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GREAT LAKES GURGAON

Business Analytics

Liveability Index: The Best Cities in India

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INDEX:

EXECUTIVE SUMMARY:

The Liveability Index is a methodical study of the quality of living conditions in various Indian cities. We tried to create an index which takes into account the climatic factors of the cities. It entirely relies on objective analysis. We have considered 11 parameters over a period of 7-months for the year 2024. The data is fetched from the datasets of Google Earth Engine catalogues to eliminate the prejudices in the findings which is possible in survey-based analysis. The cities were identified and ranked on the basis of the 2011 population census.

The model depicted is an adaptation of Diamond Model proposed by Prof. Michael Porter of Harvard University.

The selected cities are ranked on the below mentioned 11 parameters.

INTRODUCTION:

Purpose of Report

To measure a country's economic growth, we refer to the Gross Domestic Product (GDP) data. But it is also a well-established fact that the GDP cannot fully explain the broader well-being of a region and its inhabitants. Even if millions are lifted out of poverty, it's still not sufficient for ensuring the welfare of the society.

By 2050, India is projected to add 416 million urban dwellers to the world's population and. This newly added population will be an advantage as urban population contributes approximately 65% to India's GDP, currently.

It is necessary to have an index or a holistic outlook which is not limited to economic performance and evaluates other factors affecting the human wellbeing. Therefore, to ensure sustainable urban development and a high quality of life for its citizen, it is imperative to evaluate the environmental conditions of Indian cities.

This report aims to provide a comprehensive assessment of the top 100 liveable cities in India based on a range of environmental factors. By analysing data on Carbon Monoxide, Methane, Ozone, PM 2.5 etc., this report aims to:

- **Identify Cities with optimal environmental conditions:** The report highlights cities that exhibit favourable levels of air quality, green house emission and green space coverage.
- **Promote Sustainable Living:** The report encourages individuals and businesses to choose cities with better environmental conditions, fostering a more sustainable way life.
- **Informed decision-making:** The report will provide valuable insights to individuals, businesses, and policymakers, enabling them to make informed decisions about where to live, work, and invest.

Finally, this report seeks to contribute to the understanding and improvement of urban liveability in India, focusing on the critical role of environmental factors in creating sustainable cities.

Definition of "Liveable City"

A liveable city is the one that offers a high quality of life for its residents, characterized by:

- **Optimal environmental Conditions:** Low level of air pollutions, greenhouse gas emissions and favourable climate conditions
- **Green Space and Infrastructure:** Adequate green space is created in the city to maintain good environmental balance of the city and offset any damage done while creating the infrastructure.
- **Sustainable development:** Efficient use of resources and keeping the environmental pollution as low as possible to ensure long term viability of the city and its residents.

Here are some key reasons why liveability indices are important:

- **Informed decision-making:** Liveability indices provide a data-driven basis for decision-making, allowing governments and businesses to make informed choices about where to invest, locate facilities, and promote development.

- **Attracting talent and investment:** Cities with high liveability scores are more attractive to businesses, investors, and skilled workers. This can lead to economic growth and job creation.

- **Promoting sustainable development:** Liveability indices can help identify areas where cities can improve their sustainability performance, such as reducing pollution, conserving resources, and promoting green infrastructure.

- **Improving quality of life:** By addressing the factors that contribute to a high quality of life, cities can enhance the well-being of their residents and create more desirable places to live and work.

- **Benchmarking and comparison:** Liveability indices allow cities to compare themselves to other cities and identify best practices for improving liveability.

In conclusion, liveability indices are essential tools for understanding and improving the quality of life in urban areas. By providing a comprehensive assessment of various factors, they can inform decision-making, attract investment, promote sustainable development, and enhance the overall well-being of city residents.

METHODOLOGY

Data acquisition and processing

This study leveraged the capabilities of Google Earth Engine (GEE) to collect and process satellite imagery data. The following key steps were involved:

- **Data Catalogue Selection:** Suitable satellite imagery datasets, such as Sentinel-2 and MODIS, were selected based on their spatial and temporal resolution, as well as their coverage of the study area.
- **Data Filtering and Preprocessing:** The imagery was filtered to exclude cloud-covered areas and other anomalies. Preprocessing techniques, including atmospheric correction and radiometric calibration, were applied to ensure data accuracy.
- **Feature Extraction:** Algorithms were employed to extract the desired features from the satellite imagery, including Soil Moisture, Carbon Monoxide, Humidity, Methane, Ozone, Sulphur Dioxide, PM2.5, and other features.

Index development

To create a comprehensive liveability index, the extracted features were integrated and weighted based on their relative importance in determining a city's overall liveability. The following steps were involved:

1. **Feature Standardization:** The extracted features were standardized to a common scale to ensure comparability.
2. **Weighting:** The relative importance of each feature was determined through literature review and Generative AI like Google Gemini and ChatGPT.
3. **Index Calculation:** A weighted average of the standardized features was calculated to create the overall liveability index.

Spatial analysis

The liveability index was spatially analysed to identify the top 100 Liveable cities in India. This involved:

- **City Boundary Identification:** City boundaries were delineated using GIS data or other suitable methods.
- **Index Calculation for Cities:** The liveability index was calculated for each city by averaging the index values within its boundaries like for Humidity.
- **Ranking:** The cities were ranked based on their overall liveability index scores.

Additional considerations

- **Temporal Analysis:** To assess changes in liveability over time, the analysis was conducted for the time period of January to July 2024.
- **Sensitivity Analysis:** The sensitivity of the liveability index to changes in feature weights and data sources was evaluated to ensure robustness.
- **Validation:** The results were validated using ground-based measurements and other data sources.

By following this methodology, this study provides a comprehensive and objective assessment of the liveability of India's cities based on a range of environmental factors.

DATA COLLECTION AND ANALYSIS

Sources of Data

This study utilized a combination of satellite imagery data to access the environmental liveability of Indian cities. The sources of the data were:

Feature	Google Earth Engine Dataset Catalogue
NDVI	COPERNICUS/S2_HARMONIZED
Mean_AOD	MODIS/061/MCD19A2_GRANULES
PM 2.5	COPERNICUS/S5P/NRTI/L3_AER_AI
Sulphur Dioxide	COPERNICUS/S5P/NRTI/L3_SO2
Ozone	COPERNICUS/S5P/NRTI/L3_O3
Nitrogen Dioxide	COPERNICUS/S5P/NRTI/L3_NO2
Soil Moisture	NASA/GLDAS/V021/NOAH/G025/T3H
Carbon Monoxide	COPERNICUS/S5P/NRTI/L3_CO
Humidity	ECMWF/ERA5_LAND/HOURLY
Methane	COPERNICUS/S5P/OFFL/L3_CH4
Average Surface Temperature	MODIS/061/MOD11A1

By combining these data sources, this study was able to obtain a comprehensive dataset for evaluating the environmental factors that contribute to city liveability.

Data cleaning and preprocessing

To ensure quality and accuracy of the data used in this study, following techniques were employed:

- **Georeferencing:** The satellite imagery was georeferenced to a known coordinate system (e.g., WGS84) using ground control points (GCPs).
- **Spatial Smoothing:** Spatial smoothing techniques were applied to reduce noise and improve data quality, especially for low-resolution data.
- **Pixel Aggregation:** To reduce the computational burden and improve data resolution, pixels were aggregated into larger spatial units (e.g., 30-meter or 1-kilometer grids).
- **Temporal Aggregation:** For time series data, temporal averaging or aggregation was performed to obtain monthly or annual values.
- **Fmask:** A cloud masking algorithm developed by Boston University was used to identify cloud and shadow pixels based on spectral information.

Key indicators used

The following key indicators were used to assess the environmental liveability of India's cities:

Air Quality

- **Carbon monoxide (CO):** A colourless, odourless gas that can cause health problems, especially in people with heart disease. The higher the value, worse it is for human health.
- **Ozone (O3):** A harmful air pollutant that can irritate the respiratory system and cause respiratory problems. The higher the value, worse it is for human health.
- **Sulphur dioxide (SO2):** A colourless gas that can contribute to acid rain and respiratory problems. The higher the value, worse it is for human health.
- **Particulate matter (PM2.5):** Fine particles that can penetrate deep into the lungs and cause serious health problems. The higher the value, worse it is for human health.
- **Nitrogen dioxide (NO2):** A reddish-brown gas that can irritate the respiratory system and contribute to acid rain. The higher the value, worse it is for human health.

Greenhouse gas emissions

- **Methane (CH4):** A potent greenhouse gas that contributes to global warming. The higher the value, worse it is for human health.

Climate change

- **Average surface temperature:** The average temperature of the Earth's surface. Higher temperature will be bad and will affect the quality life in the city, for its residents. In this report, we are considering 27° C as ideal.

Land use and green space

- **Soil moisture:** The amount of water in the soil.
- **Normalized Difference Vegetation Index (NDVI):** A measure of vegetation greenness. Higher value is better for human health, as higher value will indicate more green space cover in the city, which is better for its residents.

Atmospheric conditions

- **Humidity:** The amount of water vapor in the air. Higher humidity levels will be bad and will affect the quality life in the city, for its residents. In this report, we are considering 70% as ideal.
- **Mean aerosol optical depth (AOD):** A measure of the number of aerosols in the atmosphere. The higher the value, worse it is for human health.

These indicators were selected based on their relevance to environmental health, climate change, and overall quality of life. By assessing these factors, this study provides a comprehensive evaluation of the environmental liveability of India's cities.

Statistical techniques employed

For index calculation, following statistical techniques for index creation. Since, this is index creation and reordering problem therefore we decided to not pursue any other supervised or unsupervised algorithms.

Descriptive statistics:

Mean: Calculate the average value for each indicator for each city.

Median: Calculate the median value for each indicator for each city.

Standard Deviation: Calculate the standard deviation for each indicator for each city to measure variability.

Weighting and Aggregation:

Expert Weighting: Weights were generated for each feature after performing literature review and utilizing AI for performing review on multiple papers.

By combining these statistical techniques, we have created this comprehensive and robust liveability index that effectively captures the environmental factors contributing to the quality of life in India's cities.

Generated Weights for the features:

NDVI: 06%	**Mean_AOD:** 07%
PM 2.5: 22%	**Sulphur Dioxide:** 10%
Ozone: 08%	**Nitrogen Dioxide:** 16%
Soil Moisture: 04%	**Carbon Monoxide:** 07%
Humidity: 05%	**Surface Temperature:** 06%
Methane: 04%	

FINDINGS AND RESULTS

The liveability index developed in this study ranked India's cities based on their environmental performance. The city with lowest overall score was deemed as most liveable, while the city with highest score were deemed as least liveable.

Key findings

- **Regional Variations:** Significant regional variations in liveability were observed. Cities in certain regions consistently scored higher or lower than others, indicating the influence of geographic factors on environmental conditions.

- **Environmental Factors:** Air quality, greenhouse gas emissions, and land use emerged as the most critical factors influencing liveability. Cities with cleaner air, lower emissions, and more green spaces tended to have higher liveability scores.

Most liveable cities

Based on the created liveability index, the following cities were identified as the most liveable in India:

1. Aizawl
2. Srinagar
3. Shimla
4. Dibrugarh
5. Pali

Least liveable cities:

Based on the created liveability index, the following cities were identified as the least liveable in India:

1. Siliguri
2. Bhubaneswar
3. Cuttack
4. Berhampur
5. Vijaynagaram

Implications

These findings highlight the importance of addressing environmental challenges and promoting sustainable urban development in India. By implementing policies that prioritize air quality, climate change mitigation, and green infrastructure, cities can improve the quality of life for their residents and create more sustainable and resilient urban environments.

Emerging trends and future outlook

Based on the findings of this study, several emerging trends and future outlook for urban liveability in India can be identified:

Shift Towards Smaller Cities

The study suggests that smaller cities, such as Aizawl, Srinagar, and Shimla, often have higher liveability scores than larger metropolitan areas. This trend may continue as people seek a better quality of life away from the congestion and pollution of larger cities.

Growing Importance of Environmental Factors

Environmental factors, such as air quality, greenhouse gas emissions, and green spaces, are increasingly recognized as critical determinants of urban liveability. As awareness of climate change and its impacts grows, cities will need to prioritize sustainable development and environmental protection to attract residents and businesses.

Increased Focus on Urban Planning

The study highlights the importance of urban planning in shaping city liveability. Cities with well-planned urban structures, efficient transportation systems, and adequate infrastructure tend to have higher liveability scores. Future urban development in India will likely focus on creating more sustainable and resilient cities through effective planning and design.

Technological Advancements

Technological advancements, such as smart city initiatives, renewable energy technologies, and advanced data analytics, will play a crucial role in improving urban liveability. These technologies can help cities optimize resource use, reduce pollution, and enhance the quality of life for their residents.

Citizen Engagement and Participation

Citizen engagement and participation will be essential for creating liveable cities. By involving residents in decision-making processes and fostering a sense of community, cities can ensure that their development aligns with the needs and preferences of their citizens.

Challenges and Opportunities

Future outlook for urban liveability in India is promising, several challenges remain. Rapid urbanization, population growth, and economic development put pressure on resources and infrastructure. However, these challenges also present opportunities for innovative solutions and sustainable development. By addressing these emerging trends and challenges, India can create more liveable, sustainable, and resilient cities for its citizens. The future of urban liveability in India depends on a commitment to environmental protection, sustainable development, and citizen engagement.

RECOMMENDATIONS AND IMPLICATIONS

Policy recommendations for improving city liveability

- **Strengthen environmental regulations:** Implement stricter regulations to control air pollution, reduce greenhouse gas emissions, and protect water resources.
- **Invest in green infrastructure:** Promote green building practices, expand urban green spaces, and improve public transportation systems to reduce carbon emissions and enhance liveability.
- **Promote sustainable urban planning:** Develop urban plans that prioritize sustainable development, mixed-use zoning, and compact urban form to reduce sprawl and improve walkability.
- **Support renewable energy:** Encourage the adoption of renewable energy sources, such as solar and wind power, to reduce dependence on fossil fuels and mitigate climate change.
- **Improve public health infrastructure:** Invest in healthcare facilities, public health programs, and disease prevention measures to ensure the well-being of city residents.

Potential business opportunities in liveable cities

- **Sustainable infrastructure:** Businesses can invest in green infrastructure projects, such as renewable energy plants, energy-efficient buildings, and sustainable transportation systems.
- **Environmental services:** Companies can provide environmental consulting, pollution control, and waste management services.
- **Green products and technologies:** Businesses can develop and market environmentally friendly products and technologies, such as electric vehicles, energy-efficient appliances, and sustainable building materials.
- **Tourism and hospitality:** Liveable cities can attract tourists and business travellers, creating opportunities for the tourism and hospitality industry.
- **Quality of life services:** Businesses can offer services that cater to the needs of residents and improve their quality of life, such as education, healthcare, and recreational facilities.

Implications for urban planning and development

- **Prioritize sustainability:** Urban planners and developers should prioritize sustainable development principles in their projects, including energy efficiency, water conservation, and green infrastructure.

- **Promote mixed-use development:** Create mixed-use neighbourhoods that combine residential, commercial, and cultural uses to reduce reliance on cars and promote walkability.
- **Enhance public transportation:** Invest in efficient and affordable public transportation systems to reduce traffic congestion and improve accessibility.
- **Create green spaces:** Develop parks, green roofs, and other green spaces to improve air quality, reduce heat island effects, and provide recreational opportunities.

Areas for further research

- **Long-term trends:** Conduct longitudinal studies to analyse changes in liveability over time and identify emerging trends.
- **Social and economic factors:** Explore the relationship between environmental factors and social and economic indicators, such as poverty, inequality, and crime rates.
- **Citizen engagement:** Investigate the role of citizen participation and engagement in improving urban liveability.
- **International comparisons:** Compare the liveability of Indian cities with cities in other countries to identify best practices and areas for improvement.

CONCLUSION

This study provides a comprehensive assessment of the environmental liveability of India's cities, ranking them based on a range of key environmental indicators. The findings demonstrate significant regional variations in liveability, with cities in certain regions consistently outperforming others.

Key Findings

- **Environmental factors:** Air quality, greenhouse gas emissions, and land use emerged as the most critical factors influencing liveability.
- **Urban development patterns:** Cities with more compact urban forms, better public transportation, and mixed-use development tended to have higher liveability scores.
- **Regional variations:** Regional differences in liveability were observed, reflecting the influence of geographic, cultural, and economic factors.

Importance of Liveability Indices

Liveability indices are essential tools for understanding and improving the quality of life in urban areas. They provide a comprehensive evaluation of various factors that contribute to a city's desirability, including environmental conditions, infrastructure, economic opportunities, and social factors.

Future Directions and Potential Applications

This study provides a foundation for future research and policy development. Potential areas for further exploration include:

- **Longitudinal studies:** Analysing changes in liveability over time to identify emerging trends and assess the effectiveness of policy interventions.
- **Social and economic factors:** Investigating the relationship between environmental factors and social and economic indicators to gain a more comprehensive understanding of urban liveability.
- **Citizen engagement:** Exploring the role of citizen participation and engagement in improving urban liveability.
- **International comparisons:** Comparing the liveability of Indian cities with cities in other countries to identify best practices and areas for improvement.

The findings of this study can inform policy decisions, urban planning, and business strategies. By prioritizing sustainable development, improving environmental conditions, and enhancing the quality of life for its citizens, India can create more liveable and resilient cities for the future.

Most Liveable Cities:

City	Liveability _Score
Aizawl	96.57926096
Srinagar	97.05389426
Shimla	100.0364226
Dibrugarh	101.4742524
Pali	104.4965055
Jammu	106.6597303
Udaipur	106.927881
Rajkot	107.2557811
Amreli	107.4064219

Least Liveable Cities:

City	Liveability _Score
Siliguri	146.673148
Bhubaneswar	146.2667235
Cuttack	145.5561997
Berhampur	144.8434983
Vijayanagaram	144.4131059
Gopalpur	143.7994223
Sambalpur	143.3861895
Bardhaman	142.4248119
South Dumdum	141.7128358

Note: Lower the liveability score, better the city

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- Environmental Protection Agency
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  - McGregor, G. R., & Vanos, J. (2018). "Heat Stress and Human Health."
- Google Earth Engine Dataset catalogues
  - MODIS
  - Sentinel-5P
  - ERA5
  - Copernicus
  - NASA/GLDAS

Appendix

- Snapshot of collected Data

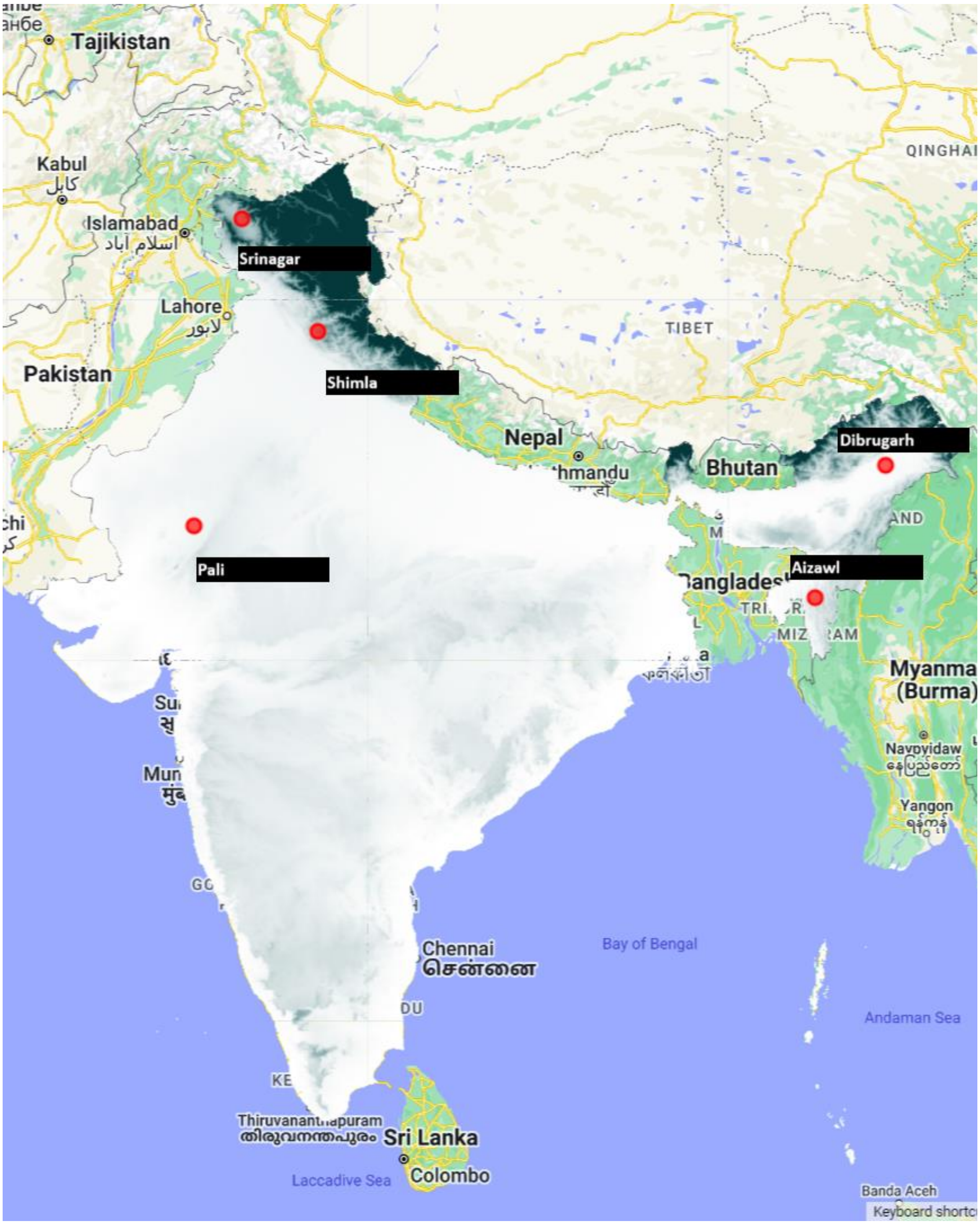
City	Soil Moisture	CO Density	Humidity	Mean Methane	Ozone Density	SO2 Density	PM25	Mean AOD	NO2 Density	NDVI	Temperature Celsius
Agartala	25.476	0.0446	93.096	1944.750	0.126	4.570E-05	-0.281	579.265	3.630E-05	0.066	31.0075
Agra	16.537	0.0424	83.390	1938.845	0.131	1.360E-04	0.205	639.342	6.280E-05	0.042	36.0910
Ahmedabad	20.659	0.0395	81.814	1937.173	0.125	3.360E-04	0.366	557.269	1.100E-04	0.008	36.9543
Ahmednagar	19.910	0.0376	82.444	1916.100	0.122	1.270E-04	-0.251	512.173	3.710E-05	0.092	37.4372
Aizawl	25.355	0.0381	92.679	1929.306	0.125	8.050E-05	-0.539	280.683	1.830E-05	0.047	27.3007
Ajmer	15.532	0.0356	78.704	1913.714	0.129	9.040E-05	0.108	465.005	4.350E-05	0.131	34.0938
Akola	21.666	0.0429	84.092	1922.881	0.123	1.550E-04	-0.137	692.063	3.630E-05	0.097	39.0954
Alappuzha	25.543	0.0401	95.145	1926.639	0.118	6.340E-05	-0.683	602.589	2.100E-05	0.079	34.7543
Aligarh	17.136	0.0422	83.691	1941.123	0.132	2.090E-04	0.206	576.843	7.070E-05	0.269	36.0963
Allahabad	17.608	0.0454	84.696	1936.459	0.129	1.510E-04	0.083	675.492	5.900E-05	0.025	35.4929
Ambattur	18.868	0.0399	92.174	1928.336	0.119	1.080E-04	-0.181	567.531	6.220E-05	0.055	37.1088
Ambikapur	13.523	0.0413	84.968	1921.240	0.126	1.890E-04	-0.296	661.067	4.850E-05	0.048	34.6872
Amravati	22.185	0.0428	83.911	1922.481	0.123	1.670E-04	-0.241	710.867	3.570E-05	0.117	38.8041
Amreli	18.979	0.0364	81.845	1928.539	0.124	9.440E-05	0.099	440.605	3.040E-05	0.030	40.0077
Amritsar	15.784	0.0403	84.580	1919.920	0.140	2.020E-04	0.195	555.513	6.710E-05	0.025	36.0213
Anand	13.636	0.0388	83.178	1930.473	0.125	1.990E-04	0.001	539.435	5.260E-05	0.065	37.2698
Anantapur	16.806	0.0393	82.227	1934.407	0.119	5.010E-05	-0.217	481.136	3.250E-05	0.084	38.7579
Arrah	15.179	0.0454	86.393	1937.712	0.129	1.400E-04	-0.066	618.929	4.670E-05	0.088	35.6800
Asansol	17.732	0.0498	86.875	1930.711	0.127	3.690E-04	-0.161	779.544	1.170E-04	0.293	34.3022
Aurangabad	23.449	0.0394	82.747	1929.170	0.122	1.190E-04	-0.103	522.523	4.330E-05	0.019	38.2847
Avadi	18.868	0.0399	92.112	1927.332	0.119	9.390E-05	-0.275	552.681	5.750E-05	0.110	36.4979
Bangalore	20.482	0.0357	87.520	1929.097	0.118	8.520E-05	-0.299	569.388	8.420E-05	0.233	35.1881
Bardhaman	18.250	0.0478	90.057	1939.024	0.126	2.730E-04	-0.204	935.860	6.850E-05	0.176	32.8779
Bareilly	16.919	0.0433	85.549	1937.578	0.133	1.140E-04	0.170	629.602	4.730E-05	0.034	35.7923
Belgaum	14.777	0.0378	87.561	1924.558	0.120	1.220E-04	-0.396	502.913	3.400E-05	0.135	38.5240
Bellary	16.840	0.0406	82.726	1931.459	0.119	1.280E-04	-0.332	612.551	5.410E-05	0.162	40.7264
Berhampur	13.863	0.0472	93.415	1929.107	0.122	1.370E-04	-0.300	984.930	2.680E-05	0.035	36.9810
Bettiah	15.254	0.0468	86.226	1927.837	0.131	1.360E-04	0.045	749.842	4.070E-05	0.234	34.2859

Note: For remaining collected data, please refer shared Excel File

Code for Index Calculation

```
import pandas as pd
data = pd.read_csv('Weights_Determinations_.csv')


#ideal temperature
ideal_temperature = 27
#Deviation from the ideal temperature (absolute deviation)
data['Temperature_Deviation'] = abs(data['Temperature_Celsius'] - ideal_temperature)

#ideal humidity
ideal_humidity = 70
#Deviation from the ideal humidity (absolute deviation)
data['Humidity_Deviation'] = abs(data['Humidity'] - ideal_humidity)


'''Deviation from 27°C is bad, penalize cities with higher deviations
The greater the deviation, the worse the impact on liveability
Invert the deviation so that cities closer to 27°C get a higher score'''

data['Temperature_Adjusted'] = -data['Temperature_Deviation']
data['Humidity_Adjusted'] = -data['Humidity_Deviation']
weights = {
    'PM25': 0.22,
    'NO2_Density': 0.16,
    'SO2_Density': 0.10,
    'Ozone_Density': 0.08,
    'CO_Density': 0.07,
    'Mean_Methane': 0.04,
    'Humidity': 0.05,
    'Soil Moisture': 0.04,
    'NDVI': 0.06,
    'Mean_AOD': 0.07,
    'Temperature_Celsius': 0.06
}
data['Liveability_Score'] = (
    data['PM25'] * weights['PM25'] +
    data['NO2_Density'] * weights['NO2_Density'] +
    data['SO2_Density'] * weights['SO2_Density'] +
    data['Ozone_Density'] * weights['Ozone_Density'] +
    data['CO_Density'] * weights['CO_Density'] +
    data['Mean_Methane'] * weights['Mean_Methane'] +
    data['Humidity_Adjusted'] * weights['Humidity'] +
    data['Soil Moisture'] * weights['Soil Moisture'] +
    data['NDVI'] * weights['NDVI'] +
    data['Mean_AOD'] * weights['Mean_AOD'] +
    data['Temperature_Adjusted'] * weights['Temperature_Celsius']
)
# Sort cities by their updated liveability score (higher score = lower liveability)
created_index = data[['City', 'Liveability_Score']].sort_values(by='Liveability_Score', ascending=False)
```

Map showing Most Liveable Cities



Map showing Least Liveable Cities