, *ICT sector, globalization and urban economic growth: Evidence from Bangalore (India),* ISEC Working Paper No. 242, Bengaluru, India (2010).
7. H. S. Sudhira, T. V. Ramachandra, and K. S. Jagadish, *Urban sprawl: metrics, dynamics and modelling using GIS in Bangalore, India,* International Journal of Applied Earth Observation and Geoinformation, vol. 5, no. 1, pp. 29–39, 2003.
8. N. Bhor and D. Mayavel, *The socio-spatial distribution and equity of access to urban parks: A case study of Bengaluru, India,* Challenges, **15**(2) (2024) 20.

9. M. Cohen, *A systematic review of urban sustainability assessment literature,* Sustainability, **9**(11) (2017) 2048.
10. G. A. Melnik-Leroy and G. Dzemyda, *How to influence the results of MCDM?—Evidence of the impact of cognitive biases,* Symmetry, **15**(1) (2023) 107.
11. A. R. Afshari, M. Vatanparast, and D. Ćoćkalo, *Application of multi criteria decision making to urban planning—A review,* JEMC, **6**(1) (2016) 3–10.
12. S. Zinatizadeh, A. Azmi, S. M. Monavari, and S. Sobhanardakani, *Multi-criteria decision making for sustainability evaluation in urban areas: A case study for Kermanshah City, Iran,* Applied Ecology and Environmental Research, **15**(4) (2017) 1083–1100.
13. G. Ferla, B. Mura, S. Falasco, P. Caputo, and A. Matarazzo, *Multi-criteria decision analysis (MCDA) for sustainability assessment in the food sector: A systematic literature review,* Sustainable Production and Consumption, **35** (2023) 487–502.
14. J. Tang, H.-L. Zhu, Z. Liu, F. Jia, and X.-X. Zheng, *Urban sustainability evaluation under the modified TOPSIS based on grey relational analysis,* Sustainability, **11**(2) (2019) 494.
15. M. Cinelli, S. R. Coles, and K. Kirwan, *Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment,* Ecological Indicators, **46** (2014) 138–148.
16. A. R. Krishnan, M. M. Kasim, R. Hamid, and M. F. Ghazali, *A modified CRITIC method to estimate the objective weights of decision criteria,* Symmetry, **13**(6) (2021) 981.
17. D. Diakoulaki, G. Mavrotas, and L. Papayannakis, *Determining objective weights in multiple criteria problems: The CRITIC method,* Computers & Operations Research, **22**(7) (1995) 763–770.
18. Y. Huang, W. Li, X. Zhang, and G. Zeng, *A smart MCDM framework to evaluate the impact of air pollution on city sustainability: A case study from China,* Sustainability, **9**(6) (2017) 911.
19. M. Madanchian and H. Taherdoost, *A comprehensive guide to the TOPSIS method for multi-criteria decision making,* Journal of Data Analysis and Information Processing, **11**(2) (2023) 63–93.
20. Y. Çelikbilek and F. Tüysüz, *An in-depth review of theory of the TOPSIS method: An experimental analysis,* Expert Systems with Applications, **149** (2020) 113248.
21. H. Mahmoudzadeh, A. Abedini, F. Aram, and A. Mosavi, *Evaluating urban environmental quality using multi-criteria decision making: A case study of Tabriz,* Heliyon, **10**(4) (2024) e25687.
22. H. Taherdoost and M. Madanchian, *A review on multi-criteria decision-making (MCDM) methods and applications,* Technological Forecasting and Social Change, **190** (2023) 122371.
23. M. Žižović, B. Miljković, and D. Marinković, *Objective methods for determining criteria weight coefficients: A modification of the CRITIC method,* Scientific Review, **70**(2) (2020) 29–38.
24. M. Piasecki and K. Kostyrko, *Development of weighting scheme for indoor air quality model using a multi-attribute decision making method,* Energies, **13**(12) (2020) 3113.
25. M. Şahin, *A comprehensive analysis of weighting and multicriteria methods in the context of sustainable energy,* International Journal of Environmental Science and Technology, **18**(5) (2021) 1591–1616.

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