Understanding Air Pollution trends in various Part of Maharashtra, India

maxim rohit

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ABSTRACT

Indian Government released a first of its kind report on air pollution pattern & related health impact for the country on 8th December 2018[1].

Few of the disturbing facts presented were that 12.5% of death in India are attributable to air pollution along with the average life going down by 1.7 years owing to health loss due to high concentration level of various pollutant including suspended particulate matter(SPM).  
In the same report Prof. Balram Bhargava, Secretary of the GOI, Department of Health Research, said ‘It is important to have robust estimates of the health impact of air pollution in every state of India to have a reference for improving the situation’.

This Novel exploratory research is aimed at answering the question from Pollutant’s point of view for the State of Maharashtra, India, for the first time. This Research will try to establish the relationship between four major pollutants SO₂, NO₂, SPM2.5, and SPM10. Additionally, finding the natural grouping of cities concerning pollutants and other novel & non-novel factors impacting them. A few examples of novel factors under consideration are Elevation from Sea level, Forest & Industrial Area Distribution among others. Few non-novel features like population density, seasonal patterns are also evaluated for their impact.

We found that Mumbai although being a commercial hub of India still maintains low levels of NO₂ and SO₂ as per Indian pollutant acceptable standards, whereas Pune being the 2nd most progressive city in Maharashtra is doing much worse but still within standards. Other major upcoming cities like Nagpur, Nashik & Amravati has the lowest level of pollutant concentration, signifying that the progression of the cities does have an impact on them. Hence proper consideration needs to be put in place while planning new and upcoming cities, as to not to repeat the pattern.

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LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| SPM | Suspended particle concentration in air that can be inhaled is considered as air pollutants |
| SPM2.5 | Suspended particulate matter of diameter below or equal to 2.5 μm. Our nasal hair cannot prevent their inhalation and they reach our lungs and blood circulation directly. |
| SPM10 | Suspended particulate matter of diameter between 2.5 μm and 10 μm.  Inhalation is prevented by our nasal hair |
| SO₂ | Sulphur dioxide, its concentration in air is representative of the sulphur oxide family’s concentration. |
| NO₂ | Nitrogen dioxide, its concentration in air is representative of the nitrous oxide family’s concentration. |

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CHAPTER 1

INTRODUCTION

The research aims to understand pollutant spread, correlation and growth pattern over the region of Maharashtra, India.  
Indian government’s first comprehensive report[1] released stated ‘1.24 million deaths in India are attributable to air pollution in 2017, of which 50+% were in individuals younger than 70 years’. A more recent example of the seriousness of this issue is the government school’s remaining closed for 2 days in Nov’2019 due to unbreathable living conditions post-Diwali celebration.  
Building an understanding of the pattern behind Air Pollutants is the first step towards being able to prepare for controlling/reducing these pollutants.

**Past and Current**

1. Part I: Natural grouping of cities will be explained via clustering in terms of pollutants and properties of cities like elevation from sea level, population-density, total area, industrial area, number and type of industries among others.  
   This will enable us to compare the progression of the cities through the years and answer questions like how do major industrial and IT hub based cities - Mumbai and Pune compare against the smaller town of Kolhapur, Nashik, and Nagpur among others.
2. PART II: We will use PCA to understand the interaction between the pollutants, by quantifying their combined loading on individual components.  
   With the knowledge of the impact of SO₂ on NO₂ concentration, we will be able to plan better control measures for both.

**Future**

1. PART III: Time Series analysis to predict when the pollutant concentration will go beyond an acceptable government standard.  
   This exercise may give us a time frame for our action items.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

Most of the studies of similar nature are targeted at explaining these variable concentrations at City level, observing the pattern over the Season (New York [2]) and Nature of Area (Madrid’s Metropolitan vs Rural part [3]). Another study based on the city of Kolkata, India [4], attempts to quantify pollutants in different parts of the city and during different time frames within the day.  
Our study uses approaches applied in these analyses on a broader level for a set of neighbouring cities i.e. State Level; while comparing the cities distinguishable attributes impact on pollutant concentrations  
One of the innovative attempts towards explaining the pollutant behaviour via visual representation for Hong Kong city[5] also elaborates on the Time Series nature of pollutant concentrations. While this study concentrated on exploring the interaction between the pollutants over time, we will be concentrating on forecasting their concentration in the future.

CHAPTER 3

ANALYSIS

Data Preparation

Pollutants data for SO₂, NO₂, SPM10 & SPM2.5 was aggregated for each city at monthly levels and percentile 10, 50 & 90 were calculated to represent the range. We calculated month on month increase for these percentile values for tracking their seasonal pattern. Percentile 50 values were used for the final comparison.

Other features that are merged with the data are:

1. Population & Population Density
2. Elevation from sea level
3. Total/Forest/Industrial area spread and respective percentages
4. Roads
   1. national/state/district/rural
   2. A representative of automobile circulations & count
5. Rail line
6. Industrial
   1. services/manufacturing
   2. micro/mini/medium/large

Few interaction variables were calculated like

1. Rainfall per Area
2. Industrial area per Forest area among others.

**Clustering**

We performed two-levels of clustering, first was all variables from 2004-10 and the next set was limited to pollutant information from 1987-2015, purely due to lack of availability of data. The natural grouping found in the first exercise was validated against the longer range of the second cluster. All variables were scaled for consistency and equal weightage.

Silhouette Analysis and Elbow curves were used to decide the ideal number of clusters.

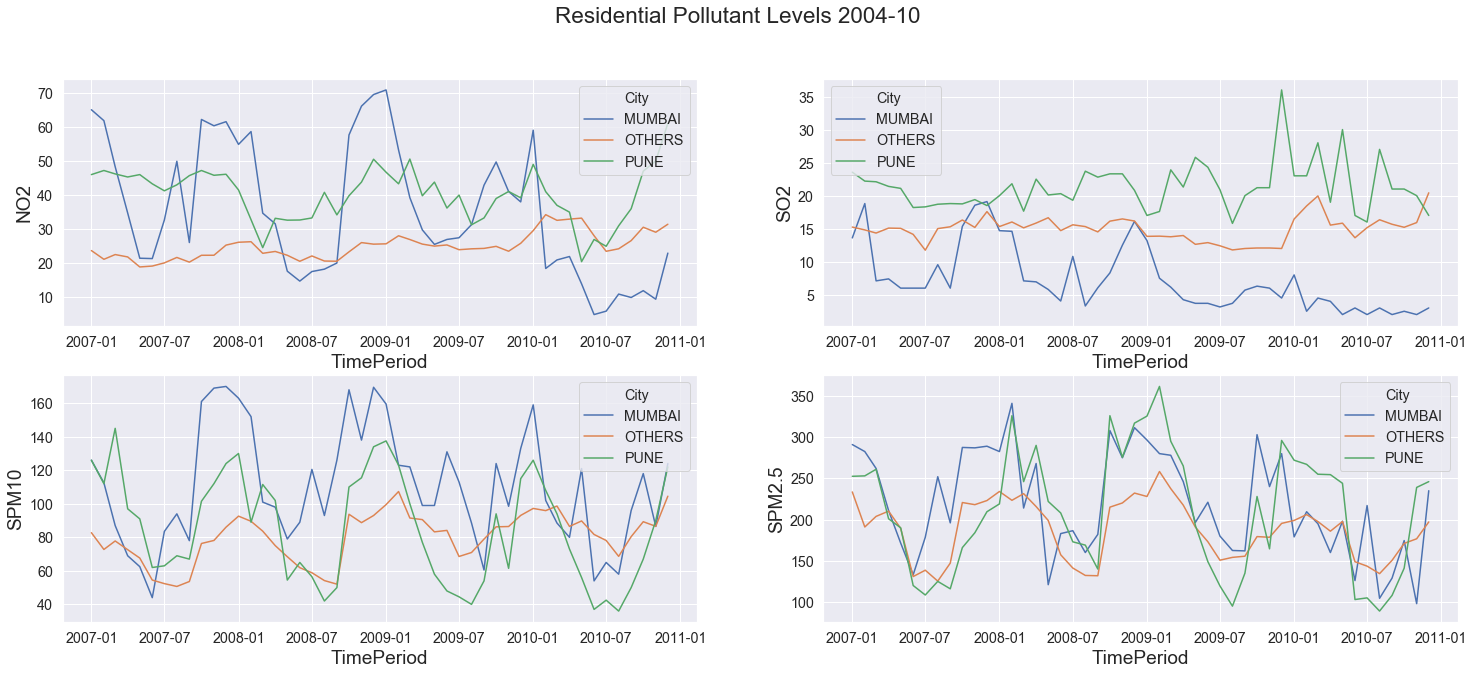
PCA and Timeseries analysis is pending and will be carried out in the 2nd half of the term.

CHAPTER 4

RESULTS AND DISCUSSION

**Part I Clustering:**

**Figure 1. Residential pollutant levels for years 2004-2010**



The above figure represents the monthly level of pollutants over the time frame 2004-2010 which was used for the first level of clustering with all variables.

**Figure 2. Residential pollutant levels for years 2011-2015**

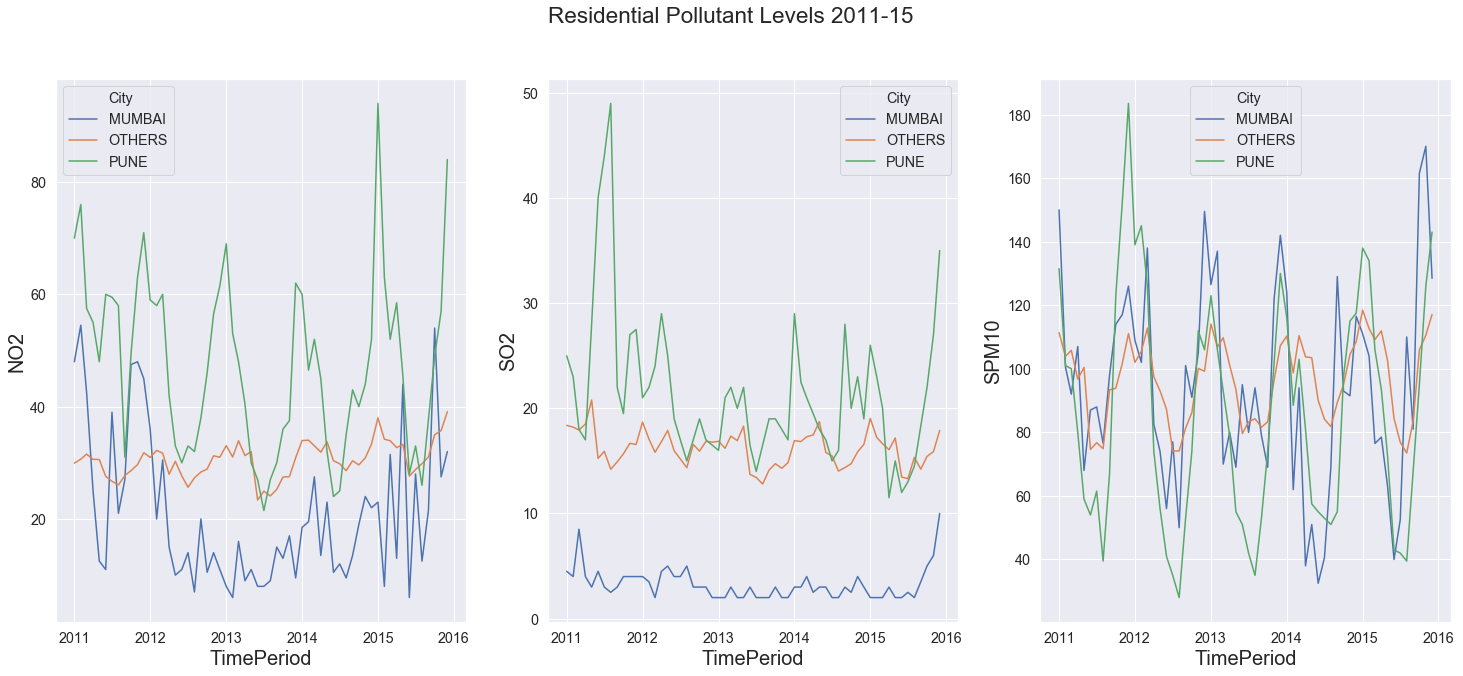


Figure 2. represents the state of the pollutants post-2010. SPM2.5 data is sparingly present for this period hence dropped from the graph.

Table 1. Indian Government Permissible Concentration Level.[6]

|  |  |  |
| --- | --- | --- |
| **Pollutant** | **Time Weighted Average** | **Concentration in Ambient Air: Industrial, Residential, Rural and Other Areas (in** µg/m3**)** |
| **Sulphur Dioxide (SO₂), µg/m3** | Annual\* | 50 |
| **Nitrogen Dioxide (NO₂), µg/m3** | Annual\* | 40 |
| **Particulate Matter (size less than 10 µm) or SPM10 µg/m3** | Annual\* | 60 |
| **Particulate Matter (size less than 2.5 µm) or SPM2.5µg/m3** | Annual\* | 40 |
| Note: \* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hours at uniform intervals. | | |

**Cluster 2004-2010**

Three major clusters were observed one for Mumbai & Pune each and the third one composed of all the remaining cities.

1. **Pune cluster** has the highest level of average monthly levels of SO₂ @29µg/m3 & NO₂ @39µg/m3 over the year, still lower than acceptable levels of NO₂ 40µg/m3 & SO₂ 50µg/m3. The **Residential** **area** of Pune has shown an increasing pattern for months Oct, Dec, Jan post the year 2006 till 2009 for SPM2.5/10. The **Industrial** **area** replicates the same behaviour and decreases during the remainder of the year. Even monthly Percentile 10 values for SPM2.5 is above the acceptable level of 40µg/m3.

Attribute wise Pune cluster stands out with the highest elevation i.e. 34% higher than others. Highest Roads length including national, state highways and internal district and rural roads also stand out. Micro-industries are also highest for this cluster in terms of manufacturing & services both, questions can be asked about them following effective measures to control their share of pollutants. Rainfall per area is also lowest for Pune along with the low population density and lowest percentage of forest area.

Pune’s behaviour over the clustering exercise for years 1987-2015 saw that the residential area consistently had higher values as compared to other cities whereas industrial area has seen a decline in NO₂, SO₂, and SPM2.5 levels.

1. **Mumbai cluster** stands out for its lowest SO₂ level.

For **Industrial** **area** level of NO₂, SPM2.5&10 decreases during Feb till Aug and is within the acceptable standards accompanied by higher rainfall levels. Also, the range of all the pollutants except SPM2.5 remains under acceptable levels. During the remainder of the year the level of the three pollutants increases, specifically SPM2.5 level rises dangerously to @229 µg/m3 and SPM10 goes beyond acceptable level @124 µg/m3. **Residential** **area** observes the increasing phase during Aug, Oct & Dec and decreases during the remainder of the year.

Attribute wise Mumbai site on the opposite end of the spectrum with the lowest elevation & highest rainfall per area when compared to the Pune cluster. Another standout feature of the cluster is the largest industrial area and the highest number of large manufacturing firms all that is packed in the lowest overall area and forest portion-wise among the cities. 1987-2015 clustering also shows similar results w.r.t pollutant concentration behaviour as compared to the other clusters. The only exception being NO₂ whose levels starts decreasing from the year 2010 and continues dropping into the next decade.

1. **Other Clusters** display a similar pattern as in Mumbai cluster’s decreasing phase but at 20-30% lower intensity, except for SO₂ concentration which is 230% higher.

Attribute wise these cities are placed in between Mumbai & Pune in terms of elevation, rainfall (per total area). These cities stand out in terms of the highest forest area (per total area), the lowest population density, industrial area and count of large industries.

While validating the behaviour over 1987-2015 few exceptional observations were made:

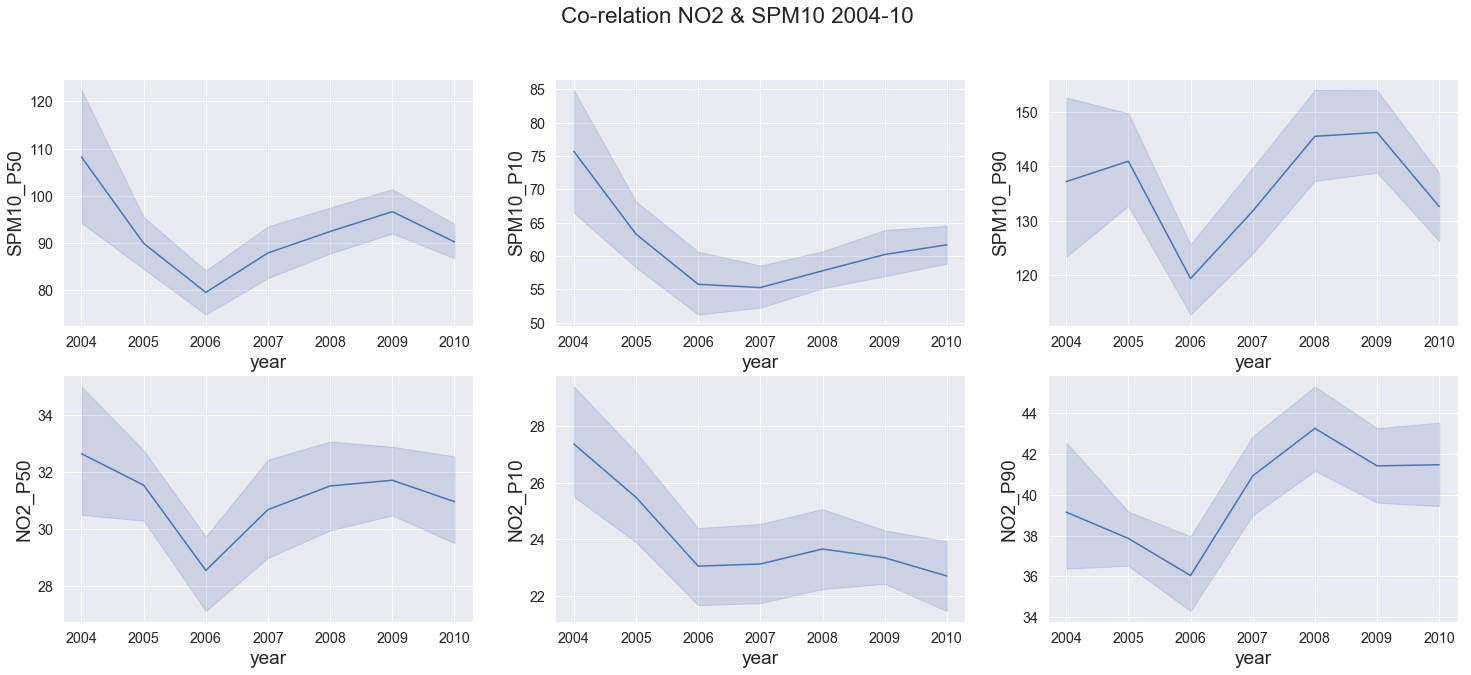
1. Aurangabad is seeing a rise in all four pollutant levels over the years.
2. Solapur and Mahad are the only cities reducing the level of SPM2.5, the pollutant with the most extreme values.

**Exceptional Observations** - Chandrapur is an exception to these clusters and shows the highest value for SO₂ @24.3µg/m3 (still acceptable), RSPM2.5 & 10 (extremely high) from all the clusters with a monthly increase in RSPM2.5 & 10 values over the years 2004-2010.

S02 being high signals towards Diesel based instrumentation not being optimally levelled. For the years 2006-2010 and months Sep, Oct & Dec Nagpur displayed similar behaviour.

**PART II PCA:**

**Figure 3. NO₂ & SPM10 co-relation for years 2004-2010**

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First principle component has a high loading for SPM10 & NO₂, figure 3 displays the annual tread across Maharashtra, the relation is highlighted at al1 three level P10, P50 & P90.

Except for SMP10 P90 growth vs drop of NO₂ P90 between 2004-05, the trend matches for all other years. Variance in SPM10 P10 & P50 values are less as compared to others.

**Figure 4. Co-relation SO2 & SPM2.5 2004-10**

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On the 2nd principle component, SO₂ l has high positive loading and inversely SPM2.5 has negative loading. Their behaviour across the year as depicted in figure 4 confirm similar movement before 2008 and 2008 onwards both variables start to move in inverse directions. One exception of inverse movement was between 2004-05 for P90 values of SPM2.5 which saw an increase while all other values decreased.

CHAPTER 5

CONCLUSION

Mumbai although heavy on the industrial area and large industries count still registered smaller pollutants concentration numbers, this can be co-related to its properties of lower elevation and high rainfall. Pune is on the other end of the spectrum with higher elevation and lower rainfall and shows the highest pollutant concertation levels.

All other less progressive cities of the state fall under the same umbrella. They exhibit the least pollutant concentration (other than SO₂) correlated with the higher forest area percentage, lower industrial area and large industries counts. This behaviour answers our question about the city’s progression resulting in higher pollutant level, which should point us in the direction of better planning for future development keeping measure to control air pollutant in mind.

Lowest SO₂ level observed in Mumbai warrants further research, its relationship to humidity may be a factor here as Mumbai has highest humidity number owing to its closeness to the Arabian Sea.

Findings for PCA analysis for pollutant concentration impacts on each other and time-series analysis for future pollutant levels will be shared in the final report.

REFERENCES

[1] Public Health Foundation of India, New Delhi, 6 Dec 2018, Press Release https://phfi.org/wp-content/uploads/2018/12/first-comprehensive-estimates-of-the-impact-of-air-pollut ion-india.pdf –

[2] Emami, Fereshteh & Masiol, Mauro & Hopke, Philip. (2017). Air pollution at Rochester, NY: Long-term trends and multivariate analysis of upwind SO₂ source impacts. The Science of the total environment. 612. 1506-1515. 10.1016/j.scitotenv.2017.09.026. –

[3] Núñez-Alonso, David & Pérez-Arribas, Luis & Manzoor, Sadia & Caceres, Jorge. (2019). Statistical Tools for Air Pollution Assessment: Multivariate and Spatial Analysis Studies in the Madrid Region. Journal of Analytical Methods in Chemistry. 2019. 1-9. 10.1155/2019/9753927.

[4] Haque, M.S. & Singh, R.B.. (2017). Air Pollution and Human Health in Kolkata, India: A Case Study. Climate. 5. 10.3390/cli5040077.

[5] Qu, Huamin & Chan, Wing-Yi & Xu, Anbang & Chung, Kai-Lun & Lau, Alexis & Guo, Ping. (2007). Visual Analysis of the Air Pollution Problem in Hong Kong. IEEE transactions on visualization and computer graphics. 13. 1408-15. 10.1109/TVCG.2007.70523.

[6] Government of India, Ministry of Environment, Forest & Climate change, Permissible Level for Pollutants: http://www.indiaenvironmentportal.org.in/files/file/Permissible%20Level%20for%20Pollutants.pdf

**Additional References**

* Fotopoulou, Eleni & Zafeiropoulos, Anastasios & Papaspyros, Dimitris & Hasapis, Panagiotis & Tsiolis, George & Bouras, Thanassis & Mouzakitis, Spiros & Zanetti, Norma. (2015). Linked Data Analytics in Interdisciplinary Studies: The Health Impact of Air Pollution in Urban Areas. IEEE Access. 4. 1-1. 10.1109/ACCESS.2015.2513439. [10]
* Shaban, Khaled & Kadri, Abdullah & Rezk, Eman. (2016). Urban Air Pollution Monitoring System With Forecasting Models. IEEE Sensors Journal. 16. 1-1. 10.1109/JSEN.2016.2514378.[11]
* Geng, Zhaowei & Chen, Qixin & Xia, Qing & Kirschen, D.s & Kang, Chongqing. (2017). Environmental Generation Scheduling Considering Air Pollution Control Technologies and Weather Effects. IEEE Transactions on Power Systems. 32. 127-136. 10.1109/TPWRS.2016.2544851.[12]

APPENDICES

Data is being collected from the following government repositories: -

* Pollutant:-https://data.gov.in/catalog/historical-daily-ambient-air-quality-data
* Vehicle Registration:-http://mospi.nic.in/statistical-year-book-india/2017/189
* Rainfall:-https://www.indiawaterportal.org/
* Elevation:-https://en.wikipedia.org/wiki/<CityBasedURL>
* Industrial Area:- [http://dcmsme.gov.in/<CityBasedURL](http://dcmsme.gov.in/%3cCityBasedURL)>
* Population:-https://mahasdb.maharashtra.gov.in/population1.do