

Final Report on

Carrying Capacity of Air Environment, NCT Delhi

(VOLUME -II)



Sponsored by:

Delhi Pollution
Control Committee



School of Planning &
Architecture, New Delhi



This page is intentionally left blank.

PREFACE

The National Capital Territory of Delhi is situated in the Northern Plains which is surrounded by the Himalayas in the North and the Deccan Plateau in the South which traps the air pollution in its bowl like formation. Being one of the most populous and dense metropolitan cities in semi-arid climate, the air pollution levels are consistently high and is a matter of great concern. The study has been conducted to assess the Carrying Capacity of NCT Delhi w.r.t Air Environment with the support of the Delhi Pollution Control Committee. Air pollution levels in any urban settlement is a result of sources outside and within the settlement. Some studies estimate that about one third of the air pollution in NCT Delhi is from sources within the settlement based on monitoring data available during lockdown. In a dense settlement pollution also concentrates in areas due to air flow modulation as a result of the landuse, built form and resultant micro-climatic conditions. The study has looked into sources of air pollution at Regional, City and Local levels, alongwith listing of landuse activities. Analysis of land use, built form and activities around monitoring stations of Delhi before and after lockdown has brought forth the need to have more detailed study to further understand the co-relation in a scientific manner.

The study concludes with strategies and recommendations to take forward the National Policies and regulations by embedding them into all the sectors of development. Identification and addressing the sources in all sectors some of which are currently unaccounted would help in arriving at specific areas, landuses and activities that need to be phased out or controlled. The study also puts forth methods to control and regulate exposure to air pollution which could be further strengthened by more detailed studies.

This page is intentionally left blank.

ACKNOWLEDGEMENT

We are thankful to Shri Sanjeev Khirwar, Chairman and Shri K.S.Jayachandran, Member Secretary, Delhi Pollution Control Committee for involving the Department of Environmental Planning, School of Planning and Architecture, New Delhi for conducting the study on Carrying Capacity of Delhi w.r.t Air Environment. The study would not have been completed without the support of Dr. M.P.George, Additional Director Air Pollution and Shri. B.L.Chawla, Senior Environmental Engineer, Research and Development, Planning Cell by sharing their insights relating to the degradation of air quality and valuable inputs during the assessments. We are also thankful to the team of RDPCC for their support in co-ordination for smooth progress of the study.

TEAM MEMBERS:

The document has been prepared by the Department of Environmental Planning, School of Planning & Architecture, New Delhi consisting of the following members:

Project Co-ordinator : Prof. Dr. Meenakshi Dhote

Research Associates: Shri Jwngma Basumatary and Shri Himanshu Panwar

MANDATE & SCOPE

Subsequent to Source Apportionment Studies for Delhi carried out by (i) IIT Kanpur in May, 2016, (ii) The Energy and Research Institute (TERI) in August, 2018 and (iii) Centre for Science and Environment (CSE) in 2019, Hon'ble National Green Tribunal in a matter of: News Item Published in the The Times of India authored Sh. Vishwa Mohan titled ***“NCAP with multiple timelines to clean air in 102 cities to be released around August 15”***, had issued directions for study to assess Carrying Capacity of NCT Delhi on the environmental aspects. **.(Order dated 20.11.2019, w.r.t OA No. 681/2018 (I.A. No. 411/2019) with O.A No. 10/2019(EZ))** In response to the direction of the NGT order, Delhi Pollution Control Committee (DPCC), Delhi issued the work order for the project **“Study on Carrying Capacity of Air Environment in NCT Delhi” to School of Planning and Architecture, New Delhi.**

As per the Work Order dated 6th March 2020; the duration of the project was 21 days from the date of acceptance of the order and the methodology to be followed for the assessment of Carrying Capacity would include **the proposed methodology prepared by Central Pollution Control Board (based on IIT Guwahati's framework) and the methodology submitted by School of Planning and Architecture New Delhi .**

MEETINGS AND PRESENTATIONS

19th March 2020 - The First meeting was held at the Conference Room DPCC, when a presentation was made on the methodology of the study and request for latest data w.r.t. Source apportionment studies, Meteorological data, emission factors, transport, industries, DG sets etc. was made. While the work was in progress the imposition of Lockdown w.e.f from 22nd March 2020 effected the pace of the work as data was not easily available and discussions with officials could not take place.

28th March 2020 - The First Draft Report was submitted incorporating whatever data was available by that time. Comments and observations to the report were received vide mail dated 6th of May 2020, mentioning about certain anomalies in the data, need for incorporation of latest measures undertaken by DPCC in control of air pollution and need to clarify the basis of the observations especially w.r.t quantitative assessments. A request was made to DPCC to allow for extension of work to incorporate the changes. It was also requested that since during the lockdown the air pollution levels showed a substantial dip (perhaps the lowest ever recorded till then), hence an assessment w.r.t to activities and pollution could be possible and may be added to the scope of the study. The same was agreed upon.

15th July 2020 - Draft Final Report was submitted incorporating the suggestions along with work done related to the lockdown period.

13th October 2020 - The draft Final Report was again reviewed and presentation was made to Chairman DPCC. It was emphasised that **recommendations specific to Master Plan of Delhi** should be emphasised upon. Subsequent to the meeting the report was discussed and modified with inputs from DPCC.

5th February 2021- Presentation of the report was made to member Secretary DPCC and suggestions were incorporated and the Final Report was submitted in two volumes for final

acceptance

18th March 2021 – A meeting including presentation was fixed with Chairman and Member Secretary DPCC at Delhi Secretariat for finalization of the report. The present report is being submitted incorporating all the suggestions received.

BACKGROUND

Urban areas are characterized by high population density and economic development. The resulting pollutant emissions place an increasing pressure in the air quality of these areas. Whereas in the past the major reasons for poor air quality were industrial activity and domestic heating but, nowadays as a result of the rapid increase in mobility the major current urban air pollutants come from road traffic (Sturm et al., 1997). This is particularly significant for developing countries, where the rapid rates of both urbanization and growth in vehicle fleet (Faiz, 1993) are expected to be the highest in the world (World Health Organization/United Nations Environment Program, 1992). The simple reason being means of transportation is an important infrastructural facility. These play a very important role in the overall development of a country. As the numbers of vehicles are increasing rapidly, it has slowly but surely started hindering our atmospheric purity with the vehicular and noise pollution. The pollutants emitted from these are transported, dispersed or deposited by meteorological and topographical conditions. Thus, the resulting ground level concentration patterns have to be estimated to save the environment and indirectly the human race. It's for this reason that the assessment of carrying capacity is urgently required.

CONCEPT OF CARRYING CAPACITY

The concept of carrying capacity is very important for developmental planning and hence needs to be defined properly. Carrying capacity, in broad terms, is an indicator of potential for future growth keeping in view the resources such as air, water, land etc. Air environment is important as most of the developmental activities tend to have an impact on the surrounding air quality.

FRAMEWORK FOR CARRYING CAPACITY BASED DEVELOPMENT PLANNING

The development of framework for carrying capacity-based planning involves, mainly, identification of the resources of the region and scope of their utilization vis-à-vis environmental impacts. The carrying capacity of air environment gives a rough estimate of the emission load (from various sources; man-made and natural) it can sustain under a set of specific conditions (resource allocation, topographic and atmospheric). We should put our efforts to explore strategies for planned and sustainable development within the carrying capacity.

SUPPORTIVE CAPACITY DIMENSIONS OF AIR ENVIRONMENT

Supportive capacity determines the developmental potential of a region and economic progress

and quality of life. Supportive capacity includes Urban Land and Shelter Resource, Urban Social, Physical and Communication Infrastructure, Urban Utilities and Human and Institutional Resource. The aspects have been assessed based on comparison with existing norms and standards arriving on adequacy/ deficiency, above or below standards. This has been followed by recommendations relating to assessment.

ASSIMILATIVE CAPACITY DIMENSIONS OF AIR ENVIRONMENT

Assimilative capacity refers to the ability of the environment or a portion of the environment (such as a stream, lake, air mass, or soil layer) to carry waste material without adverse effects on the environment or on users of its resources. Assimilative capacity includes Air Environment, Water Environment, Land/Soil Environment, Biological Environment and Acoustic Environment. The term “assimilative capacity” of the atmosphere is believed to be used interchangeably with the “carrying capacity”. The assimilative capacity of the atmosphere gives roughly an idea of the extent to which the atmosphere is capable of sustaining the pollution load from various emission sources. Thus, a thorough study of the assimilative capacity is essential for judging proper siting of new industrial units and for regulating the operating of the industries according to the atmospheric conditions. The assimilative capacity depends on various physical parameters such as the atmospheric stability, the topography of the region etc. The atmospheric stability is a crucial parameter which is based on solar insolation, mean wind speed and temperature profile. The assimilative capacity of the atmosphere is directly proportional to the ventilation coefficient and inversely proportional to the pollution potential. Further, the ventilation coefficient is expressed as a product of the mixing height and the transport wind speed within the mixing layer. The use of atmospheric stability for the estimation of assimilative capacity is manifested in the mixing height and the transport wind. A region with large pollution potential would have less carrying capacity.

RESOURCE ALLOCATION STRATEGIES

Optimum and proper utilization of the resources is an important aspect of the carrying capacity based development. For an integrated approach towards sustainable development there is a need to evolve proper strategies for balanced allocation of the resources in the region. The knowledge of assimilative capacity would be desirable for determining the resource allocation strategies for various parts of the region. This is very essential for decision making related to overall regional development .

STUDY AREA: NATIONAL CAPITAL TERRITORY OF DELHI

Delhi faces a severe air pollution problem due to the number of sources which are impacting the ambient air quality. Vehicular pollution in Delhi has grown from 64% to 72% from 1990 to 2000, whereas petrol and diesel consumption have grown by 400% and 300% respectively. Other sources such as biomass burning, refuse burning, construction dust and other unregulated sources are becoming major sources in some areas of high pollution levels. Two previous studies (IIT Kanpur and TERI) show considerable trend in the emission inventory of the city, which further needs to be enhanced and reciprocated in upcoming years.

APPROACH

- **Source Apportionment Study:** The source apportionment study of NCT of Delhi has already been carried previously. Two studies (CPCB and IIT Kanpur) were limited to Delhi and three (Guttikunda, SAFAR, and TERI) to the NCR. Among the studies of the NCR, Guttikunda (2018) covered only urban areas of NCR - Gurugram, Faridabad, and Ghaziabad - and excluded rural areas. The SAFAR study considered Gurugram, Faridabad, Sonapat, and Jhajjar (Haryana) and Ghaziabad, Baghpat, and Gautam Buddha Nagar (Uttar Pradesh). These studies extensively provide the information of various sources of pollution in Delhi. They can be used for analysing the trend of pollutants and emission sources over the course of time.
- **Baseline Study:** It includes the comprehensive studies of land-use, demography, transportation, tourism and air pollution trend. These parameters are required to carry out the correlation between air pollution, land use, economic activities and infrastructure. It will serve as a determinant for formulation of carrying capacity framework and establish carrying capacity of Delhi city.
- **Projections:** The projections for the above mentioned parameters would be calculated for short term (5 years), medium term (10 years) and long term (20 years).
- **Analysis** Operating air quality monitoring stations for measurement of air quality is highly resource intensive in terms of time and cost. The appropriate spatial interpolation techniques can be used to estimate concentration where air quality monitoring stations are not available. Spatial mapping of air pollutants and the above mentioned parameters (land-use, transportation, etc.) would help in establishing correlation between the same.
- **Development of suitable framework for calculating carrying capacity:** Based on the above mentioned baseline data, a suitable framework would be developed considering the air environment for Delhi city. As of now, there is no carrying capacity framework established with respect to air environment.
- **Carrying capacity assessment:** The terms “Carrying Capacity” and “Assimilative Capacity” of the atmosphere are interchangeably used. Assimilative Capacity of the atmosphere gives roughly an idea of the extent to which atmosphere is capable of sustaining the pollution load from various emission sources. The assimilative capacity depends upon the various physical parameters such as atmospheric stability and the topography of the region. Understanding of both the capacities is essential for establishing action plans.
- **Recommendations:** As per the estimated carrying capacity and assimilative capacity interventions would be suggested at different scales and suitable action plans (short, medium and long term) will be formulated

SCOPE OF WORK

The study is limited only to NCT Delhi and does not cover National Capital Region. The scope of work includes: Study of existing source apportionment reports (IIT-K, 2016 & TERI 2018), Compilation & baseline study for 2019, Projections for short, medium and long term of all the selected parameters, Spatial mapping of Parameters & Overlay Analysis of Pollutants, Revision in carrying capacity assessment framework, carrying capacity assessment and proposing action plan and recommendations.

METHODOLOGY

SNO.	ASPECTS	PARAMETERS	ELEMENTS
1	LITERATURE STUDY: SOURCE APPORTIONMENT STUDY REPORT	2016	PM10, PM2.5
		2018	PM10, PM2.5
2	BASELINE STUDY (DELHI)	Study Area Profile	Physiography, Climate & Natural Resources
		Demography	Existing Population And Projections - Domestic & Floating Population
		Land Use Study	Residential, Commercial, Psp, Industry, Mixed Use & Recreational
		Transportation	Traffic Movement, Modal Split, V/C Ratio
		Industries	Type Of Industries And Their Emissions
		Tourism	Trend
		Air Pollution (Emission Loads)	Emission Inventory (As per secondary survey)
3	PROJECTIONS	Short Term (2025)	Projections Of Above Mentioned Parameters (land-use, demography, infrastructure, transportation, tourism, air pollution)
		Medium Term (2030)	
		Long Term (2040)	
4	ANALYSIS	Demography	Spatial Mapping of Parameters and Overlay Analysis of Pollutants
		Landuse	
		Urban Built-Form	
		Wind Speed & Direction	
		Transportation	
		Emission Estimations	
		Air Pollution	Air Quality at all monitoring stations with respect to land use and local activities, Air Quality During COVID-19 Pandemic Lock-down In Delhi and Effect of lockdown at few monitoring stations selected based on predominant landuses
5	DEVELOPMENT OF SUITABLE FRAMEWORK FOR CALCULATING CARRYING CAPACITY*	*(Note: The existing urban land carrying capacity formulated by IIT Guwahati represents only the urban aspect and doesn't consider the air environment hence a framework for addressing air environment needs to be worked out)	
6	CARRYING CAPACITY ASSESMENT	Based on the framework developed	
7	SCALES OF INTERVENTIONS	Regional, City and Local level	
8	ACTION PLAN	SHORT TERM (2025)	Recommendations
		MEDIUM TERM (2030)	
		LONG TERM (2040)	

EXECUTIVE SUMMARY

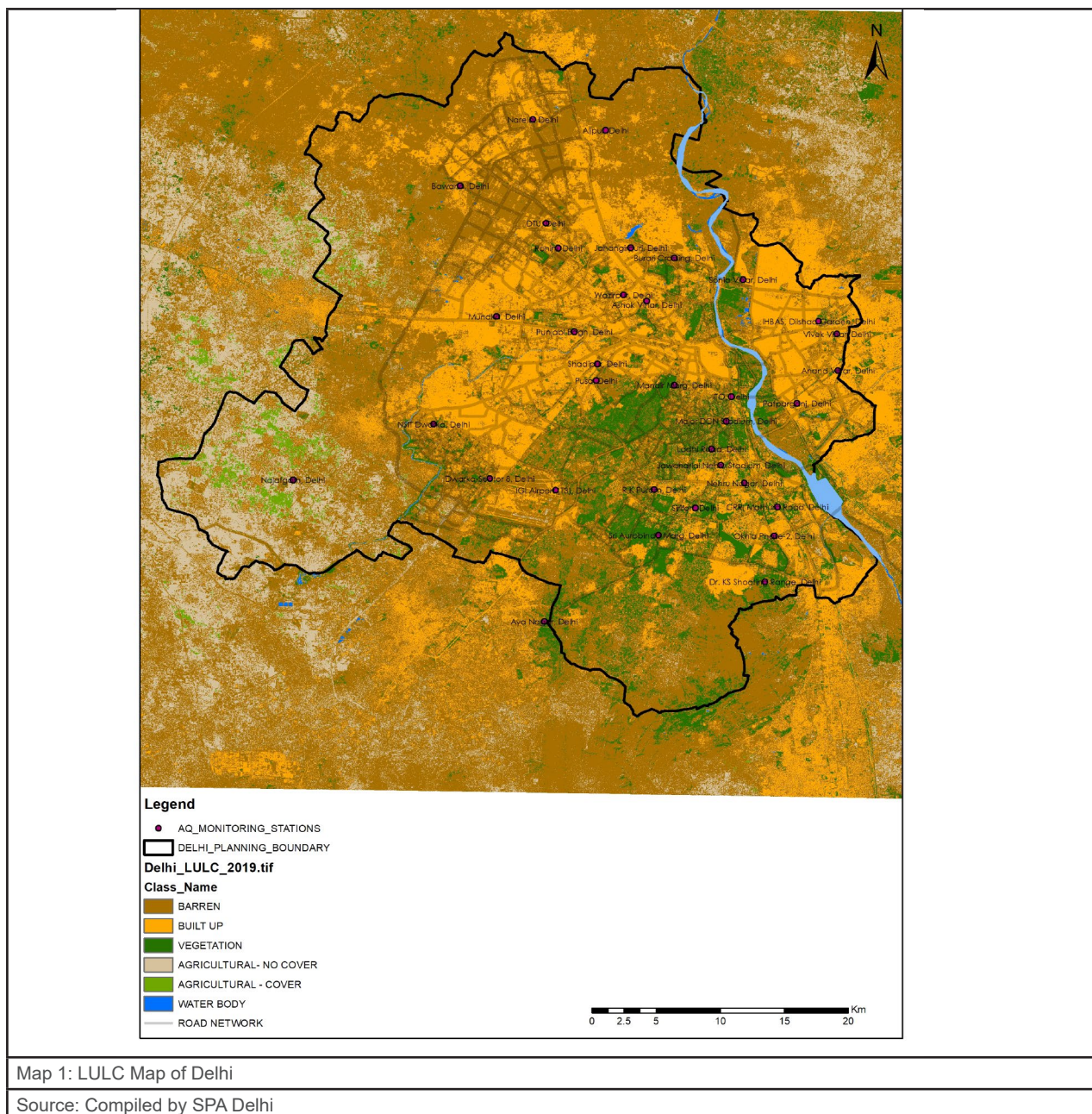
INTRODUCTION

Subsequent to Source Apportionment Studies for Delhi carried (i) IIT Kanpur in May, 2016, (ii) The Energy and Research Institute (TERI) in August, 2018 and (iii) Centre for Science and Environment (CSE) in 2019, Hon'ble National Green Tribunal in a matter of: News Item Published in the The Times of India authored Sh. Vishwa Mohan titled "NCAP with multiple timelines to clean air in 102 cities to be released around August 15", has issued directions for study to assess Carrying Capacity of NCT Delhi on the environmental aspects. So, Delhi Pollution Control Committee (DPCC), Delhi have sponsored this project "Study on Carrying Capacity of Air Environment in NCT Delhi" to SPA Delhi. This document constitutes the report that has addressed all important points of scope of work and methodology for carrying out the carrying capacity with respect to land-use. The study extensively used spatial techniques using GIS and have concluded with strategies and recommendations to take forward the National Policies and regulations by embedding them into all the sectors of development. The study analyses the data of $PM_{2.5}$ and PM_{10} of 2019, carried out for 37 monitoring stations (CPCB, DPCC and IMD) spread all over the city.

Some major findings of sources of air pollution at regional, city and local levels, emission inventory, analysis based on landuse, built form and activities around monitoring stations of Delhi before and after lockdown and future projections are summarized in subsequent paragraphs.

PHYSIOGRAPHY, CLIMATE, NATURAL RESOURCES & DEMOGRAPHY

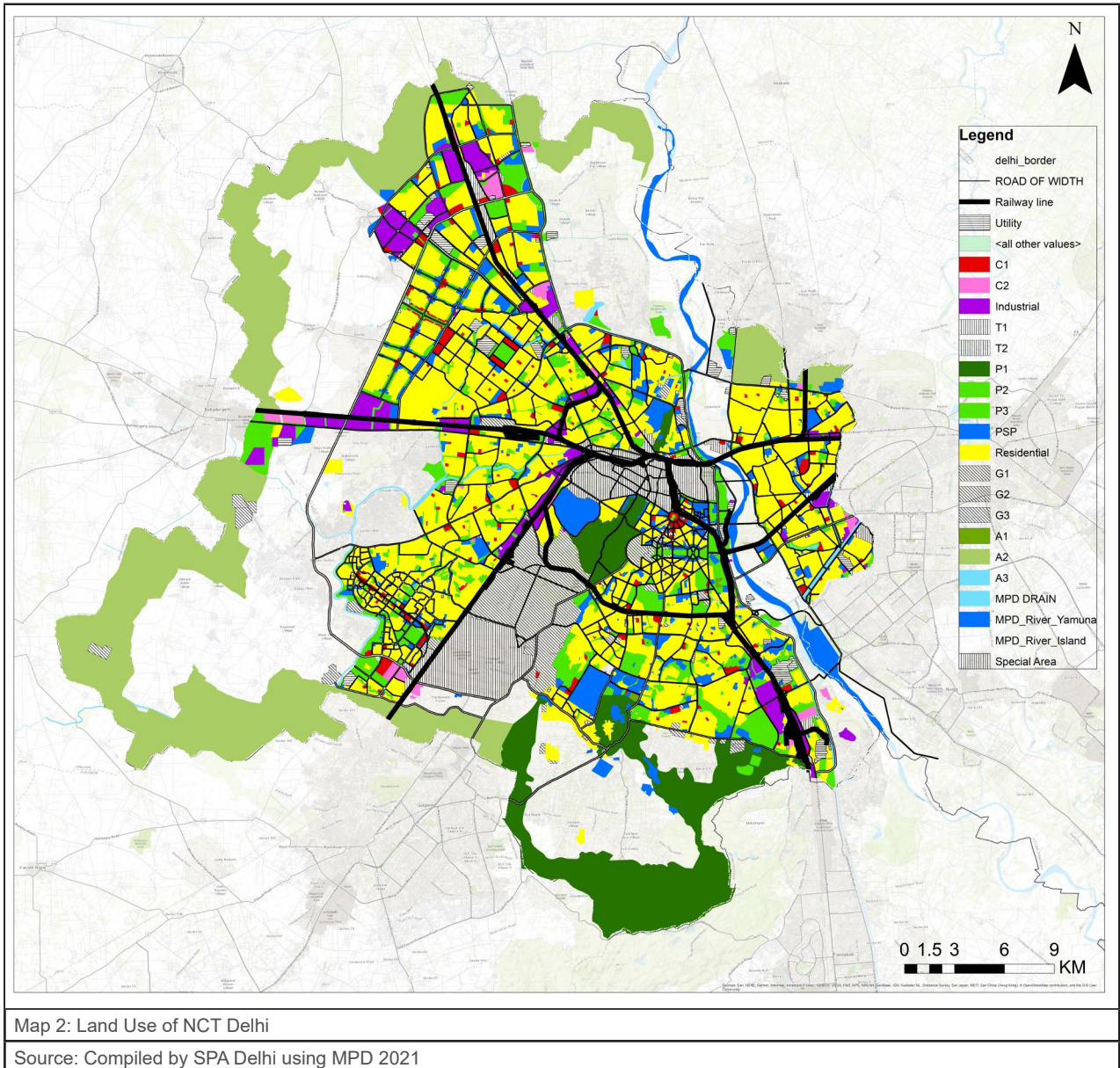
Physiographically, Delhi lies between Indo-Gangetic alluvial plains in the north and east, the Thar Desert in the west and the Aravalli Range in the south. The Indo-Gangetic Plains (IGP) experiences frequent dust storms every year during the pre-monsoon season. Dust storms observed in India come either from the Thar Desert located in the western parts of India or from distant source of the Arabian Peninsula. In cities, closer to the coast, the sea breeze and moisture helps in dispersion of pollutants. But, the Indo-gangetic plain is land-locked by the Himalayas and other mountain ranges. Polluted air in this region is unable to escape due to low wind speed. This results in smog over most of North-India. The city has around 11.88% of the forest or vegetation cover which is also responsible for the biogenic emissions. The biogenic volatile organic compounds (BVOCs) emissions are functions of the species leaf mass (Leaf Area Index), emission factors, temperature and light conditions. BVOC emissions requires an emission inventory model with region-specific input databases and a high degree of spatial and temporal resolution. Delhi accounts for 1.38% of the total country's population and its annual growth rate is 1.92%. As per the Best Fit Curve model, the population of Delhi is likely to increase to around 25 million by 2030 and 31 million by 2040.



LAND-USE

Delhi as the National Capital has a distinct and unique character. It is a growing and expanding magnet of attraction for people from all across the country and also a hub for the region surrounding it. With the imperatives of growth and development, the problems of Delhi have become complex, which have to be viewed both as a challenge in terms of the pressures of regular and floating in-migration, as well as an opportunity in terms of planning and development in a regional context. In order to control the development in Delhi, the areas were designated as one of the 27 use zones. These use zones have been classified broadly in nine categories of land uses namely Residential, Commercial, Industrial, Recreational, Transportation, Utility, Government, Public & Semi - Public Facilities and Agriculture & Water Body. As there was no study conducted on existing land-use of the city lately, so land-use as per the Mater Plan of Delhi, 2021 was assumed to be the land use for 2020. As per the master plan, Major development and construction activities will be proliferating in Dwarka, Rohini, Narela to accommodate additional

population. Population growth induces vehicular growth to meet the demands of movement of people, goods and services. Vehicles discharge gases that harm the environment and human health.



POLLUTANT CONCENTRATION

The SO₂ levels in Delhi are recorded much below the annual permissible limit of 50 µg/m³. In post- 2000, the annual average of SO₂ has declined that is attributed to the shifting of industries and reduction in Sulphur content in the fuel used in automobiles. Researches on NO₂ in Delhi point out that the use of CNG has proved to be a paradigm shift in improving the quality of environment in the city. The PM_{2.5} and PM₁₀ levels are strikingly soaring in the city. These are most prominent during winters, especially in the form of smog formation. In post-2005, sharp rise is observed in PM content. Increased SPM may be due to various factors like the natural sources like road dust and meteorological conditions contribute to PM in the air. Various anthropogenic sources are incomplete combustion from industries and vehicles, agriculture, construction, fireplaces, refuse burning, etc.

SECTOR	Emissions (kg/day)	
	PM _{2.5}	PM ₁₀
CREMATORIUM	120.8	1232.69
RESTAURANT	11545.8	10023.25
AIRPORT	-	3863.88
SOIL DUST	133.26	66.63
WASTE INCINERATORS	-	14.37
LANDFILL FIRES	861.04	1266.24
TOTAL	82149.33	49942.06

With the increase in population and urbanization in Delhi, the economic activity is going to increase rapidly catering to the growing needs of people. The intensity of activities will increase leading to proliferation of longer period of air pollution. Emission Loads for Business as Usual Scenario (BUA) for 2019, 2025, 2030 & 2040 are represented below (Table 2).

Table 2: Estimation of overall emissions

SECTOR	2019_Emissions (kg/day)		2025_Emissions (kg/day)		2030_Emissions (kg/day)		2040_Emissions (kg/day)	
	PM _{2.5}	PM ₁₀	PM _{2.5}	PM ₁₀	PM _{2.5}	PM ₁₀	PM _{2.5}	PM ₁₀
TRANSPORT	1224.18	-	1275.59	-	1318.43	-	1404.13	-
INDUSTRIES	62501.2	0	65626.26	0	68751.32	0	71876.38	0
POWER PLANTS	-	-	-	-	-	-	-	-
RESIDENTIAL	99.02	630.18	143.704	914.48	162.448	1033.76	193.688	1232.56
AGRICULTURAL WASTE BURNING	1041.10	1301.37	1041.10	1301.37	249.97	312.46	0	0
ROAD DUST	2871.56	22751.02	2992.17	23706.59	3092.68	24502.88	3293.68	26095.39
CONSTRUCTION	-	1074.9	-	1074.9	-	1074.9	-	1074.9
DG SETS	-	785.5	-	785.5	-	785.5	-	785.5
REFUSE BURNING	861.04	1266.24	1015.59	1493.51	1148.06	1688.32	1368.84	2013.00
CREMATORIUM	120.85	1232.69	120.85	1232.69	120.85	1232.69	120.85	1232.69
RESTAURANT	11545.80	10023.25	12123.09	10524.41	12700.38	11025.58	13277.67	11526.74
AIRPORT	-	3863.89	-	3863.89	-	3863.89	-	3863.89
SOIL DUST	133.26	66.63	120.03	60.01	106.80	53.40	100.79	50.39
WASTE INCINERATORS	-	14.37	-	14.37	-	14.37	-	14.37
LANDFILL FIRES	861.04	1266.24	1015.59	1493.51	1148.06	1688.32	1368.84	2013.00
TOTAL	81259.05	44276.28	85473.97	46465.25	88798.99	47276.06	93004.87	49902.42

AIR POLLUTION AT REGIONAL SCALE

Airshed: Management of air pollution sources, particularly those which affect territories over thousands of kilometres such as stubble burning, require high levels of co-ordination and co-operation. In the current administrative and legal framework, where state looks at air quality within their respective administrative boundaries, it is bound to catastrophically fail, as can be seen all around us. We will need to evolve new frameworks which will focus on reducing air pollution in an 'airshed', i.e. the entire area over which the pollutants disperse due to meteorological and geographical factors. Such airshed- based air quality management has been successfully tried in many places across the world, especially in California, United States. The concept is very similar to 'watershed', an area of land that drains all the streams and rainfall into a common outlet like a river. The region of the Indo-Gangetic plain, for example, may be

considered as one airshed. The region extends from Rawalpindi in Pakistan to Rangpur in northern Bangladesh and passes through some of the most populous states of India - Punjab, Delhi, Haryana, Uttar Pradesh, Bihar and West Bengal.

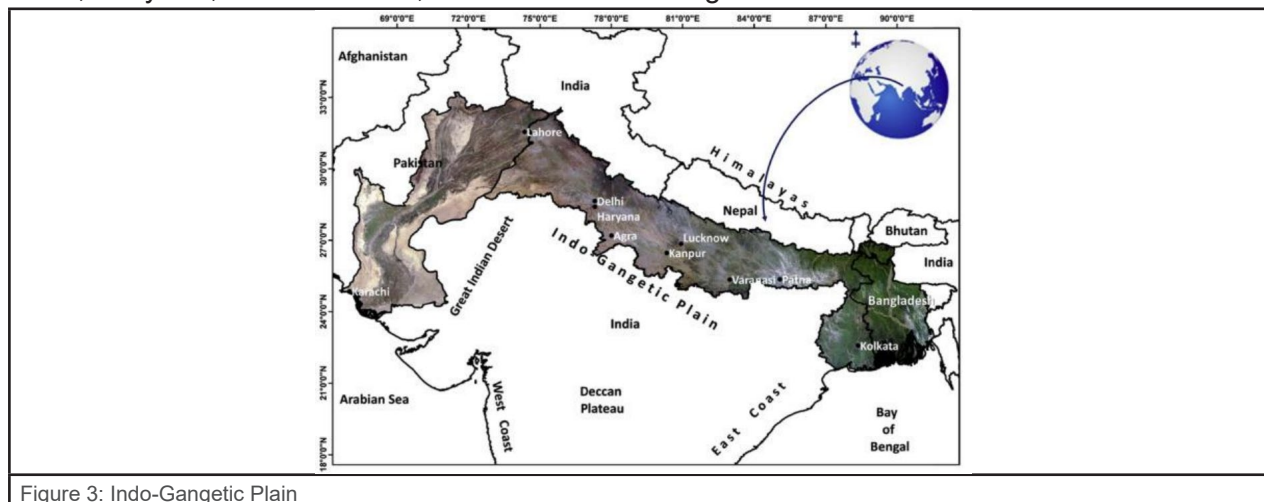


Figure 3: Indo-Gangetic Plain

METHODOLOGY AT SUB CITY LEVEL

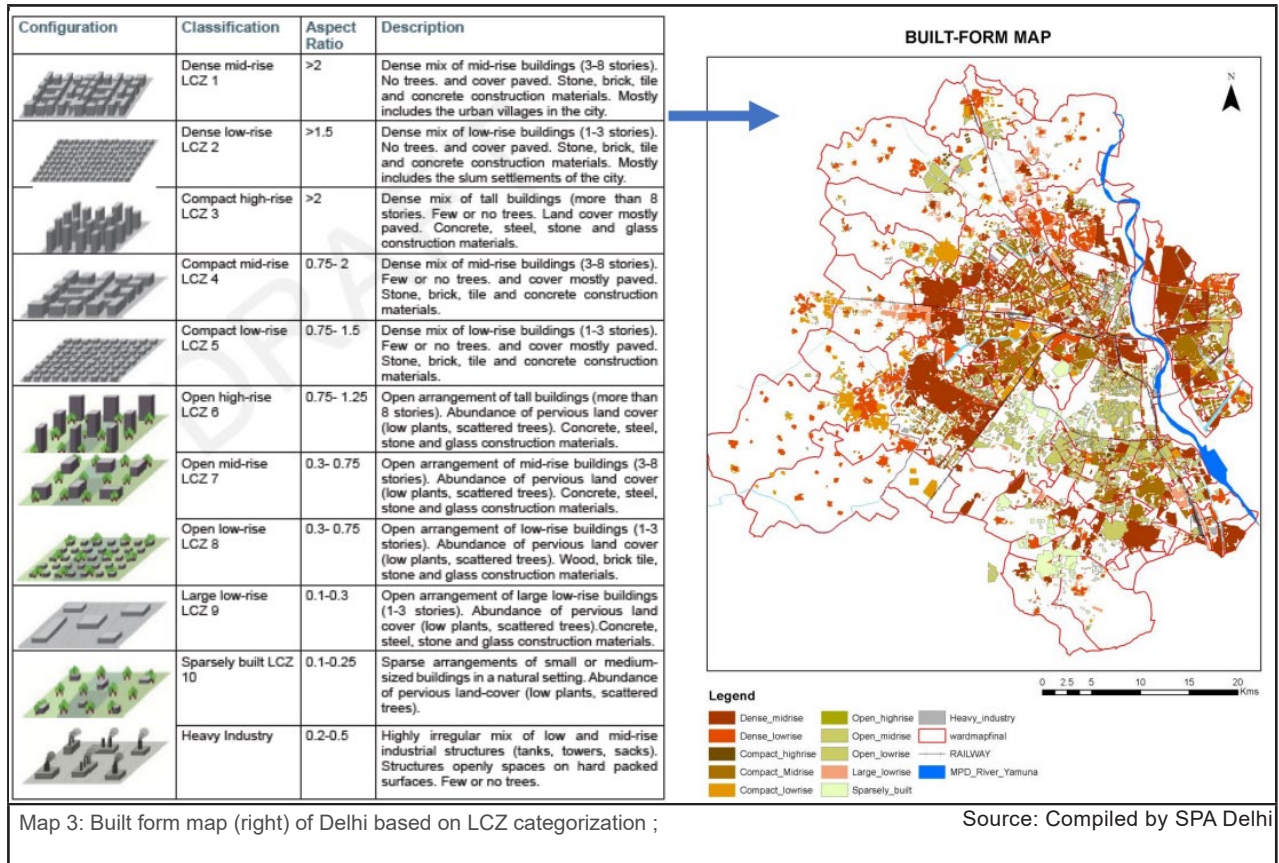
Land Use: The concentration of emissions is closely related to the land use type and type of activities involved. Studies have shown a positive correlation between the spatial patterns of air pollutants and urban built-up density. However, the study on degree of land-use contribution to pollution has not been explored to such depth. It gives a generally overview of how the sources are spatially distributed on the land-use map of the city.

Table 3: Land Use wise distribution of sub-sectoral contribution to $PM_{2.5}$ & PM_{10} in Delhi in 2016

Sno	MPD 2021		Land-use AS PER URDPFI	SECTOR (TERI REPORT)	$PM_{2.5}$ (%)		PM_{10} (%)	
	LANDUSE	%			WINTERS	SUMMERS	WINTERS	SUMMERS
1	Residential	45-55	36-38	Residential (R)	10	8	9	8
2	Agriculture	Balance	Balance	Agricultural Burning (A)	4	7	4	7
3	Industrial	4-5	7-8	Industry (I)	30	22	27	22
4	Commercial	4-5	5-6	Restaurant	1	0.4	0.6	0.5
				DG sets	5	2	4	2
5	PSP	8-10	10-12					
6	Circulation	10-12	12-14	Transport	28	17	24	15
				Road Dust	4	3	8	10
				Airport	1	0.2	0.4	0.1
7	Green / Recreational	15-20	14-16					
8	Vacant Land			Dust-Others	12	33	11	28
	TOTAL				95	92.6	88	92.6

Source: Compiled by SPA Delhi

Local Climatic Zones (LCZs) as proposed by Stewart and Oke in 2012 were used to study the urban built forms affecting the mechanism of dispersion processes in urban neighborhoods.

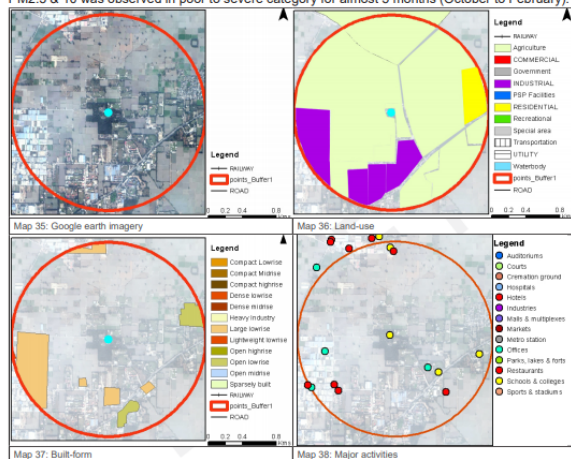


METHODOLOGY AT LOCAL LEVEL

Activities: The local level assessment was done for 38 monitoring stations present in Delhi. For this a buffer of 1Km (influence area/zone) around the monitoring stations was earmarked and accordingly the broad land uses, activities and LCZs were mapped.

8.1 ALIPUR, DELHI - DPCC

The majority (80%) of the influence area lies in agricultural zone, with very less distribution of roads and contains mainly industrial settlements. Data of wind speed wasn't available. Concentration of PM_{2.5} & 10 was observed in poor to severe category for almost 5 months (October to February).

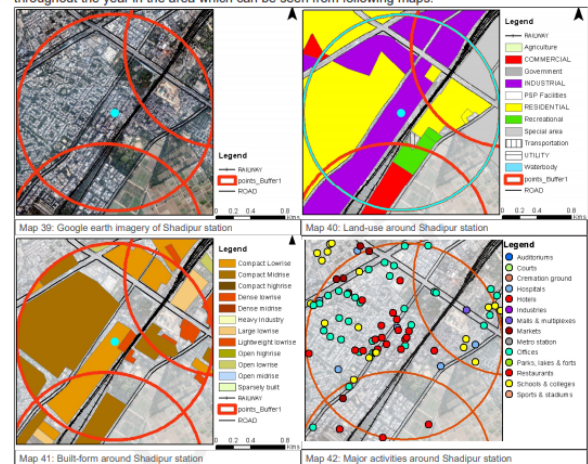


LCZ	Area (sq.km)	%	Types	Area (sq.km)	%	ALTIMUDE (m)	POLLUTION CONC.	VC	WS (m/s)
Dense lowrise	0.002	0.06	COMMERCIAL	0	0.0				
Dense midrise	0.000	0.00	INDUSTRIAL	0.6	19.1				
Open midrise	0.000	0.00	TRANSPORTATION	0.17	5.4				
Open highrise	0.000	0.00	RECREATIONAL	0	0.0				
Open lowrise	0.001	2.58	RESIDENTIAL	0.2	6.4				
Compact lowrise	0.000	0.00	PSP FACILITIES	0	0.0				
Compact midrise	0.000	0.00	GOVERNMENT	0	0.0				
Compact highrise	0.000	0.00	UTILITY	0	0.0				
Large lowrise	0.283	9.02	SPECIAL AREA	0	0.0	200-220			
Sparsely built	0.000	0.00	WATERBODY	0	0.0				
Green belt	2.600	82.80	GREEN BELT	2.18	69.4				
Open area	0.000	0.00							
Waterbody	0.000	0.00							
Road	0.170	5.41							
Heavy Industry	0	0.00							

Table 85: Percentage distribution of Built-form (LCZ) & land-use, pollution concentration, wind speed and ventilation coefficient

8.2 SHADIPUR, DELHI - CPCB

Concentration of PM_{2.5} was observed in poor to severe category for almost 9 months (October to June). It could be because of the emissions from industrial and construction activities happening throughout the year in the area which can be seen from following maps.



LCZ	Area (sq.km)	%	Types	Area (sq.km)	%	ALTIMUDE (m)	POLLUTION CONC.	VC	WS (m/s)
Dense lowrise	0.078	7.25	COMMERCIAL	0.11	3.5				
Dense midrise	0.000	0.00	INDUSTRIAL	0.7737	24.6				
Open midrise	0.000	0.00	TRANSPORTATION	0.055	11.3				
Open highrise	0.000	0.00	RECREATIONAL	0.2717	8.7				
Open lowrise	0.012	0.37	RESIDENTIAL	1.0265	32.7				
Compact lowrise	0.452	14.33	PSP FACILITIES	0	0.0				
Compact midrise	0.994	31.66	GOVERNMENT	0	0.0				
Compact highrise	0.000	0.00	UTILITY	0	0.0				
Large lowrise	0.057	1.80	SPECIAL AREA	0.209	6.7	200-240			
Sparsely built	0.000	0.00	WATERBODY	0	0.0				
Green belt	1.000	31.05	GREEN BELT	0.4	12.7				
Open area	0.200	6.27							
Waterbody	0.000	0.00							
Road	0.34	10.83							
Heavy Industry									

Table 86: Percentage distribution of Built-form (LCZ) & land-use, pollution concentration, wind speed and ventilation coefficient

The pollution inventories TERI (2018), IIT Kanpur(2016), SAFAR (2018), varies drastically when are compared to each other. Methodology, scale, season of study and the pollution estimation, all differ from each other (except the pollution sources) and there isn't any common parameter where significant inferences can be taken out. All the studies were done for different time slots and none of them were covered for entire year. The resolution of the grid used also varied from 400 x 400 sq. to 4 x 4 sq.km. There was drastic difference observed in the sectoral emissions of the all the studies, which leads to large variance in the concentration of pollution and uncertainty around the actual contribution of each source to pollution. The studies didn't incorporate the impact of land use on air pollution or how the trend of pollution differs at each zone geographically. Also, various unaccountable factors or sources of pollution linked to the main pollution source have not been emphasized. Like the impact of loading and unloading of goods linked to the industrial activities and the effect of informal sector and their emissions have been missed out. Even there is fuel change in industries which have lowered the direct emissions; these supporting activities continue to impact emission contribution from this sector. There are many more unaccountable factors which put immense pressure on the concentration of air pollution in the city. If receptor modeling at all the monitoring stations is being carried out throughout the year month wise, significant observations can be made, which could further enhance the data quality and bold out better inferences. It will subsequently lead to effective policy measures.

Air Pollution is influenced by:

- Regional Factors (Macro-Level)
- Local Factors (Micro-Level)

At regional level, the factors include:

- Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
- Topography
- Land Use and Land Cover
- Activities around the city limits and its location.

At Local level, the factors include:

- Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
- Land Use: Primary activity and Secondary activity (Travel Demand)
- Location of Activities – Industries, Power Plants, Commercial Centres, etc.
- Building Heights: Local Climatic Zones

Delhi faces frequent dust storms every year during the months of March to June, which increases the pollution concentration in the region. These storms originate from Thar Desert located in the western parts of India or from distant source of the Arabian Peninsula. Erosion of forests along the northern and central Aravalli tracts has caused the advancement of the desert particularly in the gap area with increasing intensity of dust storms. So, increase in forest cover in the Aravalli might reduce the intensity of such storms.

The city receives most of the rainfall in July, August and September and during these months only the pollution concentrations are low, as the rain settles down the atmospheric pollutants

onto the ground. So, it can be said that for these months only Delhi can handle its pollution with activities normally running. Sirifort station showed higher PM_{10} concentration in this season (20 polluted days in July), it could be because there is urban forest in the area, which increases the moisture in the area due to increase in humidity. The increase of relative humidity in the atmosphere reduces the amount of solar radiation reaching the earth's surface. The heat from the solar radiation is observed by the air, resulting in minimizing atmospheric temperature nearer to the surface of earth. The air layer nearer to the surface of the earth becomes colder than the upper layers, thus reducing the upgoing currents and leading to the increase of pollutant concentrations. But station like Dwarka sec-8, showed higher PM_{10} concentration as it had uncovered open spaces which on high wind speed increases the dust in the air on non-rainy days in these months. During this season the wind speed is often higher compared to the rest of the year, it increases the dispersion rate of the pollutants hence lowering the concentration. Also, it was found that built form (refer map 3) also affects the wind speed inside the city, which creates chunks of land where there is negligible wind speed when compared to the areas nearby.

Predominant wind direction in Delhi is from North West. Westerly and north-westerly winds bring dust from western regions and smoke caused by burning of crop residue in neighbouring Punjab and Haryana to Delhi-NCR. Despite a ban on stubble burning in Punjab and Haryana, farmers continue to defy it amid a lack of financial incentives.

When temperature is high in summers, mixing height in Delhi is observed to be high and hence low pollution is observed in these areas. And when temperature is low in winters, mixing height reduces significantly, increasing the pollution in the city. So, in the months November to January when the temperature is low, the concentration is expected to be higher, as the dispersion rate is negligible and mixing height is really low.

These meteorological factors constitute the variable factors which are uncontrollable and highly influence the concentration of pollution in the atmosphere. Although certain alterations can be done to influence the factors like wind speed and direction by changing the urban form, but it is difficult to achieve in already developed city like Delhi.

Built-form map (Map 3) and the vegetation map of Delhi present how unevenly the vegetation has been distributed in the city. There are large pieces of land which are densely midrise and without any open spaces. These increase the activity rate in the zone and the decreases the pollution absorption areas. It lowers the scope of deposition, absorption or dispersion of pollution in the area.

In absence of mixing height data, solar radiation values can be accounted due to its higher correlation or dependency with mixing height. As solar radiation increases so does mixing height and vice versa. The solar radiation varies over region to region and the cloud cover over the region has strong influences over it. Solar radiation and wind speed are predominant factor of atmospheric stability (refer to Pasquill Atmospheric Stability Classes).

Hours above standard are total hours where pollutant concentration is beyond $60 \mu\text{g}/\text{m}^3$ breakpoint for $PM_{2.5}$ and $100 \mu\text{g}/\text{m}^3$ breakpoint for PM_{10} .

Equivalent Polluted Days is equal to total hours where pollutant concentration is beyond $60 \mu\text{g}/\text{m}^3$ breakpoint for $PM_{2.5}$ and $100 \mu\text{g}/\text{m}^3$ breakpoint for PM_{10} divided by 24.

The case of Delhi is unique in the sense that it has both geographical and meteorological disadvantages.

Data shows that even during high conditions of higher mixing heights, Delhi observes higher pollutant concentration. The main reason is the concentration and growing number of activities. Concentration of activities has huge influences on air pollutant concentration.

Even with revised fuel standards such as shifting of industries and vehicles to cleaner fuel, the situation of air pollution in Delhi would remain similar. The factors being

- increased population growth,
- increased number of activities,
- increased count of vehicles,
- increased demand for goods (transportation of goods)
- improper zoning of industries w.r.t air environment

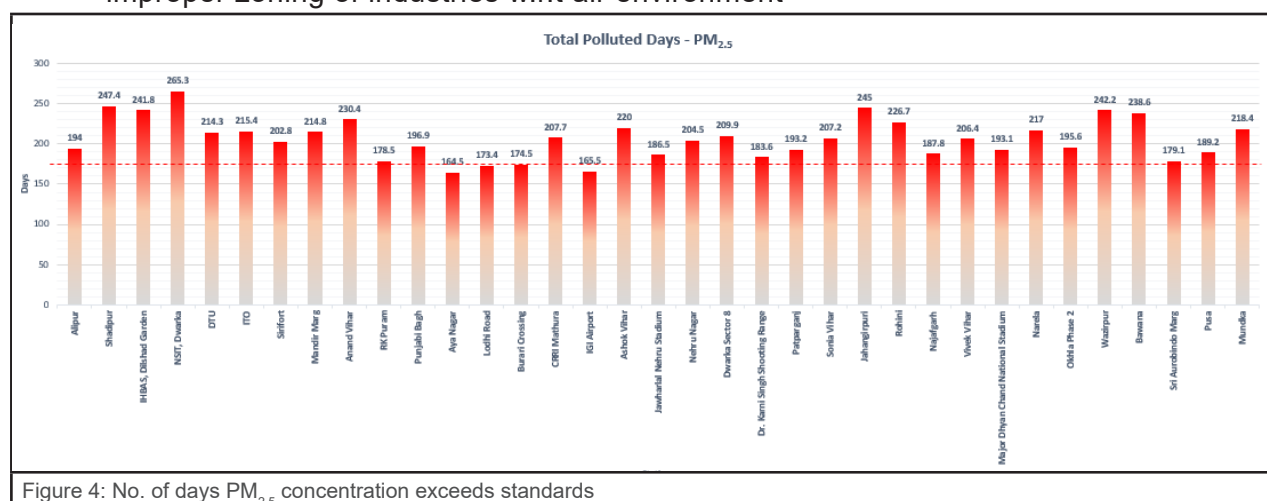


Figure 4: No. of days PM_{2.5} concentration exceeds standards

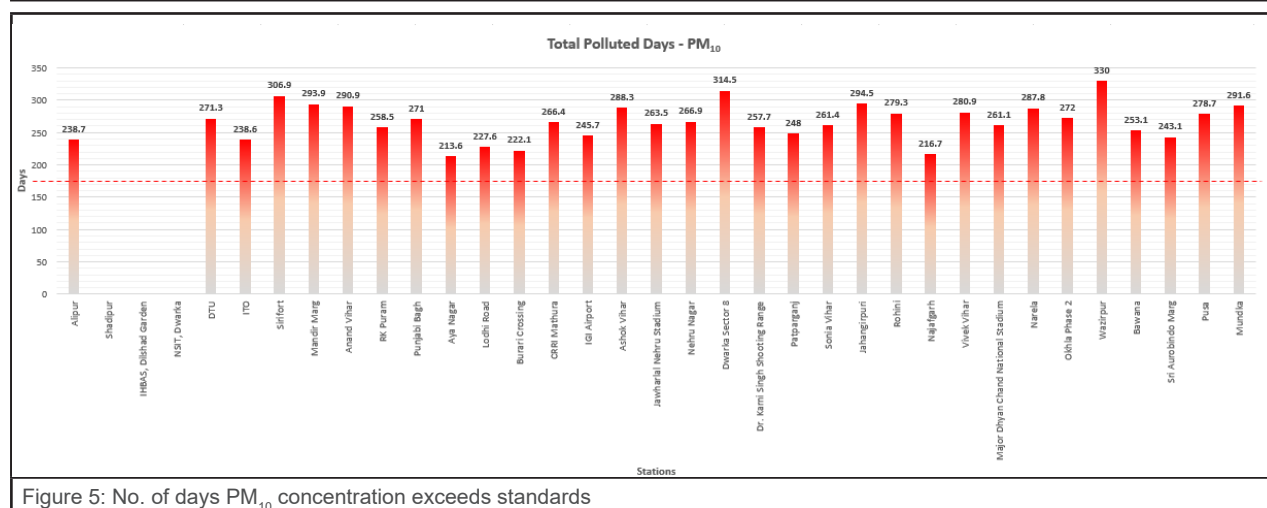


Figure 5: No. of days PM₁₀ concentration exceeds standards

Table 4: No. of polluted day (PM_{2.5}), Landuses and activities

Sno.	Monitoring Stations	No. of days PM _{2.5} concentration exceeding standards	% Area under Landuses- (Industrial + Transportation)	% Area under Landuses- (Recreational+ Green belt+ Agriculture)	Remarks
1	Aya Nagar	164.5	7.6	54.1	
2	IGI Airport	165.5	91.4	0.0	Although landuse falls in transportation, but IGI has mostly green surfaces

Sno.	Monitoring Stations	No. of days PM _{2.5} concentration exceeding standards	% Area under Landuses- (Industrial + Transportation)	% Area under Landuses- (Recreational+ Green belt+ Agriculture)	Remarks
3	Lodhi Road	173.4	9.2	20.2	"Landuse falls in PSP & Residential but have significant amount of trees "
4	Burari Crossing	174.5	11.1	55.1	More the % of greens, less is the no. of polluted days
5	RK Puram	178.5	9.2	19.7	Delhi Cantt. With significant greens lie in the direction from which the wind is blowing
6	Sri Aurobindo Marg	179.1	6.4	63.4	More the % of greens, less is the no. of polluted days
7	Dr. Karni Singh Shooting Range	183.6	0.0	96.0	
8	Jawaharlal Nehru Stadium	186.5	7.0	22.6	Although landuse falls in PSP, but stadium has mostly green surfaces and less activities
9	Najafgarh	187.8	4.8	88.5	More the percentage of greens, less the no. of activities and lesser is the no. of polluted days
10	Pusa	189.2	26.9	48.3	
11	Major Dhyan Chand National Stadium	193.1	0.8	45.5	
12	Patparganj	193.2	17.7	5.5	Lies on the Yamuna bank with the river in the direction of wind implying no major activities except residential
13	Alipur	194	24.5	69.4	More the percentage of greens, less is the no. of polluted days
14	Okhla Phase 2	195.6	54.5	20.4	The area under recreation is high
15	Punjabi Bagh	196.9	29.8	19.8	The area above monitoring station mainly has greens, although is under transportation
16	Sirifort	202.8	5.7	27.5	More the percentage of greens, less is the no. of polluted days
17	Nehru Nagar	204.5	12.1	5.0	Less percentage of greens, more are other activities, causing more polluted days in a year
18	Vivek Vihar	206.4	24.7	9.6	
19	Sonia Vihar	207.2	6.4	28.3	Due to advection, the area would have more polluted days even though has more greens.
20	CRRI Mathura	207.7	34.8	13.8	Less percentage of greens, more are other activities, causing more polluted days in a year
21	Dwarka Sector 8	209.9	25.7	26.3	The green land-uses which are located, are non-vegetative and exposed to soil dust.
22	DTU	214.3	7.3	11.0	Less percentage of greens, more are other activities, causing more polluted days in a year
23	Mandir Marg	214.8	9.7	41.0	It has major roads with heavy traffic throughout the year.
24	ITO	215.4	9.6	19.0	Less percentage of greens, more are other activities, causing more polluted days in a year
25	Narela	217	86.6	2.4	
26	Mundka	218.4	26.2	8.8	
27	Ashok Vihar	220	18.4	21.7	
28	Rohini	226.7	9.3	11.5	
29	Anand Vihar	230.4	55.4	1.6	
30	Bawana	238.6	48.1	13.5	
31	IHBAS, Dilshad Garden	241.8	23.1	3.6	
32	Wazirpur	242.2	37.0	11.7	
33	Jahangirpuri	245	4.8	13.3	

Sno.	Monitoring Stations	No. of days PM _{2.5} concentration exceeding standards	% Area under Landuses- (Industrial + Transportation)	% Area under Landuses- (Recreational+ Green belt+ Agriculture)	Remarks
34	Shadipur	247.4	28.3	24.0	The greens are in the opposite direction of the wind
35	NSIT, Dwarka	265.3	8.9	3.7	Less percentage of greens, more are other activities, causing more polluted days in a year
36	EAST ARJUN NAGAR		7.6	0.2	Data not available
37	NORTH CAMPUS		28.9	4.1	

It is quite evident from the above table how activities and land uses affect the number of days the air is polluted at each station. Mostly all the areas which have more 40 % land use under greens have considerably less no. of polluted days when compared to the areas with more no. of polluted days. Those stations (with less polluting days) which doesn't show correlation directly with land-uses have significant number of trees or green cover. Some stations continue to show high number of polluted days even if the greens are more than 20 %, it is because either the greens are in the opposite direction of the wind or lies in the major traffic junctions. Rest all shows how with the decrease in greens or increase in activity rate effects the no. of polluting days.

AIR QUALITY DURING COVID-19 PANDEMIC LOCK-DOWN

In this section, the detailed impact of meteorological conditions, landuse, built-form and activities on pollution concentrations during the phases of lock-down have been discussed. A buffer area of 1km around the monitoring stations have been analyzed with respect to the above-mentioned factors in it.

Lock Down Assessment: Alipur, Delhi

The station lies in the North-east region of the city, with predominant landuse under greenbelt carrying out agricultural activities. Industrial areas and godowns can also be seen in the buffer area.

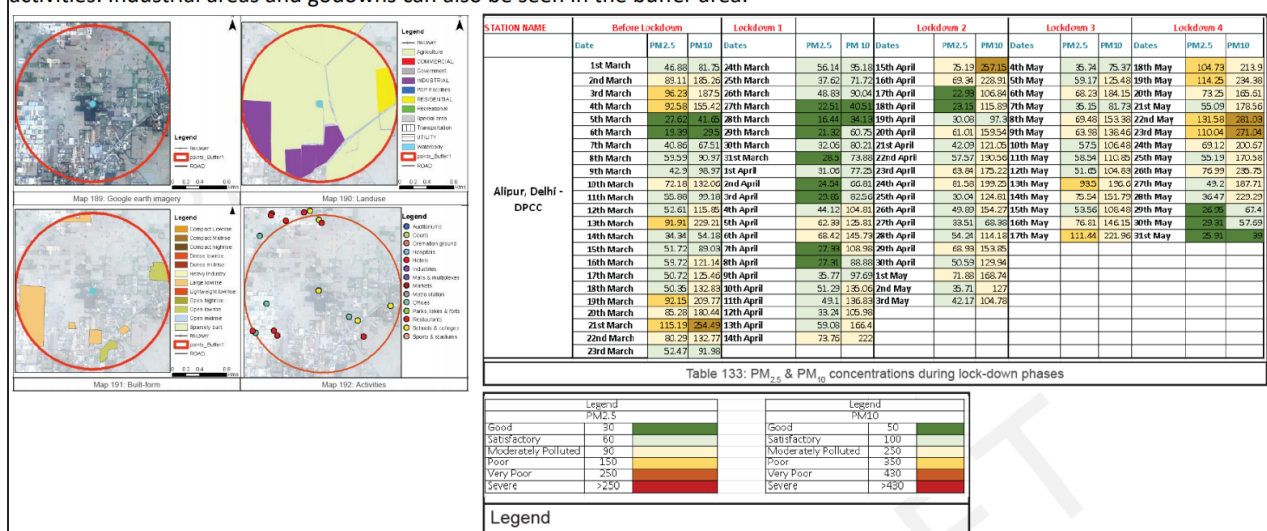


Figure 6: Assessment of air quality at Alipur station (before and during lockdown)

All the stations attributing different predominant landuses were analysed during the phases of

lock-down, 2019 and 2018, and some common observations were made. The stations on the south side of Delhi; Dr. Karni Singh Shooting Range, Aya Nagar and IGI airport mainly located on the fringes of the city, presented a common pattern. The emission loads attributed from these zones along the monitoring station were negligible as observed from the lock-down period as their concentration remained good to satisfactory in the first three phases of lock-down. It was observed that they mainly projected the concentrations arising through the influence of regional activities. $PM_{2.5}$ concentrations in all the three zones were good throughout the lock-down, whereas the PM_{10} concentration was good only in first three phases and increased in the 4th phase when the regional concentrations increased of other stations in the city.

The stations located in North Delhi were DTU and Alipur, which had agricultural as the predominant land use and activity. They both showed a gradual decline in the pollution concentration during the first lock-down phase, but the concentrations increased in the second phase after the harvesting activity began which usually happens after Baisakhi on 14th April every year. The concentration of pollutants remained similar from 2nd and 3rd phase, as only few restrictions were lifted in phase 2 and it remained the same thereafter as no additional activities were permitted/allowed in these zones which would have made a significant impact on the emission loads in these zones. The concentration at Alipur was observed to be similar only in 4th phase just like the 2nd and 3rd at the station, but was found to be increased at DTU, because of the influence of fire incidents which brought emission loads from North east direction to the station. Although, the wind direction at Alipur was also North east only, but there weren't any fire incident observed in the north east of the station which could have influenced the concentration.

The monitoring stations at Bawana, ITO and Ashok Vihar which had different predominant land uses; Industrial, PSP and residential respectively showed diverse pattern in the concentration throughout the lock-down phases.

Ashok Vihar Station which had residential land use had a decrease in concentration of pollutants when the lock-down was established, and thereafter remained the same (i.e., good quality) throughout the 4 phases. Hence, the emission loads from the residential activities are very less. Whereas, in Bawana industrial area, the concentrations during first three phases were similar only and increased significantly in the fourth phase when the major relaxation in movement of people, goods and services inside and outside the city were allowed. So, the pollution levels at this station depends highly on the emission load from the movement of vehicles supporting the industrial activities.

On contrary, the concentrations at ITO station increased majorly in the phase 2 itself, because of high vehicular traffic in the area. As the data of phase 3 and 4 at the station is insufficient, so nothing can be stated to analyse the pattern.

CARRYING CAPACITY ASSESSMENT

The ventilation coefficient, which is the product of mixing depth and the average wind speed, is an atmospheric condition which gives an indication of the air quality and pollution potential, i.e., the ability of the atmosphere to dilute and disperse the pollutants over a region.

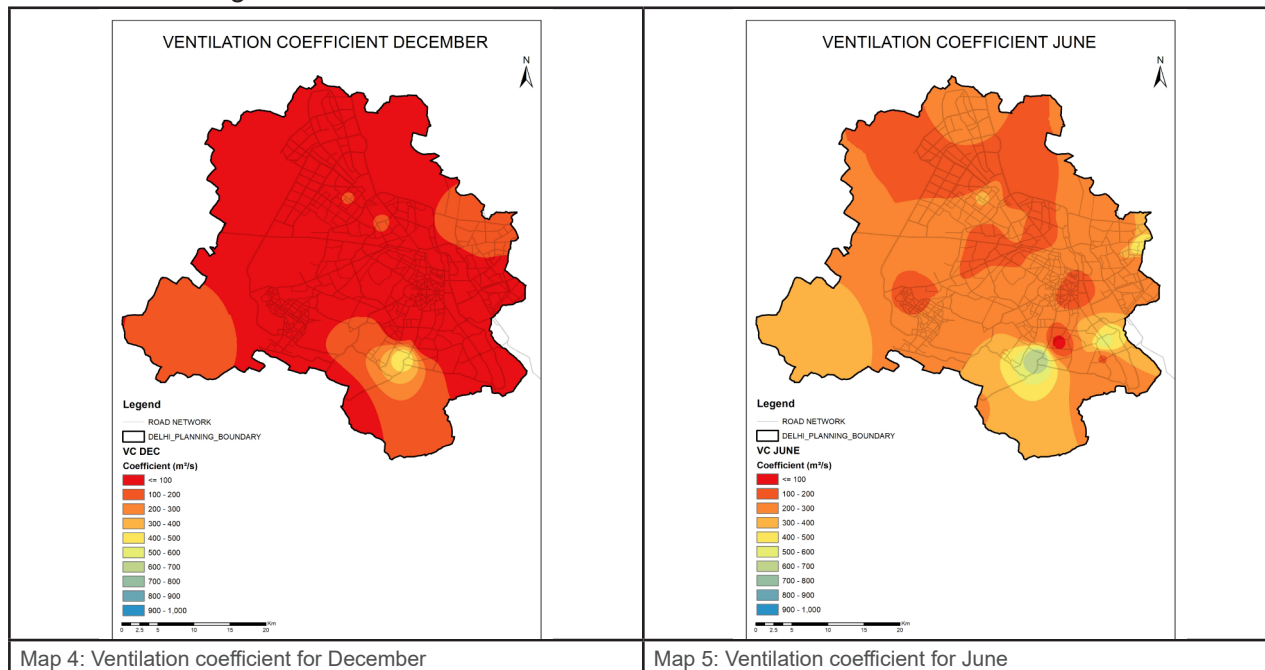
The ventilation coefficient (VC) is computed as:

$\text{Ventilation Coefficient} = \text{Mixing Height} \times \text{Mean wind speed}$

Table 5: Ventilation Coefficient in morning and afternoon

	PM _{2.5}	PM ₁₀	Wind Speed (m/s)	Mixing Height (m)	Ventilation Coefficient*
Morning	≤ 60	≤ 100	> 4	> 500	> 2000
Afternoon			> 4	> 1500	> 6000

Ventilation Coefficient simply provides a broad indication of the dispersion potential in terms of low (<2000 m²/s), medium (2000-6000 m²/s) or high (>6000 m²/s) of the atmosphere. But it does not give any idea about the amount of emission loads that can be assimilated in the given airshed of the region.



Carrying capacity is the ‘maximum capacity of environment that can support the existing emission load by a land use and its associated activities over a particular time period’. The concentrations of substances in the atmosphere are determined by: 1) transport, 2) diffusion, 3) chemical transformation, and 4) ground deposition.

Based on Anthropogenic activity:

$$\text{Emission Concentration} \propto a * K$$

Where, a – activity rate (units/hour), K – emission factor (g/unit)

Based on Meteorological factors:

$$\text{Emission Concentration} \propto \frac{1}{\text{Wind Speed}} \propto \frac{1}{\text{Mixing Height}} \propto \frac{1}{\text{Temperature}} \propto \frac{1}{\text{R.H}} \propto \text{Pressure}$$

Therefore, we can say that;

$$\text{Emission Concentration} \propto \frac{\text{Activity Rate} * \text{Emission Factor}}{\text{Wind Speed} * \text{Mixing Height}} \propto \frac{1}{\text{Temperature}} \propto \frac{1}{\text{R.H}} \propto \text{Pressure}$$

It is expressed as:

Carrying Capacity = (Emission Standard as per CPCB)/(Pollutant Concentration) × Ventilation Coefficient; (1)

$$\text{Carrying Capacity} = \left(\frac{\text{Emission Standard as per CPCB}}{\text{Pollution Concentration at monitoring station}} \times \text{Ventilation Coefficient} \right) - \text{Ventilation Coefficient}$$

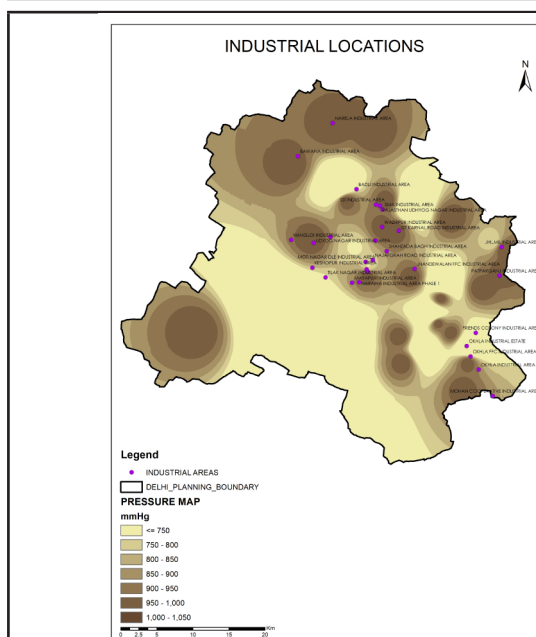
i.e.,

The Ventilation coefficient shows only the dispersion potential. So, to actual capture the Real Carrying Capacity (RCC), the parameters such as diffusion, chemical transformation and ground deposition needs to be factored in the calculations.

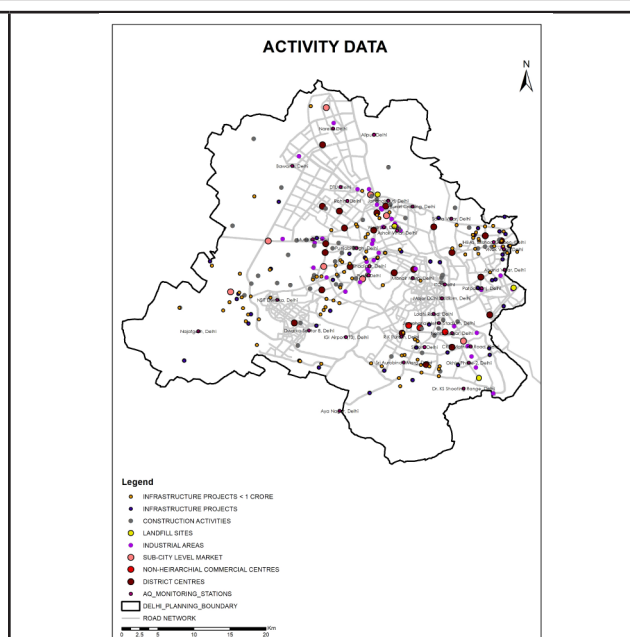
The carrying capacity changes over time as it depends on atmospheric stability and emission load over a certain period of time.

Carrying Capacity is said to be good when the estimated C.C is greater than the ventilation coefficient. Thus, the carrying capacity is dependent majorly on the activities i.e., emission load per day generated by land use based activities. This suggest that no matter what the ventilation coefficient is, the goal is to keep the emission below its standard.

Month	Mean Wind Speed (m/s)	Min Mixing Height (m)	Max Mixing Height (m)	V.C. (m ² /s)		Avg V.C	Avg. PM _{2.5} conc. (µg/m ³)	Avg. PM ₁₀ conc. (µg/m ³)	Estimated CC (m ² /s) PM 2.5	Estimated CC (m ² /s) PM 10	PM 2.5 C.C = E.C.C-V.C	PM 10 C.C = E.C.C-V.C	Rainfall (in mm)	Rainy Days	Mixing Height (max)	Wind Speed	Stubble Burning
				Min	Max												
January	1.09	70	2003	76.3	2183.27	1129.785	203.89	324.26	332.469	348.4195	-797.316022	-781.365522	42.3	6	2003	1.09	
February	1.31	90	2087.8	117.9	2735.08	1426.49	140.96	240.42	607.1893	593.3325	-819.300726	-833.157499	85.3	11	2087.8	1.31	
March	1.38	65	2215	89.7	3056.7	1573.2	88.48	186.48	1066.817	843.6293	-506.38264	-729.570656	15.4	6	2215	1.38	
April	1.43	70	2066.6	100.1	2955.24	1527.67	85.22	236.67	1075.571	645.4853	-452.098538	-882.184725	112.3	4	2066.6	1.43	
May	1.46	70	4140	102.2	6044.4	3073.3	85.96	244.92	2145.161	1254.818	-928.13946	-1818.4821	10.6	10	4140	1.46	
June	1.9	60	1685	114	3201.5	1657.75	62.96	208.18	1579.813	796.3061	-77.9374206	-861.443919	8.3	5	1685	1.9	
July	1.37	120	6874.76	164.4	9418.42	4791.41	46.63	141.26	6165.228	3391.909	1373.81839	-1399.50146	271	28	6874.76	1.37	
August	1.33	100	1876	133	2495.08	1314.04	34.62	83.35	2277.366	1576.533	963.325685	262.492693	99.9	29	1876	1.33	
September	1.16	60	1727	69.6	2003.32	1036.46	40.11	98.46	1550.426	1052.671	513.966328	16.2111355	54.1	21	1727	1.16	
October	0.98	80	2045	78.4	2004.1	1041.25	123.44	241.74	506.1163	430.7314	535.132668	-610.518636	3.5	5	2045	0.98	high
November	1.01	60	1749	60.6	1766.49	913.545	204	315.78	268.6897	289.2979	644.855294	-624.247071	30.2	7	1749	1.01	high
December	0.91	50	1664	45.5	1514.24	779.87	203.62	310.48	229.8016	251.182	-550.068409	-528.687959	35.5	3	1664	0.91	



Map 6: Industrial Locations and Pressure Map of Delhi

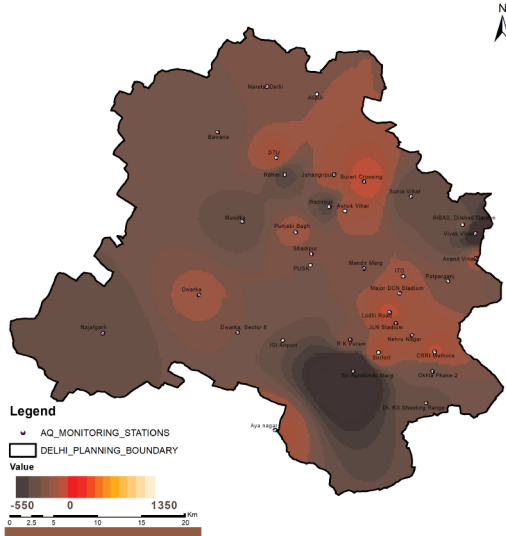
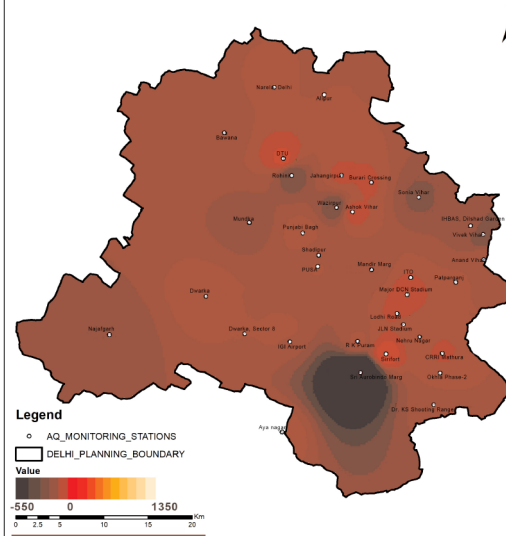
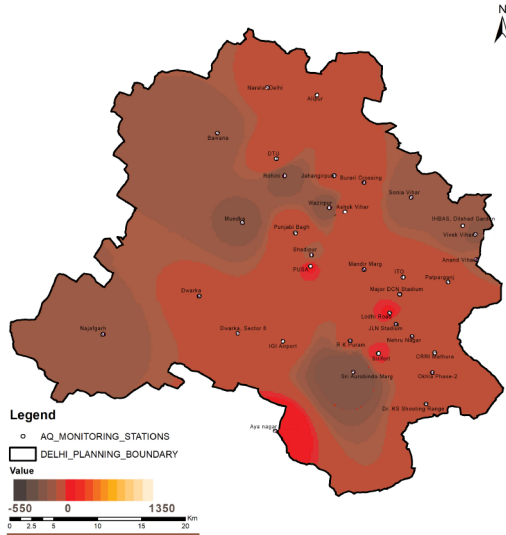
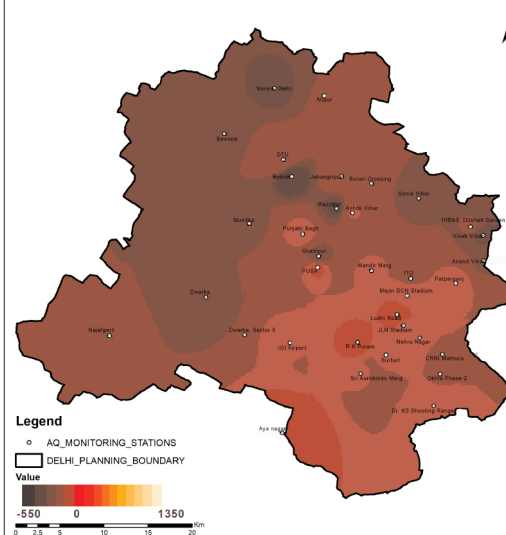
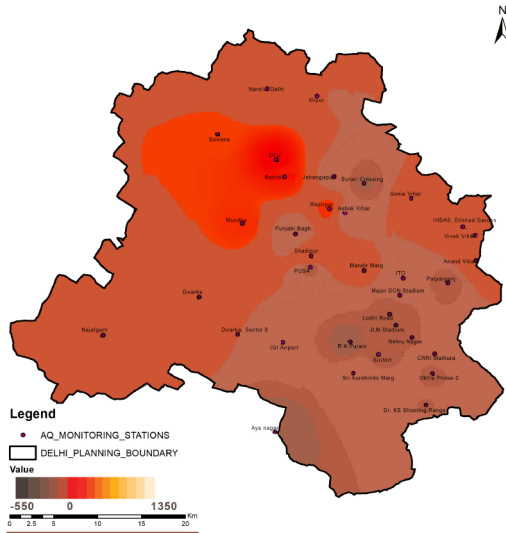
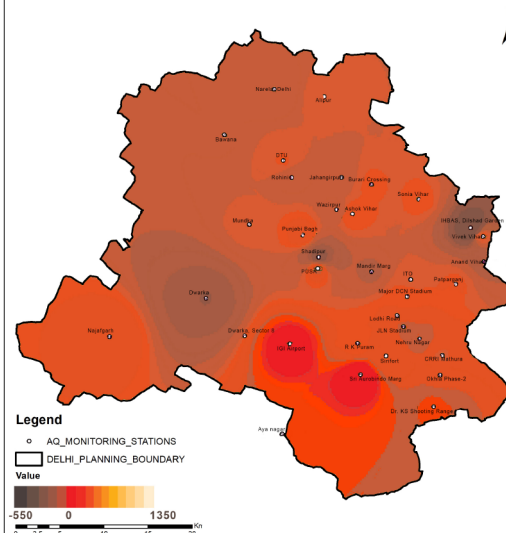


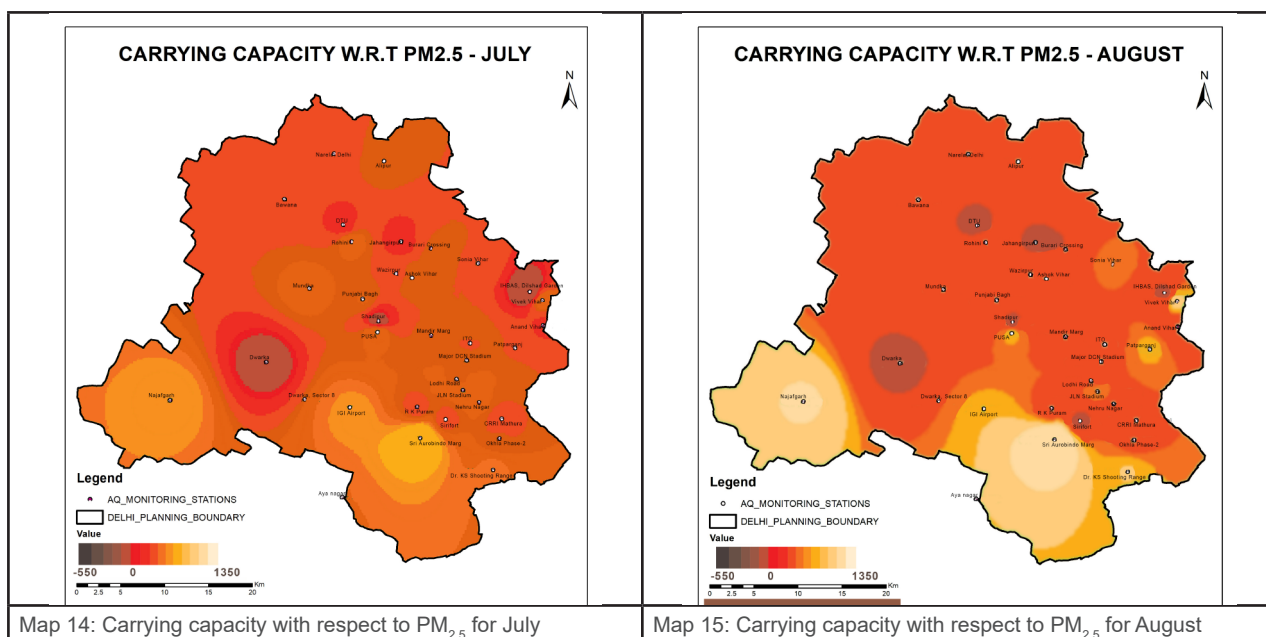
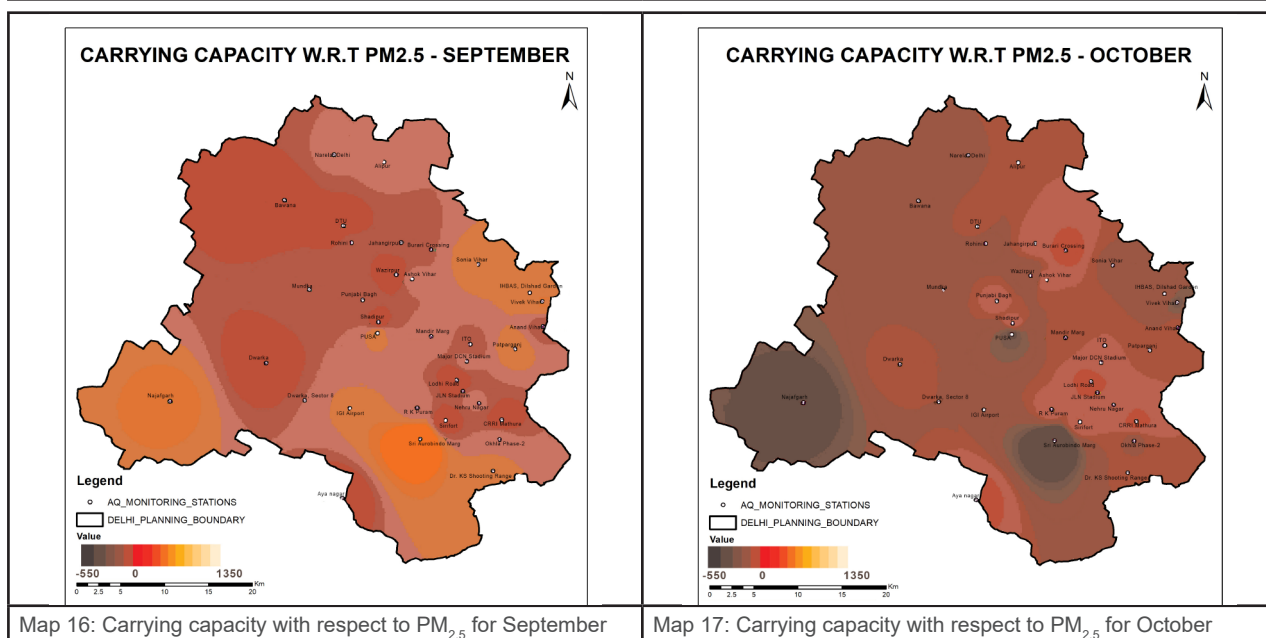
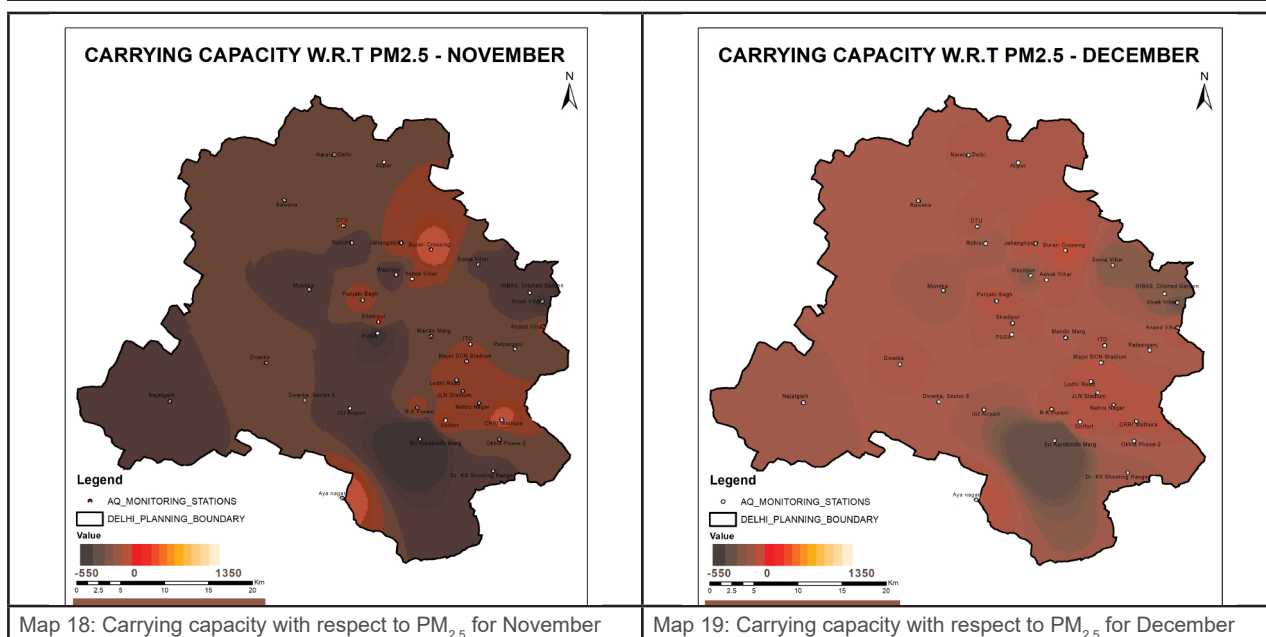
Map 7: Major Activity Locations in Delhi

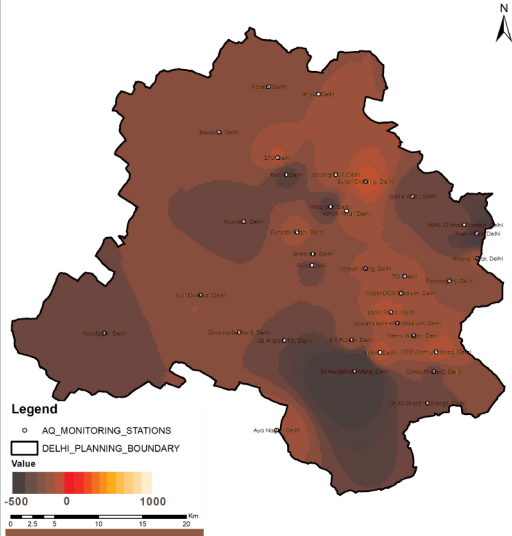
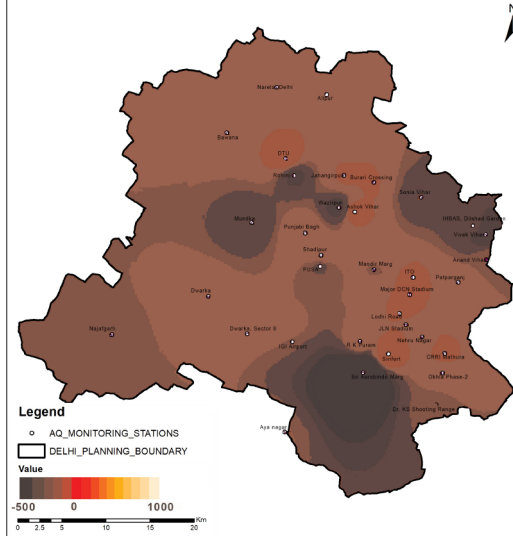
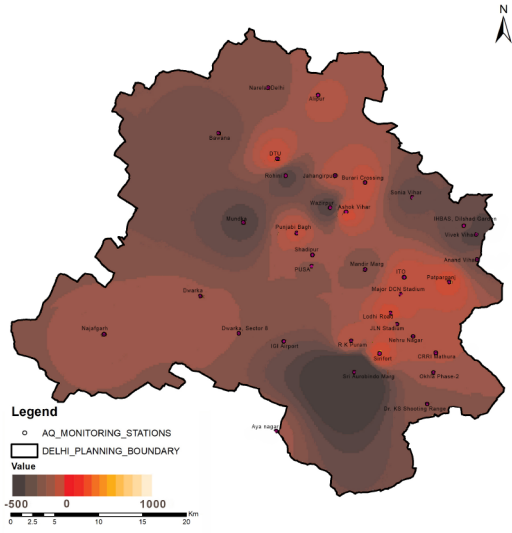
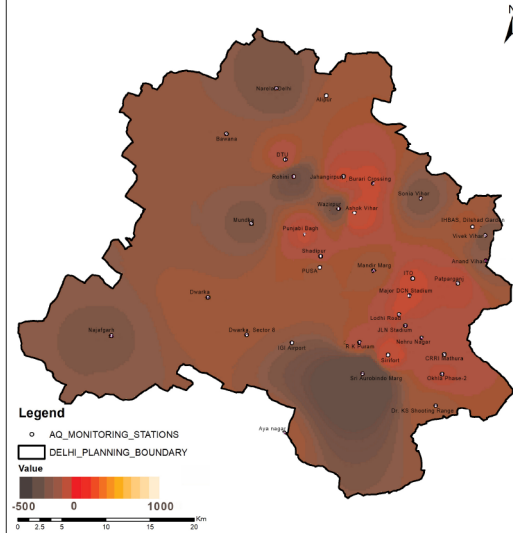
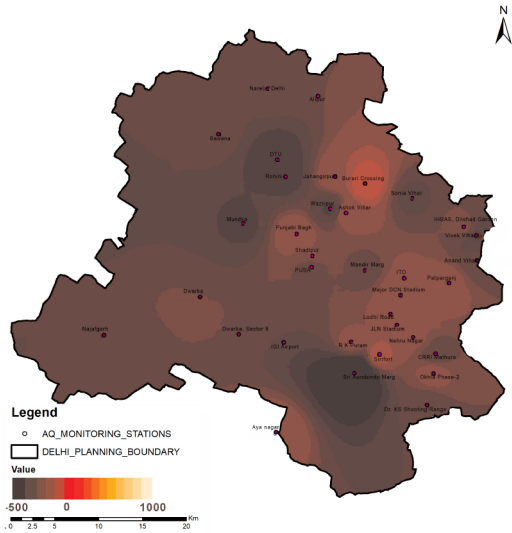
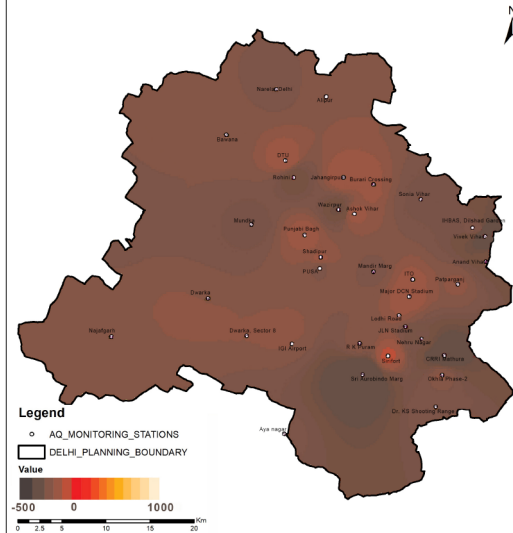
The meteorological factors such as wind speed, temperature, mixing height, pressure, relative humidity and emission loading have been considered in preparation of Carrying Capacity Profile of Delhi. This however does not represent the Real Carrying Capacity as factors such as diffusion, chemical transformation and ground deposition have not been factored in. This is possible only through air quality modelling.

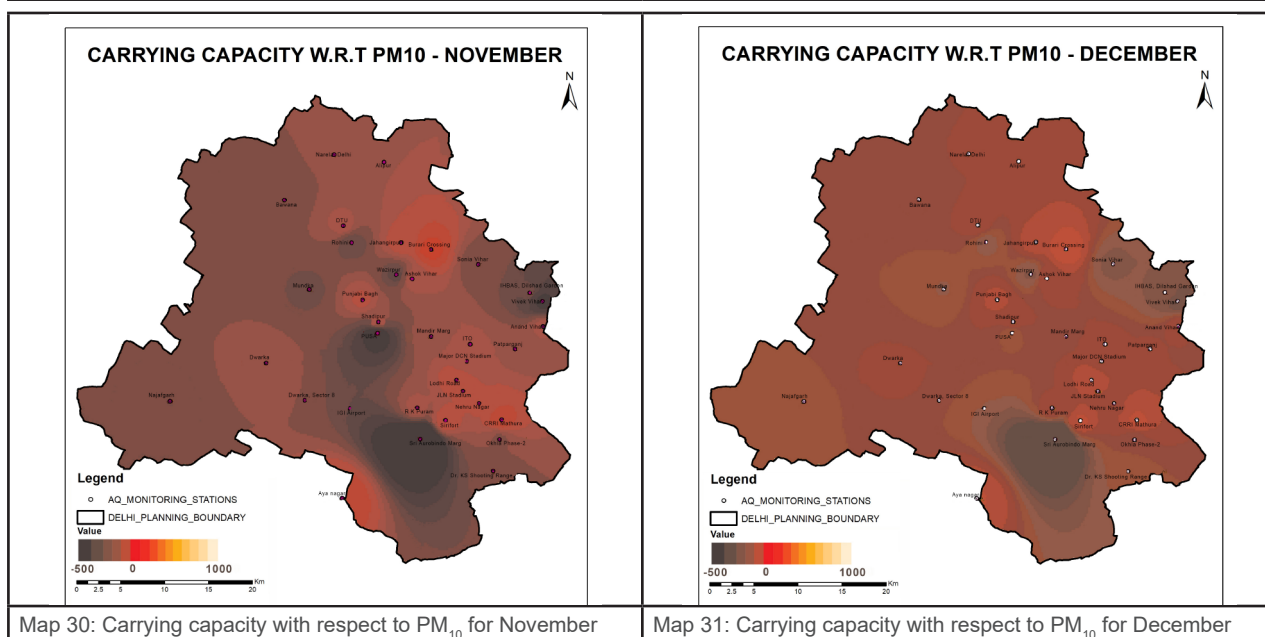
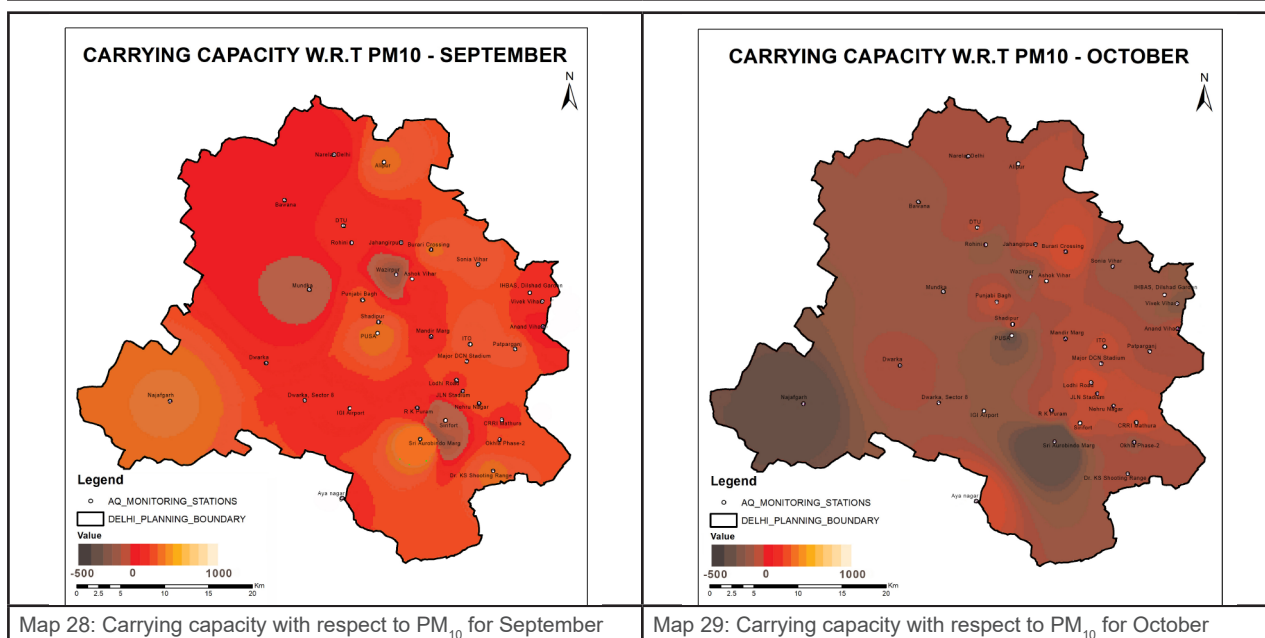
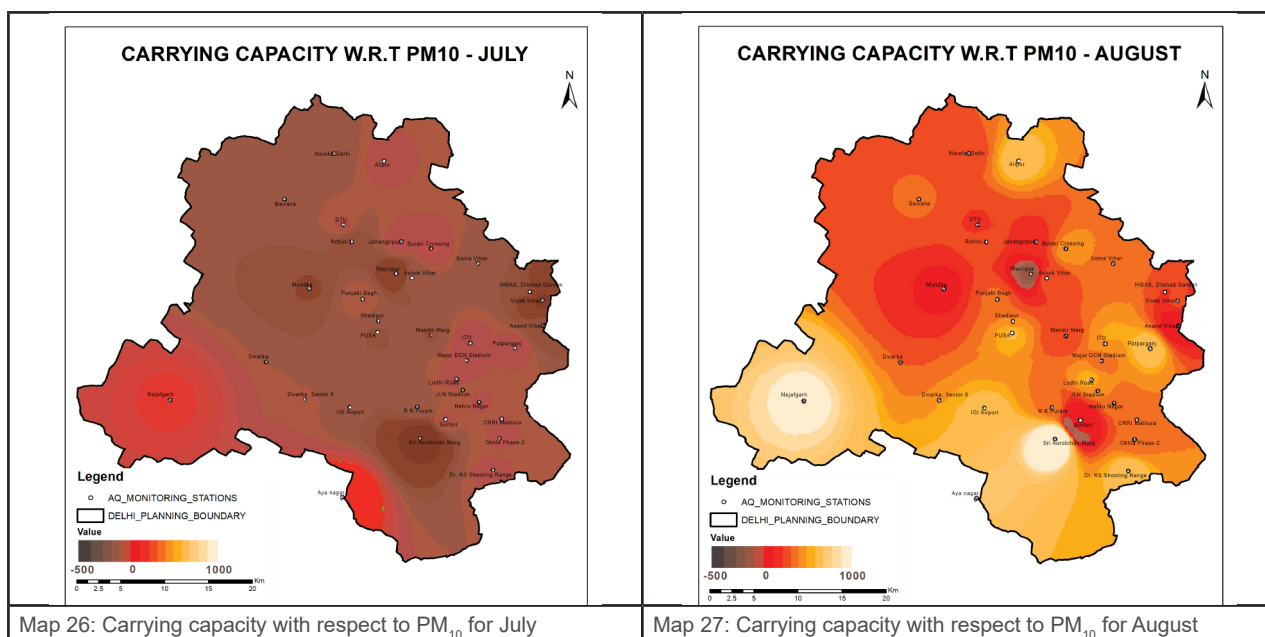
Carrying capacity for all the months has been carried out for both PM_{2.5} (see Maps:8-19) and PM₁₀ (see Maps:20-32) and is represented by following table:

Category	Condition	Code
High	Carrying Capacity > Ventilation Coefficient	
Moderate	Carrying Capacity = Ventilation Coefficient	
Low	Carrying Capacity < Ventilation Coefficient	

CARRYING CAPACITY W.R.T PM_{2.5} - JANUARYMap 8: Carrying capacity with respect to PM_{2.5} for JanuaryCARRYING CAPACITY W.R.T PM_{2.5} - FEBRUARYMap 9: Carrying capacity with respect to PM_{2.5} for FebruaryCARRYING CAPACITY W.R.T PM_{2.5} - MARCHMap 10: Carrying capacity with respect to PM_{2.5} for MarchCARRYING CAPACITY W.R.T PM_{2.5} - APRILMap 11: Carrying capacity with respect to PM_{2.5} for AprilCARRYING CAPACITY W.R.T PM_{2.5} - MAYMap 12: Carrying capacity with respect to PM_{2.5} for MayCARRYING CAPACITY W.R.T PM_{2.5} - JUNEMap 13: Carrying capacity with respect to PM_{2.5} for June

Map 14: Carrying capacity with respect to PM_{2.5} for JulyMap 15: Carrying capacity with respect to PM_{2.5} for AugustMap 16: Carrying capacity with respect to PM_{2.5} for SeptemberMap 17: Carrying capacity with respect to PM_{2.5} for OctoberMap 18: Carrying capacity with respect to PM_{2.5} for NovemberMap 19: Carrying capacity with respect to PM_{2.5} for December

CARRYING CAPACITY W.R.T PM₁₀ - JANUARYMap 20: Carrying capacity with respect to PM₁₀ for JanuaryCARRYING CAPACITY W.R.T PM₁₀ - FEBRUARYMap 21: Carrying capacity with respect to PM₁₀ for FebruaryCARRYING CAPACITY W.R.T PM₁₀ - MARCHMap 22: Carrying capacity with respect to PM₁₀ for MarchCARRYING CAPACITY W.R.T PM₁₀ - APRILMap 23: Carrying capacity with respect to PM₁₀ for AprilCARRYING CAPACITY W.R.T PM₁₀ - MAYMap 24: Carrying capacity with respect to PM₁₀ for MayCARRYING CAPACITY W.R.T PM₁₀ - JUNEMap 25: Carrying capacity with respect to PM₁₀ for June



All the above maps were developed through raster (factor) analysis using the carrying capacity formula (Equation:1) for all the monitoring stations across NCT Delhi in GIS.

The Carrying Capacity is negative in the month of January and February owing to the fact that the low temperature (winter) giving rise to low mixing height and lower wind speeds. The emission loads are high as usual which worsens the situation. The meteorological data supplements the situation for low carrying capacity during this month owing to high pressure profile, low temperature & low wind speeds.

The Carrying Capacity begins to improve from July as monsoon season starts from July to September. The month of August experience cleaner air with high amount of precipitation to wash away the pollutants. From November onwards the Carrying Capacity begins to remain negative throughout the winter season until February. The low mixing height, lower temperature and lower wind speeds deteriorates the air quality during winter season.

STRATEGIES TO ENHANCE CARRYING CAPACITY

Management Capacity:

Factors if properly managed will increase the capacity further such as

(i) Biomass Burning:

- a. Increase in LPG penetration in city
- b. Zero open burning and
- c. Use of residue briquettes in power plants

(ii) Transport:

- a. Public transportations system on electric vehicles followed by private vehicles
- b. Fleet modernization – all vehicles to BS-VI
- c. Reducing emissions from vehicles by congestion management
- d. Shift of cars and 2w to shared commuter transport.

(iii) Industries:

- a. Power plant controls with continuous monitoring
- b. Strict PM control on all industries
- c. Fuel switch to gas from solid fuels

(iv) Road Dust and Construction:

- a. Vacuum cleaning of roads
- b. control of dust from construction activities without proper control measures

(v) Other

- a. Use of refuse in WTE – reducing emissions from refuse burning in WTE plants fitted with controls
- b. 24 x 7 electricity supply – reduce DG set emissions
- c. Control of burning of waste in landfill sites

Effective strategies month wise needs to be developed based on given meteorological conditions and recurring anthropogenic activities observed in the past such as stubble burning.

The study done by TERI and IIT K provides the emission load per year. However, the question still remains unanswered such as to what quantity of emissions (in kgs/day) needs to be maintained in order to achieve the NAAQ standard for $PM_{2.5}$ and PM_{10} ? The receptor modeling of some locations in TERI Report provides a glimpse of contributing sources based on winter and summer seasons and such receptor modeling outputs needs to be prepared for all the monitoring stations in Delhi for all the months in order to fully capture the emission sources at that particular location.

Pollution Control Efficiency [%] = capture efficiency [%] x destruction (or collection) efficiency [%]

Maximum controlled emissions rate [Kgs/hr] = Emission rate [Kgs/hr] x {(100 - Pollution control efficiency) ÷ 100}

Max. controlled emissions [Kgs/year] = Max. uncontrolled emissions [Kgs/year] x {(100 - Pollution control efficiency) ÷ 100}

Table 6: Strategies and their pollution control efficiency

Sl. no.	Strategies	Description	Pollution Control Efficiency (%)	
			PM _{2.5}	PM ₁₀
	Biomass burning			
1	Increase in LPG penetration in residential sector in NCR by 75% in 2025- 100% in 2030	Convert 75% and 100% biomass to LPG in 2025 and 2030, respectively.	10	9
2	Supply and use improved biomass cook-stoves	Supply improved biomass cook-stoves to 75% and 100% of households using biomass in 2025 and 2030, respectively.	7	5
3	Supply and use improved induction cook-stoves	Supply improved induction cook-stoves 75% and 100% to households using biomass in 2025 and 2030, respectively.	10	8
4	Use of agricultural residues in WTE	Zero open burning through WTE plants (With adequate tail-pipe controls)	12	9
5	Use of agricultural residues in power plants (NCR)	Zero-open burning and use of residue briquettes in power plants	15	11
6	Use of agricultural residues in local households	Zero-open burning and use of residues briquettes in local households	15	12
	Transport			
7	Electrification of vehicular fleet	Bus (25-50%), two (20-40%) and three wheelers (100%), and cars (20-40%) in 2025 - 2030	1.4	0.6
8	Public transportation- Buses	25% and 50% electric buses in 2025 and 2030		
9	Electric vehicles- 2/3 wheelers	20% in 2025 and 40% in 2030 electric two-wheelers, and 100% three-wheelers		
10	Electric vehicles - Cars	20% in 2025 and 40% in 2030 electric cars		
11	Fleet modernization - Restricted entry/movement of pre-BS-VI vehicles	All vehicles to be BS-VI equivalent	1	0.4
12	Banning entry of pre BS-IV trucks and buses	All old trucks and buses to be modernised to BS-VI equivalent		

Sl. no.	Strategies	Description	Pollution Control Efficiency (%)	
			PM _{2.5}	PM ₁₀
13	Improved inspection and maintenance system	High emitter emissions go down from 25% to 10% (2025) and 25% to 5% in 2030	1	0.3
14	Reducing real world emissions from vehicles by congestion management	Reduce real world emissions to 50% in both 2025 and 2030		
15	Shift of 50% cars and 2-w to shared commuter vehicles	Shift 50% of personal transport on shared commuter transport on EV in 2025 and 2030	0.4	0.2
16	Increased penetration of biodiesel	12% penetration by 2025 and 20% by 2030	0.3	0.6
17	Increased penetration of hybrid and EV cars	35% hybrid and 15% EV cars by 2025 and 70% hybrid and 30% EV by 2030	0.1	0.3
Industries				
18	Power plant controls with continuous monitoring	Implement stricter NOx and SO2 standards	50	10
19	Stricter enforcement of standards in industries through continuous monitoring	In industries, reduce real world emissions by 50% in both 2025 and 2030	10	9
20	Introduction and enforcement of new SO2 and NOx standards	75% and 100% enforcement of SO2/NOx standards in other industries in 2025 and 2030, respectively.		
21	Enforcement of Zig-Zag brick kiln technology (NCR)	75% and 100% enforcement of Zig-Zag brick kiln technology in 2025 and 2030, respectively	3	4
22	Fuel switch to gas from solid fuels	50% and 100% fuel switch to gas from solid fuels in 2025 and 2030, respectively.	23	24
23	Strict PM control on stone crushers	Increase PM ₁₀ control efficiency to 80% and PM _{2.5} to 40% in both 2025 and 2030.	3	6
24	Introduce stringent PM ₁₀ and PM _{2.5} norms	Introduce and implement stricter PM standards in industries through installations of wet scrubbers	9	18
Road dust and construction				
25	Vacuum cleaning of roads	Silt load reduction 25% and 50% (in 2025 and 2030, respectively)	7	12
26	Wall to wall paving	Silt load reduction 25% and 50% (in 2025 and 2030, respectively)	7	12
27	Control of dust from construction activities	Barriers and water based controls -30% and 60% in 2025 and 2030, respectively.	1	2
Others				
28	Full ban on refuse burning activities and use of refuse in Waste to Energy (WTE)	Reduced emissions from refuse burning in Waste to Energy (WTE)	5	3
29	Landfill fire control	Zero landfill emissions	0.4	0.2
30	DG sets controls using innovative technologies	PM and NOx controls at DG sets (80% reduction in PM and NOx emissions in 2030)	0.3	0.1
31	Supply 24x7 electricity	Supply 24x7 electricity, DG set emissions falls to 10% and 5% in 2025 and 2030, respectively.	0.4	0.2

It can be derived that air pollution is influenced by:

- Regional Factors (Macro-Level)
- Local Factors (Micro-Level)

At regional level, the factors include:

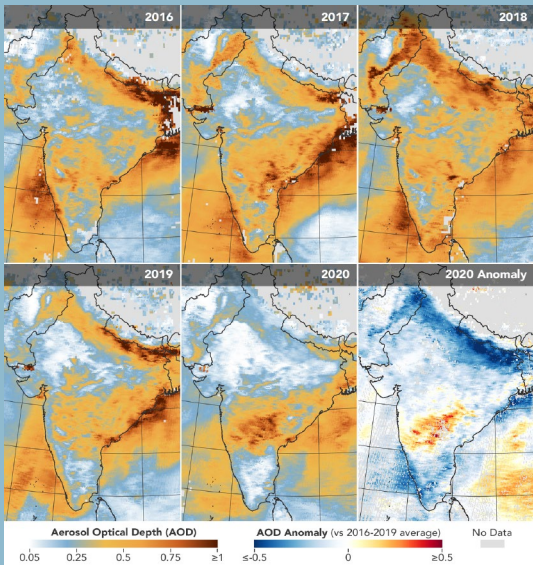
- Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
- Topography
- Land Use and Land Cover
- Activities around the city limits and its location.

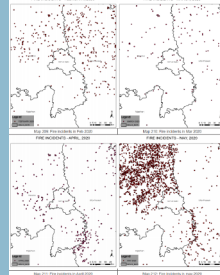
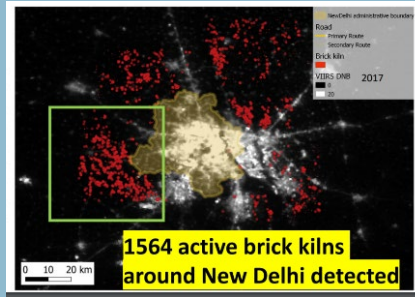
At Local level, the factors include:

- Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
- Land Use: Primary activity and Secondary activity (Travel Demand)
- Location of Activities – Industries, Power Plants, Commercial Centres, etc.
- Building Heights: Local Climatic Zones

As observed in the analysis, the buffer zones around the monitoring stations which have industrial areas shows high concentration of both PM_{10} & $PM_{2.5}$ pollutants in comparison to other landuses, because of the supporting activities of industrial zones like vehicular traffic for loading/ unloading of goods, etc. So recommendations are proposed to further reconsider the location of industrial estates.

ECOLOGICAL SETTING OF NCT DELHI & ASPECTS TO BE ADDRESSED TO CONTROL POLLUTION

ECOLOGICAL ZONES	OBSERVATIONS	RECOMMENDATIONS
Biogeographic Zone  NCT Delhi is located in Sem-Arid Bio -Geographic Region and is characterised by low rainfall, thorny and open forests, wetlands.	- Located in the bowl like Ganga Plains, the dust laden winds predominantly from west get trapped around and within NCT Delhi contributing to almost 65 percent of the pollution here.(IITM, 2018) - AOD (Aerosol optical depth) measurements over India during March 31 to April 5 period for each year from 2016 through 2020. The 6th map (anomaly) shows how AOD in 2020 compared to the average for 2016-2019. 	- It is important to incorporate dust mitigation measures by planting the appropriate trees, maintaining moisture in urban and rural areas. Incase of NCT Delhi measures for propagating greenery and maintaining waterbodies at both the Regional i.e National Capital Region Level (NCR) and NCT Delhi level - Studies on appropriate vegetation to be propagated need to be undertaken
Agro-climatic Zones  NCT DELHI and NCR lie in V- Upper Gangetic plain region -Uttar Pradesh & VI- Trans Gangetic plain region- Chandigarh, Delhi, Haryana, Punjab, Rajasthan	This indicates the suspension of dust in the air due to physiographic reasons	

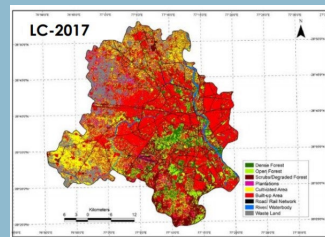
SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
SPATIAL PLANNING SCALES – Regional Plan, Master Plan, Zonal Plans and Local Area Plans of NCT Delhi		
REGIONAL LEVEL	OBSERVATIONS	RECOMMENDATIONS
National Capital Region 	Fire incidents during lockdown 	NCR PLAN TO INCLUDE Demarcation of Air shed in Sub-Regional Plans of Uttar Pradesh, Rajasthan and Haryana and regulating air polluting activities: -burning of garbage, agricultural wastes etc. -relocation of brick kilns / change to clean fuel -control of Industrial pollution especially in identified CEPI areas (Critically Environmentally Polluted Industrial Areas) -preparation of Clean Air Action Plan (CAP) for the identified Non Attainment Cities (NAC
Sub Regions – NCT Delhi, Uttar Pradesh, Haryana and Rajasthan 	Brick Kilns around Delhi  1564 active brick kilns around New Delhi detected	
Proposed Landuse around NCT Delhi as per Master Plans 	Western and Eastern peripheral highways  Proposed developments Loni, Gaziabad, Noida and Greater Noida, Faridabad, Gurugram and Sonapat indicates a spurt in activities and traffic movement around NCT Delhi in the Region	Green belt along highways to be maintained in order to ensure trapping of dust and control of pollution by planting the right type of tree species. Delineation of airshed to identify sources of pollution outside NCT Delhi which impact the air pollution Levels in Delhi

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION

SPATIAL PLANNING SCALES – Regional Plan, Master Plan, Zonal Plans and Local Area Plans of NCT Delhi

NCT DELHI

Landcover of NCT Delhi, 2017



OBSERVATIONS

Percentage change in Landcover class during 1977-2017

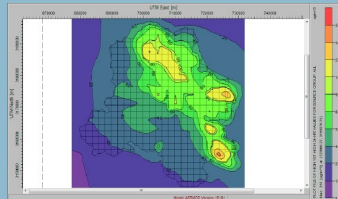
LAND COVER CLASS	1977	%	1993	%	2005	%	2011	%	2017	%	NET CHANGE	%CHANGE
Built-up	157.19	10.1	383.71	25.9	782.6	52.8	805.5	54.32	834	56.3	676.81	46.2
Agriculture	736.43	50	418	28.2	564.4	38	545.19	36.77	522.4	35.2	-214.03	-14.4
Forest	492.69	33	496.42	33.6	30.43	2	28.72	1.937	25.9	1.7	-466.79	-31.5
Barren/Waste lands	64	4.3	153	10.3	70.55	4.76	68.38	4.611	73.46	5.0	3.46	0.2
Wetlands/ Water Bodies	27.69	1.9	30.36	2.04	34.96	2.36	35.04	2.363	26.24	1.8	-1.45	-0.1
TOTAL	1483		1483		1482.94		1482.83		1482			

There is significant reduction in green cover and increase in built up areas

The growth and development of NCT Delhi has resulted into substantial increase in built up area,

And associated built form and activities such as transportation and construction

Isopleths of highest 24-hr values of PM10



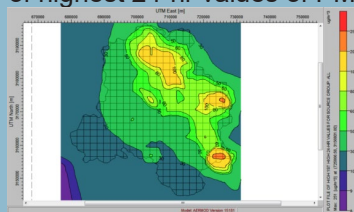
Airpollution levels

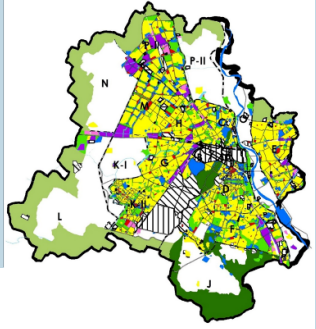
Based on the Source Apportionment Studies there are high pollution levels especially w.r.t PM levels in Delhi, the hot spot from PM level point of view is Shahdara, East Delhi, Badarpur, Rithala and Badli Samaypur.

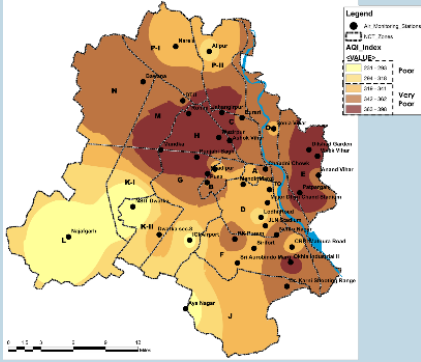
PM 2.5 and PM 10 are above permissible limits almost all year round and certain areas are emerging as hotspots.

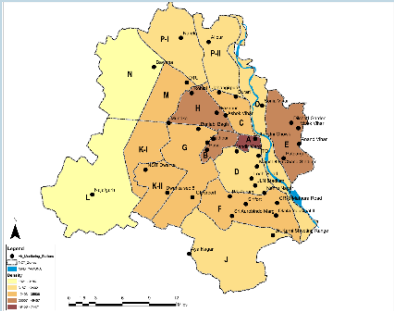
As per SUPPORTIVE CAPACITY estimates the Carrying Capacity of NCT Delhi has been surpassed.

Isopleths of highest 24-hr values of PM2.5



SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
SPATIAL PLANNING SCALES – Regional Plan, Master Plan, Zonal Plans and Local Area Plans of NCT Delhi		
 MASTER PLAN FOR DELHI-2021	Recommendations of MPD 2021 MASTER PLAN -2021 Air quality is a matter of concerned has been responsible for respiratory diseases, heart ailments, eye irritation, asthma etc. 3 main sources of pollution are: Vehicular emission, Industrial emissions, Thermal power plants, Diesel generator sets, Domestic cooking, Burning of Biomass All commercial vehicles (like trucks and tempos) are converted into CNG Increase the green cover of Delhi Public transportation planning must, therefore, drive the future policy that will focus on aspects like frequency, inter-model integration, a possible single ticketing system, use of parking policy as a means to influence vehicle use, etc., the quality of public transport, particularly buses Relocation of non-confirming industries Policy measures for the operation of power plants Thermal Power plants located in the NCT of Delhi should be gradually converted to gas-based plants	While the Master Plan Delhi recognizes the rising air pollution levels the recommendations are primarily regulatory in nature. However long term landuse and built form, etc. control measures need to be formulated to control the impact on rising health problems

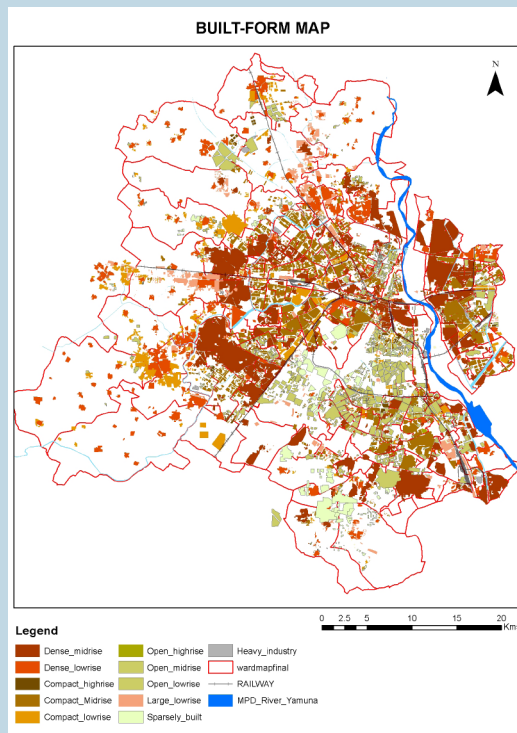
SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
PLANNING ZONES	OBSERVATIONS	RECOMMENDATIONS
(Existing) Air pollution hotspots and Planning Zones	VERY-POOR AQI (360-400) in January- ZONE E •High density areas (425-745 pph) Landuse •Industrial –Shahdara, Gandhi Nagar, Shastri Nagar •Residential-Trilokpuri, KaLyanpuri, Seemapuri •Mixed Landuse- Laxmi Nagar •Transport Terminal- Anand vihar	The Master Plan NCT Delhi 2041 should discourage development in Zones E and H , and high density parts of Zones C, M,B and F as the AQI levels are very poor .
		

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
PLANNING ZONES	OBSERVATIONS	RECOMMENDATIONS
Density of Planning Zones 	VERY-POOR AQI (360-400) in January -ZONE H, C, M & B • High density areas (425-745 pph) Landuse • Industrial –Mundka, Jahangirpuri, Wazirpur, Burari, Ashok Vihar, Bawana • Slums-Bhalswa, Jahangirpuri, Kirtinagar, Kathputli Colony • Mixed Landuse-Parts of Punjabi Bagh, Shadipur VERY-POOR AQI (340-398) in January-ZONE F • High density areas (425-745 pph) Landuse • Industrial –Okhla • Residential- Khirki Village • Slums- Sangam Vihar, Sanjay Colony • Mixed Landuse- Urban villages Hauz Rani, Chirag Delhi, Shahpur Jat	The Master Plan NCT Delhi 2041 should discourage development in Zones E and H , and high density parts of Zones C, M,B and F as the AQI levels are very poor .
Planning Zones (Proposed) Master Plan Delhi 2021 and planning zones	Zone L is slated for future growth as per Zonal Development Plan for Zone L with a parallel grouping of public and semi-public landuse 	The Public-SemiPublic and Commercial areas proposed should be so planned that they allow for dispersion of air pollution . The built form and air flow should be studied before finalizing the building heights AdequateGreen infrastructure to be planned to address the need for air pollution sinks.

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION

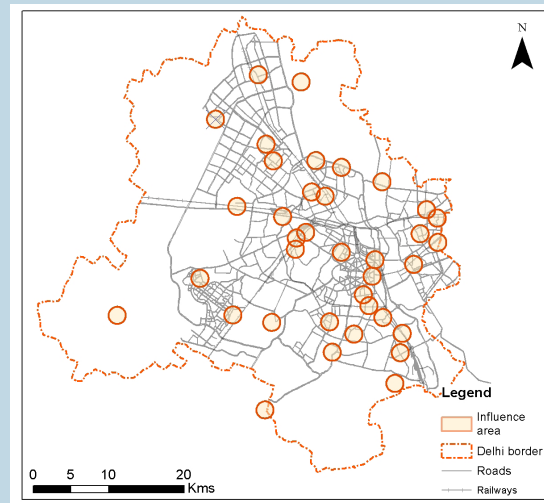
PLANNING ZONES

Local Climatic Zones (LCZs) as proposed by Stewart and Oke in 2012 were used to study the urban built forms affecting the mechanism of dispersion processes in urban neighborhoods.



OBSERVATIONS

Local Level – Activities: The local level assessment was done for 38 monitoring stations present in Delhi. For this a buffer of 1Km (influence area/zone) around the monitoring stations was earmarked and accordingly the broad land uses, activities and LCZs were mapped



IMPLICATIONS OF ACTIVITY DURING LOCKDOWN AND CORRESPONDING POLLUTION LEVELS INDICATED A CORRELATION

RECOMMENDATIONS

Detailed scientific studies need to be undertaken to arrive at the land use, built form, activity and air pollution linkage.

The carrying capacity changes over time as it depends on atmospheric stability and emission load over a certain period of time.

Carrying Capacity = (Emission Standard as per CPCB/Emission load from Land uses mix × Ventilation Coefficient) – Ventilation Coefficient
i.e.,

Category	Condition	Code
High	Carrying Capacity > Ventilation Coefficient	Orange
Moderate	Carrying Capacity = Ventilation Coefficient	Red
Low	Carrying Capacity < Ventilation Coefficient	Dark Grey

The Ventilation coefficient shows only the dispersion potential. So to capture the Real Carrying Capacity (RCC), the parameters such as diffusion, chemical transformation and ground deposition needs to be factored in the calculations.

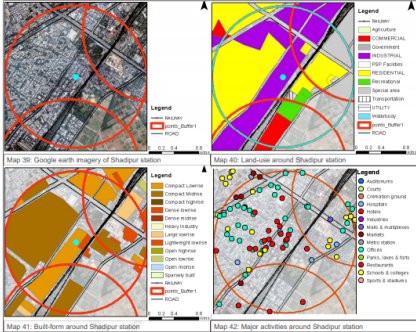
SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION

PLANNING ZONES

Local level

8.2 SHADIPUR, DELHI - CPCB

Concentration of PM2.5 was observed in poor to severe category for almost 9 months (October to June), it could be because of the emissions from industrial and construction activities happening throughout the year in the area which can be seen from following maps.



LCZ		LANDUSE		ALTITUDE	POLLUTION CONC.		VC	WS (m/s)	
Types	Area (sq.km)	%	Types	Area (sq.km)	(m)	MONTHS	PM2.5	PM10	
Dense lowrise	0.078	3.26	COMMERCIAL	0.11	1.4	January	308.02	0.246	0.875734
Dense midrise	0.000	0.00	INDUSTRIAL	0.7727	24.6	February	209.79	0.262793	0.529286
Open midrise	0.000	0.00	TRANSPORTATION	0.205	11.3	March	107.63	0.211556	1.117815
Open highrise	0.000	0.00	RECREATIONAL	0.2717	6.7	April	129.17	0.269393	1.168617
Open lowrise	0.012	0.23	RESIDENTIAL	1.6245	10.7	May	126.76	0.205798	1.145645
Compact lowrise	0.482	14.10	P&F FACILITIES	0	0.0	June	112.3	0.262534	1.286619
Compact midrise	0.794	11.65	GOVERNMENT	0	0.0	July	67.86	0.208254	1.115441
Compact highrise	0.000	0.00	UTILITY	0	0.0	August	66.86	0.203111	0.9590
Large lowrise	0.057	1.80	SPECIAL AREA	0.209	4.7	September	50.15	0.12011	0.52975
Openly built	0.000	0.00	INTERMEDIARY	0	0.0	October	109.54	0.177966	0.987236
Green built	1.000	11.05	GREEN BELT	0.4	12.7	November	148.77	0.310508	0.645617
Open area	0.200	4.27				December	179.94	0.371398	0.634595
Waterbody	0.000	0.00							
Road	0.34	10.03							
Heavy industry									

Table B6: Percentage distribution of built-form (LCZ) & land-use, pollution concentration, wind speed and ventilation coefficients

Table 86: Percentage distribution of Built-form (LCZ) & land-use, pollution concentration, wind speed and ventilation coefficient

OBSERVATIONS

Based on the studies carried out for 1km radius around monitoring stations it is observed

Location specific observations indicated landuse, activity and traffic impacting pollution levels.

RECOMMENDATIONS

Less percentage of greens, more are other activities, causing more polluted days in a year

Location and pattern of greens impact level of pollution

Intensity of traffic movement impacts level of pollution

Need for a detailed scientific study to enable formulation of specific recommendations

ACTION PLAN

Based on the outcomes of the study, certain strategies have been proposed which can be taken as important ingredients to the action plan for managing the development activities based on air pollution in the city. All the aspect wise strategies proposed by previous studies have been added to those proposed by this study.

Table 7: Strategies for Action Plan

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
1	Hotels/ Restaurants	Stop use of Coal			Eliminate use of coals which are still used for barbecues
2	Domestic Cooking	LPG to all		Eliminate use of solid fuels in households	Slum settlements continue to use solid fuels which needs to be replaced by LPG
3	MSW Burning	Stop MSW burning: Improve collection and disposal (landfill and waste to energy plants)		Scaling up of implementation of waste management—solid waste and construction and demolition waste	Management Plan for solid waste & agricultural waste should be brought with focus on discouraging burning of waste.
4	Construction and Demolition	Vertically cover the construction area with fine screens			Height restrictions should be enforced based on fluid dynamics/air movement.
		Handling and Storage of Raw Material: completely cover the material			City Infrastructure under construction should prevent congestion of traffic caused by it.
		Water spray and wind breaker			
		Store the waste inside premises with proper cover			
5	Concrete Batching	Water Spray			
		Wind Breaker			
		Bag Filter at Silos			
		Enclosures, Hoods, Curtains, Telescopic Chutes, Cover Transfer Points and Conveyor Belts			

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
6	Road Dust and Soil dust	Vacuum Sweeping of major roads (Four Times a Month)	Vacuum cleaning of roads		All the open areas (exposed to soil) should be covered with vegetation.
		Carpeting of shoulders			
		Mechanical sweeping with water wash	Wall to wall paving of roads		
		Plant small shrubs, perennial forages, grass covers in open areas	Control of dust from construction activities		
7	Vehicles	Electric/Hybrid Vehicles: 2% of 2-Ws, 10% of 3-Ws and 2% 4Ws wef July 2017: New residential and commercial buildings to have charging facilities	Public transportation system on electric vehicles; followed by private vehicles	Transform public transport at scale and enforce vehicle restraint measure in Delhi-NCR	Efficiency of public transport should be increased. The focus should be on minimizing vehicular kilometer travel (VKT) of each individual.
		Retrofitment of Diesel Particulate Filter: wef July 2018	Setting up OBD/remote sensing based and advanced I&M centres.	BS-VI-ready. Physical checks of advanced emissions control systems to prevent tampering; integration of remote sensing measurements with on-road emissions inspection to address gross polluters; and characterization of emissions of the fleet must be ensured.	Strategies for encouraging cycles as mode of travel to work should be introduced. Dedicated bicycle lane, elevated bicycle corridors or shaded bicycle corridors should be identified to encourage more bicycle users.
		Implementation of BS – VI for all diesel vehicles including heavy duty vehicles (non-CNG buses and trucks) and LCVs (non-CNG): wef January 2019	All vehicles to be BS-VI		Transport corridors connecting Delhi with nearby cities should be managed in such that heavy traffic volumes are diverted away from the observed monthly wind direction pattern.
		Inspection/ Maintenance of Vehicles	Reduce real world emissions by 50% by congestions management strategies	efforts must be made to leapfrog to electric mobility to cut down exposures	
		Ultra Low Sulphur Fuel	Shift 50% of personal transport on shared taxis in 2025 and 2030		

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
	Vehicles	2-Ws with Multi Point Fuel Injection (MPFI) system or equivalent: wef January 2019			
8	Industry and DG Sets	Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM	Power plant controls with continuous monitoring	Approved fuel lists to eliminate coal and dirty fuel streams, and new NOx and SOx standards to tighten PM emissions limits at industrial boilers need to be enforced.	Relocating warehouses for minimizing goods movement into the city via HCVs and LCVs.
		Minimize uses, uninterrupted power supply, Banning 2- KVA or smaller DG sets	Introduction and enforcement of new SO2 and NOx standards	Strong hotspot monitoring and localized action also needs to be ensured	Restricted vehicular entry to major work centres encouraging use of last mile connectivity should be enforced.
			Enforcement of zig-zag brick kiln technology		Proposed industries should not be located in areas around sensitive landuses.
			Strict PM control on stone crushers		
			Supply 24x7 electricity		
			Fuel switch to gas from solid fuels		
9	Secondary Particles	De-SOx-ing at Power Plants within 300 km of Delhi	Use of refuse in WTE	Regional action on power plants to implement new emissions standards and move to natural gas	Vegetation/green cover and urban wetlands should be developed in the green belt and peri-urban areas of Delhi.
		De-NOx-ing at Power Plants within 300 km of Delhi			
10	Secondary Organic Aerosols	Controlling Evaporative emissions: Vapour Recovery System at petrol pumps (Fuel unloading and dispensing)			

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
11	Biomass Burning	Managing crop residue burning in Haryana, Punjab and other local biomass burning, Potential alternatives: energy production, biogas generation, commercial feedstock for cattle, composting, conversion in biochar, Raw material for industry: wef July 2016	Convert 75% and 100% biomass to LPG in 2025 and 2030, respectively		Use of residue briquettes in power plants
			Zero-open burning and use of residue briquettes in power plants		Zero open burning
12	Fly Ash	Wind Breaker, Water Spraying, plantation, reclamation			
13	Air Pollution Management			Local solutions will have to be implemented not only to reduce the high local level of pollution but also to reduce exposure of local communities	Standard Operating Procedures should be identified for organized and unorganized activities (as observed during lockdown period).
					The Master Plan of Delhi should incorporate land use implications on air quality and device appropriate land use mix.
					Zoning of Land uses should be done only with detail study on the implications of land use and its associated activities on air quality. Long term average meteorological conditions or climate simulation modeling should be taken into consideration.
				Ensure enforcement, incentivization, deterrence and compliance:	Emission budget (allowable emissions in kgs/day) should be identified based on various observations.
14	Further researches				Preparation of existing land-use plan

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
					Comprehensive Transportation Management Plan based on latest year study should be prepared.
	Further researches				Air Pollution Studies i.e., called Source Apportionment Study / Emission Inventory should be done in conjunction with Land Uses and Development Authorities
					Controlling land use based activities and it should not entirely depend on ventilation coefficient which primarily signifies assimilative capacity of air environment.

An action plan has been proposed phase wise for short term, medium term and long term strategies

SHORT TERM (2025)				
Sno.	Strategies	Description	Time frame	Responsible Agency
Land Use Based Activities				
1	Relocating warehouses for minimizing goods movement into the city via HCVs and LCVs.	Goods movement into the city via HCVs and LCVs should be controlled via limiting movement to city limits. This would mean relocating a better site for warehouses.	3-4 years	DDA, MoUD and states urban development and transport departments
2	SOP for organized and unorganized activities	Standard Operating Procedures should be identified for organized and unorganized activities to minimize the emissions (as observed during lockdown period).	1 year	Municipal corporations
3	Vehicular Restrictions in clusters of Public & Semi-Public (PSP) landuse	Restricted vehicular entry to major work centres encouraging use of last mile connectivity should be enforced.	1-2 year	DDA, MoUD and states urban development and transport departments
4	Elevated bicycle corridors, dedicated cycle lanes	Strategies for encouraging cycles as mode of travel to work should be introduced. Dedicated bicycle lane, elevated bicycle corridors or shaded bicycle corridors should be identified to encourage more bicycle users.	3-4 years	DDA, MoUD and states urban development and transport departments

SHORT TERM (2025)				
Sno.	Strategies	Description	Time frame	Responsible Agency
5	Fuel switch to gas from solid fuels	Eliminate use of coals which are still used for barbeques	2 years	DPCC, Municipal corporations
6	Increase in LPG penetration in residential sector	Slum settlements continue to use solid fuels which needs to be replaced by LPG	2-3 years	DPCC, Municipal corporations
7	Better alternate routes during infrastructure development	City Infrastructure under construction should prevent congestion of traffic caused by it.	as per project	DDA, MoUD and states urban development and transport departments
8	Covering open areas (non-vegetative) through proper plantation or green cover.	All the open areas (exposed to soil) should be covered with vegetation.	1 year	DDA, Cantonment Board, Municipal corporations
Emission Budget				
1	Limiting emissions from various activities	Emission budget (allowable emissions in kgs/day) should be identified based on various observations. The case of lockdown can be taken in such case and emission limits from various activities highlighted in emission inventory should be prepared.	1 year	DPCC and CPCB

MEDIUM TERM (2030)				
Sno.	Strategies	Description	Time frame	Responsible Agency
Land Use Based Activities				
1	Identification of corridors where pollution builds up due to micro climatic factor	Transport corridors connecting Delhi with nearby cities should be managed in such that heavy traffic volumes are diverted away from the observed monthly wind direction pattern.	Study needs to be done within 2-3 years and actions can be implemented after pilot testing of the strategy.	“State transport departments NCR(Delhi, UP, Haryana, Rajasthan), MoRTH, State transport departments NCR(Delhi, UP, Haryana, Rajasthan)”
2	Use of agricultural residues in power plants	Management Plan for solid waste & agricultural waste should be brought with focus on discouraging burning of waste.	It should be brought into practice within 2 years and should be 80% implemented by 2030	DPCC, Municipal corporations
3	Limiting building heights in certain areas based on air pollution simulation studies	Height restrictions should be enforced based on fluid dynamics/air movement.	5-6 years	DDA, MoUD and states urban development and transport departments

MEDIUM TERM (2030)				
Sno.	Strategies	Description	Time frame	Responsible Agency
4	Controlling land use based activities	Landuse based activities should be controlled based on its scale of trip generation & attraction	Control mechanism should be brought in place within next 8-10 years	DDA, MoUD and states urban development and transport departments
5	Public transportation system based on last mile connectivity	Efficiency of public transport should be increased thus reducing dependencies on personal vehicles for daily trips. The focus should be on minimizing vehicular kilometer travel (VKT) of each individual.	Within 6-7 years it should be efficiently brought down to practice.	Transport department
Appropriate zoning mechanisms				
1	Incorporation of landuse implications on air quality into master plan	The Master Plan of Delhi should incorporate land use implications on air quality and device appropriate land use mix.	Should be incorporated into the 2041 master plan and efforts on enforcement should be initiated within next 2-3 years	DDA, MoUD and states urban development and transport departments
2	Improved inspection and maintenance system	Routine checks and disposal of activity-based strategies should be done in frequent interval every month.	Full Implementation by 2030	Municipal corporations
LONG TERM (2040)				
Sno.	Strategies	Description	Time frame	Responsible Agency
Land Use Based Activities				
1	Developments & Development controls based on wind movement towards city	Developments & Development controls governed by FAR should incorporate study of wind movement towards city and should help in better pollutant dispersion potential.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development departments
2	Plantation in green belt and peri-urban areas of Delhi.	Management of desertification – vegetation/ green cover and urban wetlands should be developed in the green belt and peri-urban areas of Delhi.		Municipal corporations
3	Green cover inside city should be properly maintained based on the wind directions	Green cover should be maintained based on its influence over air quality. It should not act as a barrier.	Should be part of the Zonal plans and implemented widely within next 10-15 years	Municipal corporations

LONG TERM (2040)				
Sno.	Strategies	Description	Time frame	Responsible Agency
4	Discourage allocation of landuse of high levels of activities in areas which already shows high level of pollution	Location of landuse which attracts high levels of activities should be discouraged in North West, North East and South East Delhi which show high level of air pollution	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development departments
5	Siting of industries should be away from sensitive landuses.	Proposed industries should not be located in areas around sensitive landuses.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development departments
Appropriate zoning mechanisms				
1	Proper zoning of landuse based on implications of its associated activities on air quality	Zoning of Land uses should be done only with detail study on the implications of land use and its associated activities on air quality. Long term average meteorological conditions or climate simulation modelling should be taken into consideration.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development and transport departments

The strategies and recommendations of the study have been mentioned in this report (Version-II). The strategies and recommendations will be strengthened by the outputs of further studies (see page no. 96) and could help in validating some of the observations also.

Contents

<i>Preface</i>	<i>i</i>
<i>Acknowledgement</i>	<i>iii</i>
<i>Mandate & Scope</i>	<i>iv</i>
<i>Meetings and presentations</i>	<i>iv</i>
<i>Background</i>	<i>v</i>
<i>Concept of Carrying Capacity</i>	<i>v</i>
<i>Study Area: National Capital Territory of Delhi</i>	<i>vi</i>
<i>Approach</i>	<i>vii</i>
<i>Scope of work</i>	<i>vii</i>
<i>Methodology</i>	<i>viii</i>
<i>Executive Summary</i>	<i>ix</i>
1. Responsibilities at various levels	1
1.1. At International Level:	1
1.2. At National Level (Generic):	1
1.3. At City Level (Generic – For all cities)	4
1.4. Delhi specific recommendations to curb air pollution.	7
2. Hotspots in Delhi	12
3. Location Specific Strategies for Delhi	14
3.1. Urban Development Strategies:	14
3.2. Energy Production Strategies	21
3.3. Urban Transport Strategies	22
3.4. Agricultural Strategies:	34
3.5. Industrial Strategies	37
3.6. Waste Strategies	55
3.7. Residential Strategies	57
3.8. Commercial Strategies	58
3.9. Construction Strategies	62
3.10. Dust Strategies	62
4. Criteria for Land Use Based Interventions in Delhi	69
5. Site Level Analysis	75
5.1. Alipur Monitoring Station	75

5.2.	Shadipur Monitoring Station	77
5.3.	IHBAS	80
5.4.	Other stations	82
6.	Further Studies	96
6.1.	Scientific study to correlate land use activities and air pollution	96
6.2.	Built- form characteristics, air flow and ventilation coefficient	97
6.3.	Air Pollution and Tolerant Vegetation.	97
6.4.	Delineation of Air Shed of NCT Delhi.	98
7.	Annexure	99

List of Figures

Figure 1: PM _{2.5} Concentration at stations across NCT Delhi , 2019	xii
Figure 2: PM ₁₀ Concentration at stations across NCT Delhi , 2019.	xii
Figure 3: Indo-Gangetic Plain	xiv
Figure 4: No. of days PM _{2.5} concentration exceeds standards	xviii
Figure 5: No. of days PM ₁₀ concentration exceeds standards.	xviii
Figure 6: Assessment of air quality at Alipur station (before and during lockdown)	xx
Figure 7: Total Polluted days based on PM _{2.5}	12
Figure 8: Implementation of fuel standard in India	24
Figure 9: Implications of Ban on Air Quality in Delhi	25
Figure 10: Framework of the Comprehensive Environmental Pollution Index	41
Figure 11: Revised Criteria for evaluation of CEPI	42
Figure 12: Current Price of Indane Non-Subsidised LPG	58
Figure 13: Percentage distribution of Establishment by Major Economic Activity Groups in Delhi	59
Figure 14: Percentage Distribution of Employment by Major Economic Activity Groups in Delhi	60
Figure 15: : Various physical processes at mesoscale, local scale and microscale	64
Figure 16: H/W ratio as per UTTIPEC, DDA	65
Figure 17: Relation between the maximum heat island intensity ($\Delta T_{u-r(max)}$) and the height to width ratio (H/W) of the street canyons in the centres of 31 cities.	65

List of Tables

Table 1: Total emission estimation.	xii
Table 2: Estimation of overall emissions	xiii
Table 3: Land Use wise distribution of sub-sectoral contribution to PM _{2.5} & PM ₁₀ in Delhi in 2016	xiv
Table 4: No. of polluted day (PM _{2.5}), Landuses and activities	xviii
Table 5: Ventilation Coefficient in morning and afternoon	xxii
Table 6: Strategies and their pollution control efficiency	xxix
Table 7: Strategies for Action Plan	xxxix
Table 8: Measures to adopt at National level.	1
Table 9: Measures to adopt at City level	4
Table 10: Strategies and Techniques to Mitigate Air Pollution.	7
Table 11: Strategies to mitigate air pollution in Delhi.	8
Table 12: Hotspot Categories	12
Table 13: Polluted Days of Monitoring Stations in Delhi	12
Table 14: List of villages in Green Belt where Low Density Residential Plots are permitted. . . .	14
Table 15: Airflow regimes over an array of buildings and the main flow features associated . . .	15
Table 16: Generic Matrix for Airshed Delineation	21

Table 17: Implementation of Fuel Sulfur Content Reduction in India	24
Table 18: Statistics of Bus in Delhi	26
Table 19: Growth and Vehicles per 1000 population in Delhi	26
Table 20: Number of registered vehicles	28
Table 21: Output of Odd-Even Scheme in Delhi, 2018-19	29
Table 22: Performance of Delhi Transport Corporation (DTC)	29
Table 23: : MRTS average daily ridership and rolling stock.	30
Table 24: Snow melting system using warm-water sprinklers in Japan.	33
Table 25: Street Cleaning Frequency, MoHUA	33
Table 26: Categorization of Industries	37
Table 27: Land Use Sensitivity	37
Table 28: Site Suitability to Air Polluting Industries (without considering water pollution)	40
Table 29: Revised CEPI.	42
Table 30: Status of Pollution based on CEPI - Air CEPI	47
Table 31: Problems of application of CEPI	47
Table 32: CEPI with respect to Air for Industrial Clusters of Delhi.	48
Table 33: Exceedance Factor Calculation	53
Table 34: Urban Street Canyon Standards	64
Table 35: Mean Isoprene Emission Rate ($\mu\text{g/g/h}$) from 40 Indian tree species.	68
Table 36: Emissions from landfill sites.	71
Table 37: Classification of sources (based on $\text{PM}_{2.5}$ & PM_{10} Pollutants)	74
Table 38: Emission sources around Alipur Monitoring station	75
Table 39: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient	77
Table 40: Emission sources around Shadipur Monitoring station	77
Table 41: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient	79
Table 42: Emission sources around IHBAS Monitoring station	80
Table 43: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient	81
Table 44: Emission sources around NSIT Monitoring station	82
Table 45: Emission sources around DTU Monitoring station.	82
Table 46: Emission sources around ITO Monitoring station	83
Table 47: Emission sources around Sirifort Monitoring station	83
Table 48: Emission sources around Mandir marg Monitoring station	83
Table 49: Emission sources around Anand Vihar Monitoring station	84
Table 50: Emission sources around R.K.Puram Monitoring station.	84
Table 51: Emission sources around Punjabi Bagh Monitoring station.	84
Table 52: Emission sources around ITO Monitoring station	85
Table 53: Emission sources around Sirifort Monitoring station	85
Table 54: Emission sources around Mandir marg Monitoring station	85
Table 55: Emission sources around Aya Nagar Monitoring station	86
Table 56: Emission sources around Anand Vihar Monitoring station.	86

Table 57: Emission sources around RK Puram Monitoring station	86
Table 58: Emission sources around Punjabi Bagh Monitoring station.	87
Table 59: Emission sources around Lodhi Road Monitoring station	87
Table 60: Emission sources around North campus DU Monitoring station	87
Table 61: Emission sources around Burari Crossing Monitoring station	88
Table 62: Emission sources around CRRM Mathura Monitoring station	88
Table 63: Emission sources around Pusa Monitoring station	88
Table 64: Emission sources around IGI Airport Monitoring station	89
Table 65: Emission sources around East Arjun Nagar Monitoring station	89
Table 66: Emission sources around Ashok Vihar Monitoring station	89
Table 67: Emission sources around Jawaharlal Nehru Stadium Monitoring station	90
Table 68: Emission sources around Nehru Nagar Monitoring station	90
Table 69: Emission sources around Dr. Karni Singh Shooting Range Monitoring station	90
Table 70: Emission sources around Patparganj Monitoring station.	91
Table 71: Emission sources around Sonia Vihar Monitoring station	91
Table 72: Emission sources around Jahangirpuri Monitoring station	91
Table 73: Emission sources around Rohini Monitoring station	92
Table 74: Emission sources around Najafgarh Monitoring station	92
Table 75: Emission sources around Vivek Vihar Monitoring station	92
Table 76: Emission sources around Major DCN Monitoring station	93
Table 77: Emission sources around Narela Monitoring station	93
Table 78: Emission sources around Okhla Phase-2 Monitoring station	93
Table 79: Emission sources around Wazirpur Monitoring station	94
Table 80: Emission sources around Bawana Monitoring station	94
Table 81: Emission sources around Shri Aurobindo Marg Monitoring station	94
Table 82: Emission sources around Mundka Monitoring station	95
Table 83: Emission sources around Dwarka Sec-8 Monitoring station	95

List of Maps

Map 1: LULC Map of Delhi	x
Map 2: Land Use of NCT Delhi	xi
Map 3: Built form map (right) of Delhi based on LCZ categorization ;	xv
Map 4: Ventilation coefficient for December	xxii
Map 5: Ventilation coefficient for June.	xxii
Map 6: Industrial Locations and Pressure Map of Delhi	xxiii
Map 8: Carrying capacity with respect to $PM_{2.5}$ for January	xxiv
Map 9: Carrying capacity with respect to $PM_{2.5}$ for February.	xxiv
Map 10: Carrying capacity with respect to $PM_{2.5}$ for March.	xxiv

Map 11: Carrying capacity with respect to $PM_{2.5}$ for April	xxiv
Map 12: Carrying capacity with respect to $PM_{2.5}$ for May	xxiv
Map 13: Carrying capacity with respect to $PM_{2.5}$ for June	xxiv
Map 14: Carrying capacity with respect to $PM_{2.5}$ for July.	xxv
Map 15: Carrying capacity with respect to $PM_{2.5}$ for August	xxv
Map 16: Carrying capacity with respect to $PM_{2.5}$ for September	xxv
Map 17: Carrying capacity with respect to $PM_{2.5}$ for October	xxv
Map 18: Carrying capacity with respect to $PM_{2.5}$ for November	xxv
Map 19: Carrying capacity with respect to $PM_{2.5}$ for December	xxv
Map 20: Carrying capacity with respect to PM_{10} for January.	xxvi
Map 21: Carrying capacity with respect to PM_{10} for February	xxvi
Map 22: Carrying capacity with respect to PM_{10} for March	xxvi
Map 23: Carrying capacity with respect to PM_{10} for April.	xxvi
Map 24: Carrying capacity with respect to PM_{10} for May.	xxvi
Map 25: Carrying capacity with respect to PM_{10} for June	xxvi
Map 26: Carrying capacity with respect to PM_{10} for July	xxvii
Map 27: Carrying capacity with respect to PM_{10} for August.	xxvii
Map 28: Carrying capacity with respect to PM_{10} for September	xxvii
Map 29: Carrying capacity with respect to PM_{10} for October.	xxvii
Map 30: Carrying capacity with respect to PM_{10} for November.	xxvii
Map 31: Carrying capacity with respect to PM_{10} for December.	xxvii
Map 32: Map of Delhi showing Planning Zones	18
Map 33: Road Network, Delhi NCR.	23
Map 34: Location of junctions studied by DUAC under the project Decongestion of Traffic Junctions	32
Map 35: Site suitability for industries w.r.t air pollution	38
Map 36: Site suitability for industries w.r.t air pollution & Location of Brick Kilns around Delhi.	39
Map 37: Total hours of Exceedance of $PM_{2.5}$ Concentration from prescribed NAAQ limit.	51
Map 38: Total hours of Exceedance of PM_{10} Concentration from prescribed NAAQ limit	52
Map 39: Commercial Centres in Delhi.	61
Map 40: Road Network Hierarchy of Delhi	63
Map 41: Google earth imagery	76
Map 42: Land-use	76
Map 43: Built-form	76
Map 44: Major activities.	76
Map 45: Google earth imagery of Shadipur station.	79
Map 46: Land-use around Shadipur station	79
Map 47: Built-form around Shadipur station	79
Map 48: Major activities around Shadipur station	79
Map 49: Google earth imagery of IHBAS station.	81
Map 50: Land-use around IHBAS station	81
Map 51: Built-form around IHBAS station	81
Map 52: Major activities around IHBAS station	81

Abbreviations

AERMOD- Atmospheric dispersion modeling system
 AP-42- Air Pollutant Emission Factors
 APCDs - Air Pollution Control Devices
 BAU- Business As usual
 BRTS- Bus Rapid Transit System
 BVOC- Biogenic volatile organic compounds
 CBO- Community Based Organisations
 CEEW- Council on Energy, Environment and Water
 CMAQ- Community Multiscale Air Quality Modelling System
 CPCB- Central Pollution Control Board
 CSE- Centre for science and Environment
 DDA- Delhi Development Authority
 DG- Diesel generator
 DPCC- Delhi Pollution Control Board
 EF- Exceedance Factor
 EI- Emission Inventory EC- Elemental carbon
 EIP- Economic Incentive Programs policy
 EPCA- Environment Pollution Prevention and Control Authority
 FO- Furnace oil
 FY – Financial Year
 GHG- Greenhouse gases
 GNCTD- Government of National Capital Territory of Delhi
 GRAP- Graded Response Action Plan
 HSD- High Speed Diesel
 IPT- Intermediary Public Transport
 IUPAC- International Union of Pure and Applied Chemistry
 LCZ- Land classification ZOne
 LDO- Light diesel oil
 MCD- municipal Corporation of Delhi
 MPD- Master Plan of Delhi
 MSW- Municipal solid waste
 NCAP- National Clean Area Program
 NCTD- National Capital Territory of Delhi
 NEERI- National Environmental Engineering Research Institute
 NMVOCs - Non-methane volatile organic compounds
 OC- Organic carbon
 PM10 = particulate matter less than or equal to ten microns in diameter

PM2.5 = particulate matter less than or equal to 2.5 microns in diameter
PSP- Public & Semi- Public
RWA- Residents Welfare Organisation
SA- Source Apportionment
SAFAR- System of Air Quality and Weather Forecasting And Research
SD/FF- Spray Dryer/Fabric filter
SIP- State Implementation Plans
SPA- School of Planning and Architecture, New Delhi
TCM- Transportation control measures
TDFS- Transport Demand Forecast Study
TERI- The Energy and Resource Institute
UNEP- United Nations Environment Program
URDPFI- Urban and Regional Development Plans Formulation and Implementation
USEPA- United States Environmental Protection Agency
UTTIPEC- Unified Traffic and Transportation Infrastructure (planning & engineering) centre
VKT- Vehicle kilometers travelled
VMEP- Voluntary Mobile Source Emission Reduction Program policy
WHO –World Health Organization
WMCs- Waste Minimization Circles
WRF- Weather Research and Forecasting
ZDP- Zonal Development Plan

Glossary

Air Quality Index (AQI) - A nationally uniform index for reporting and forecasting daily air quality. It is used to report on the four most common ambient air pollutants that are regulated under the Clean Air Act: ground-level ozone, particle pollution (PM₁₀ and PM_{2.5}), carbon monoxide (CO), and sulfur dioxide (SO₂). The AQI focuses on health effects that may be experienced within a few hours or days after breathing polluted air.

Aerosol: Particles of solid or liquid matter that can remain suspended in air from a few minutes to many months depending on the particle size and weight.

Air Basin: A land area with generally similar meteorological and geographic conditions throughout. To the extent possible, air basin boundaries are defined along political boundary lines and include both the source and receptor areas.

Air Quality Standard (AQS): The prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health as established by both federal and state governments. (See also ambient air quality standards.)

Ambient Surrounding: It is used to describe physical properties of air (temperature, humidity, pressure, etc) or air pollution concentration in the open air, as against, at the point of emission or indoors, for example, ambient temperature, ambient air quality.

Chimney (Stack) Height, -The effective height of a chimney is the sum of its actual physical height and the plume rise. The latter is the rise of the effluent due to buoyancy and efflux velocity.

Carbon monoxide (CO) - A colorless, odorless gas that can be harmful when inhaled in large amounts. CO is released when something is burned. The greatest sources of CO to outdoor air are cars, trucks, and other vehicles or machinery that burn fossil fuels.

Coarse particles (also known as PM_{10-2.5}) - Particles with diameters generally larger than 2.5 micrometers (μm) and smaller than, or equal to, 10 μm in diameter.

Diffusion a) On the scale of molecules, diffusion is a mixing of substances caused by molecular motion (Molecular Diffusion). b) In atmosphere it implies the spread of pollutants by turbulence or eddy motion (also called Atmospheric Diffusion).

Dispersion -The method by which a pollutant spreads from its point of emission and becomes diluted in the atmosphere. It includes transport by winds and simultaneous spread by turbulence (atmospheric diffusion).

Electrostatic Precipitator (ESP): An air pollution control device that removes particulate matter from an air stream by imparting an electrical charge to the particles for mechanical collection at an electrode.

Emission Factor: For stationary sources, the relationship between the amount of pollution produced and the amount of raw material processed or burned. For mobile sources, the relationship between the amount of pollution produced and the number of vehicle miles traveled. By using the emission factor of a pollutant and specific data regarding quantities of materials used by a given source, it is possible to compute emissions for the source. This approach is used in preparing an emissions inventory.

Emission Inventory: An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year.

Emission Offsets (also known as Emissions Trading): A rule-making concept whereby approval of a new or modified stationary source of air pollution is conditional on the reduction of emissions from other existing stationary sources of air pollution. These reductions are required in addition to reductions required by best available control technology.

Emission Rate: The weight of a pollutant emitted per unit of time (e.g., tons/year).

Emission Standard: The maximum amount of a pollutant that is allowed to be discharged from a polluting source such as an automobile or smoke stack.

Energy Content: The amount of energy available for doing work. For example, the amount of energy in fuel available for powering a motor vehicle.

Fine particles (also known as PM_{2.5}) - Particles that are generally 2.5 μm in diameter or smaller. This group of particles also encompasses ultrafine particles and nanoparticles which are generally classified as having diameters less than 0.1 μm .

Fugitive Dust: Dust particles that are introduced into the air through certain activities such as soil cultivation, or vehicles operating on open fields or dirt roadways. A subset of fugitive emissions.

Fugitive Emissions: Emissions not caught by a capture system which are often due to equipment leaks, evaporative processes, and windblown disturbances.

Inversion - An atmospheric condition where a layer of cooler air is trapped near the ground by a layer of warmer air above. When the air cannot rise, pollution at the surface also is trapped and can accumulate, leading to higher concentrations of ozone and particle pollution.

National Ambient Air Quality Standard (NAAQS) - The Clean Air Act requires EPA to set National Ambient Air Quality Standards for pollutants considered harmful to public health and the environment. The EPA has set National Ambient Air Quality Standards for six criteria pollutants: sulfur dioxide (SO₂), particulates (PM_{2.5}/PM₁₀), nitrogen oxides (NO_x), carbon monoxide (CO), ozone (O₃), and lead (Pb). Periodically, the standards are reviewed and may be revised.

Particle pollution (also known as particulate matter or PM) - General term for a mixture of solids and liquid droplets suspended in the air.

PM_{2.5}: Includes tiny particles with an aerodynamic diameter less than or equal to a nominal 2.5 microns. This fraction of particulate matter penetrates most deeply into the lungs.

PM₁₀ (Particulate Matter): A criteria air pollutant consisting of small particles with an aerodynamic diameter less than or equal to a nominal 10 microns (about 1/7 the diameter of a single human hair). Their small size allows them to make their way to the air sacs deep within the lungs where they may be deposited and result in adverse health effects. PM₁₀ also causes visibility reduction.

Precipitator: Pollution control device that collects particles from an air stream. (See Electrostatic Precipitator.)

Primary fine particles - Fine particles that are emitted directly from a source, such as construction sites, unpaved roads, smokestacks, or fires.

Remote sensing- Detection or measurement of a property of a medium like atmosphere such as temperature, concentration of pollutants, etc. For example, using Radar, rain can be detected or using Laser beam, concentration of pollutants can be measured along the path of the beam by analysing the scattered radiation from the beam. This is in contrast to in situ sampling or measurement where the sensor measures the property in the immediate vicinity of the sensor.

Secondary fine particles - Fine particles that form in complicated reactions in the atmosphere of chemicals, such as sulfur dioxides and nitrogen oxides, that are emitted from power plants, industries, and automobiles.

Sensitive groups (also called at-risk populations) - A term used for a category of persons at increased risk of experiencing adverse health effects related to air pollution exposures. These groups can be at increased risk due to intrinsic factors (biological), extrinsic factors (external, non-biological), higher exposure, and/or increased dose at a given concentration. The severity of the health effects that these groups experience may be much greater than in the general population.

Micrograms per cubic meter ($\mu\text{g}/\text{m}^3$): The mass in micrograms of a substance contained within a cubic meter of another substance or vacuum. This is the standard unit of measure for the mass density (concentration) of particles suspended in air; also sometimes used for the concentration of gases in air.

Total suspended particulates (TSP): Particles of solid and liquid matter suspended in air. TSP is collected on filtration media and analyzed by weight only. Particle sizes represented by the method are up to 100 μm in aerodynamic diameter.

Urban Airshed Model (UAM): A three-dimensional grid-based photochemical computer model of the production of ozone from precursors (VOCs and NO_x) and the dispersion of air pollution in a specific geographic area over a period of one or two days.

Urban Heat Island- A zone of excess warmth within a city over the suburban and rural environs. The warmer air in this region rises upwards and then spreads radially outwards. The colder air from the surrounding countryside at the surface flows inwards towards the heat island to replace the rising and outspreading warm air. This occurs when the heat islands are intense. This circulation is known as Urban Heat Island Effect.

Ventilation a) The process of replacing contaminated or stale air by fresh air. b) The movement and circulation of outdoor air. c) The volume of air entering or leaving the lungs in one respiratory cycle.

Ventilation Coefficient - It is defined as a product of mixing height and average wind speed.

Vehicle miles traveled (VMT): The number of vehicles that travel in a particular geographic region in a specified period of time (usually a year) multiplied by the number of miles each vehicle traveled. A measure of the total distance covered by vehicles in that area during that period. Normally the phrase refers only to travel by on-road motor vehicles.

Volatile organic compound:

An organic compound (meaning a chemical combination of carbon and other elements, whether natural or manmade) which is volatile, meaning it readily produces vapors at room temperature. Many VOCs react in the atmosphere with nitrogen oxides in the presence of heat and sunlight to form ozone. Methane and other compounds determined by EPA to have negligible photochemical reactivity are excluded from the EPA definition of VOCs. Examples of VOCs include gasoline fumes and solvents from oil-based paints.

Zoning - A method of abating air pollution at a location by a systematic planning of sites for dwellings and for factories/Industries which discharge effluents taking into account the micro-meteorological conditions in and around the location.

1. RESPONSIBILITIES AT VARIOUS LEVELS

1.1. AT INTERNATIONAL LEVEL:

The Convention on Long-Range Transboundary Air Pollution, often abbreviated as Air Convention or CLRTAP, is intended to protect the human environment against air pollution and to gradually reduce and prevent air pollution, including long-range transboundary air pollution. It is implemented by the European Monitoring and Evaluation Programme (EMEP), directed by the United Nations Economic Commission for Europe (UNECE).

The aim of the Convention is that Parties shall endeavor to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution. Parties develop policies and strategies to combat the discharge of air pollutants through exchanges of information, consultation, research and monitoring. In India, the issues are lack of proper air quality monitoring and very small number of stations per cities in India and lack of study on emission inventories. These leads to misleading figures and does not factor in a lot of unaccounted sources.

1.2. AT NATIONAL LEVEL (GENERIC):

The most important aspect to acknowledge at national level is the long-range transport of emissions. Therefore, it is necessary for every state to cooperate and follow the governments decree to minimize emission from all sources. Some of the important instruments and measures to adopt for emission reduction are mentioned in table below (see Table 8) which is affect the emission trends in the future years.

Table 8: Measures to adopt at National level

Activity	Instrument or Other Measures	Resources
Urban Development	> All States to mandate the Cities under their jurisdiction to prepare Emission Inventory, Source Apportionment Studies and Land Use Implications on Air Pollution under Air Act (1986). This should be updated every five years. > A set of generic guidelines on parameters and assessment of land use implications should be developed by Ministry of Housing and Urban Affairs (MoHUA). This will streamline the technique and degree of assessment level among all cities in at National Level for easy understanding. > Development of State of Art Climate Modelling and Air Pollution Modelling Centre under National Clean Air Programme (NCAP).	> National Mission on Sustainable Habitat > Biogenic Emissions, Environmental Protection Agency (EPA)

Activity	Instrument or Other Measures	Resources
Urban Development	The data should be made available publicly to encourage better research in environment domain. > States to mandate that Development Authorities share GIS datasets of their city under 'The National Data Sharing and Accessibility Policy (NDSAP)' – □ Land use in GIS format with sub-categories. □ Building Plots with typology and Heights to enable 3D modelling and wind dispersion modelling. □ Existing Land Use (if available for present year) □ Location of trees properly georeferenced with details of type of tree, shrub, Leaf Area Index (LAI) > Preparation of National & State Emission Budget (base as attainment year) > Legal mandate for reviewing and updating City Clean Air Action Plans annually. > Delineation of Airshed for Regional Air Pollution Management	
Energy Production	> All State Nodal Agencies (SNAs) in close coordination with Ministry of New & Renewable Energy (MNRE) should develop strategies for use of renewable energy (RE) in Indo-Gangetic Plains. > The use of coal based thermal power plants within Indo Gangetic Plain should be shifted to Natural Gas i.e., Gas based Thermal Power Plants. > Increase uptake of Solar Energy Production in Cities > All States especially in Indo Gangetic Plain should be mandated to develop Waste to Energy Plants with at least 30-50 percent capacity to process municipal waste. > Ban on Diesel GenSets. > 100 % electricity distribution	> Programmes on Energy from Urban, Industrial, Agricultural Waste/Residues and Municipal Solid Waste, Ministry of New & Renewable Energy (MNRE)
Transport	> Adopt BS VI Standards and clean fuel such as H-CNG & CNG. And promoting Electric vehicles and Bicycle Usage via developing user-friendly road network. > Promote Transit Oriented Development, Public Bike Sharing Schemes & Non-Motorized Transportation. > Ban on Old Vehicles in All States - all diesel vehicles older than 10 years and all petrol vehicles older than 15 years and Road Transport Offices to de-register such vehicles. > Registration of Vehicles (MV Tax) should be based on Vehicle Engine Capacity rather than price slab. This means the vehicles having less mileage (higher vehicle engine capacity) will pay more registration tax. E.g., Singapore Motor Vehicle Tax > Re-registration of an Old vehicle in another State should be avoided. > Design of roadside automatic sprinkling system	> National Mission on Sustainable Habitat > Sustainable Urban Transport, MoHUA; http://mohua.gov.in/cms/SUTP.php > Singapore Road Tax Rules

Activity	Instrument or Other Measures	Resources
Agriculture	> Promotion of R & D in Control of Stubble Burning and developing new technologies to promote sustainable farming. > Feasible Crop Rotation techniques suitable to specific climatic conditions should be identified. > Promoting location specific improved agronomic practices through soil health management, enhanced water use efficiency, crop diversification, progressive adoption of crop-livestock farming systems and integrated approaches like crop-sericulture, agro-forestry, fish farming, etc. under National Mission for Sustainable Agriculture (NMSA) > Action plan to reduce ammonia and nitrate emissions from agricultures. > All states to mandate the cities to prepare a Biogenic Emission of Natural Resource – Green Belt (Parks, Forests, Ridge) and Agricultural Lands.	> National Mission for Sustainable Agriculture (NMSA) > Stubble Decomposing Solution, Indian Agricultural Research Institute (IARI), Pusa, Delhi > Biogenic Emissions, Environmental Protection Agency (EPA)
Industries	> All States to prepare Zoning Atlas for Siting of Industries. This should be in synergy with land uses, meteorological conditions and industrial zoning of neighbouring states. > Regulation of Industrial Promotion in Indo-Gangetic Belt. Efforts to promote clean industries should be made. > All industries to shift to cleaner fuel especially in Indo Gangetic Belt. > More stricter regulations on Mining and Quarrying & Brick Kilns within Indo Gangetic Belt. > Environmental Protection Act (1986) - examination of such manufacturing processes, materials and substances as are likely to cause environmental pollution and thereby to mandate every State to prepare of Emission Inventories for each city within their jurisdiction.	> Ministry of Commerce & industry, Department of Industrial Policy and Promotion > National Manufacturing Policy > National Investment and Manufacturing Zones (NIMZs) > Zoning Atlas for Siting of Industries, Central Pollution Control Board (CPCB) > Comprehensive Environmental Pollution Index (CEPI), CPCB
Waste sector	> Promote setting up of projects for recovery of energy in the form of Biogas / Bio-CNG / Power from Urban, Industrial and Agricultural Waste and Captive Power and Thermal use through Gasification in Industries > Development of Circular Economy Package	> Municipal Solid Waste Management Manual, MoUD > Waste to Energy, Ministry of New Renewable Energy
Residential	> 100 % LPG Penetration in rural and urban areas. > 100 % electricity supply in rural and urban areas. > Improving the standards of EWS	
Commercial	> Fiscal incentives to commercial units. > Regulation on Vehicles used for Transportation of Goods in Retail Business	

Activity	Instrument or Other Measures	Resources
Construction	> Regulation of Construction Activities > Control of fugitive emissions > Regulation of Transfer of Development Rights (TDR) used by Developer for construction.	
Dust	> Mitigation strategies for desertification > Urban design initiatives for improving city ventilation > Green buffer technological interventions – vertical roofs, green buildings, roadside plantation	

1.3. AT CITY LEVEL (GENERIC – FOR ALL CITIES)

Table 9: Measures to adopt at City level

Activity	Instrument or Other Measures	Resources
Urban Development	> Development Authorities to study land use implications on Air Pollution. This will help identify future growth directions based on Air Management Zones. > Designing better urban design strategies to improve ventilation of city via better understanding of Local Climatic Zones (LCZ). > All the Development Authorities (DA) to prepare of set of supporting reports as a part of Air Act (1986) and SDGs; • Comprehensive Mobility Plan • Environmental Management Plan • Carrying Capacity of City with respect to Air, Water and Land environment. This should be updated every five years and every city to follow and standard SOP for preparation of these reports to enable synergy between different cities. > Development of State of Art Climate Modelling and Air Pollution Modelling Centre under National Clean Air Programme (NCAP). The data should be made available publicly to encourage better research in environment domain. > Development Authorities to share GIS datasets of city under 'The National Data Sharing and Accessibility Policy (NDSAP)' – • Land use in GIS format with sub-categories. • Building Plots with typology and Heights to enable 3D modelling and wind dispersion modelling. • Existing Land Use (if available for present year)	> National Mission on Sustainable Habitat > Local Climatic Zones https://ibis.geog.ubc.ca/urban_flux/resources/lcz.pdf > Emission Inventories and Source Apportionment Studies, CPCB > Biogenic Emissions, EPA

Activity	Instrument or Other Measures	Resources
Urban Development	• Location of trees properly georeferenced with details of type of tree, shrub, Leaf Area Index (LAI) > Preparation of Emission Budget (base as attainment year) > Legal mandate for reviewing and updating City Clean Air Action Plans > Delineation of Airshed for Regional Air Pollution Management	
Energy Production	> Shift of coal-based thermal power plants to Gas based. > All cities to exploit potential of Renewable energy, e.g., Solar Energy for Lighting Purpose, Electricity from Waste to Energy (WTE) Plants. > Ban on Diesel GenSets. > Uninterrupted Power Supply in cities to avoid requirement of operating DG sets and inconveniences to public. > Increase uptake of solar rooftop	> Delhi Solar Policy, 2016 > National Building Byelaws > BMPTC Green Building
Transport	> Preparation of Comprehensive Mobility Plan (CMP) > Adopt BS VI Standards and clean fuel such as H-CNG & CNG. > Enhance Public Transport – The goal is to Move People, Not Vehicles. > Improving road infrastructure to promote bicycle friendly environment. Shading spaces for bicycle networks can prove useful in arid and semi-arid areas. > Promoting Electric vehicles and Bicycle Usage via developing user-friendly road network. > Scaling up of CNG based Public Transport and CNG infrastructure > Ban on Old Vehicles in All States - all diesel vehicles older than 10 years and all petrol vehicles older than 15 years and Road Transport Offices to de-register such vehicles. > Registration of Vehicles (MV Tax) should be based on Vehicle Engine Capacity rather than price slab. This means the vehicles having less mileage (higher vehicle engine capacity) will pay more registration tax. E.g., Singapore Motor Vehicle Tax > Traffic Calming Measures > Greening of Roads > Design of roadside automatic sprinkling system > Improving efficiency in Street Sweeping (dust collection system). > Retrofitting diesel vehicles (especially trucks for inter-state supply of goods) with particulate filters. > Maintaining pothole free roads	> National Mission on Sustainable Habitat > Singapore Road Tax Rules > Guidance Documents for Public Bike Sharing Schemes (PBS), MoHUA > Guidance Documents for Non-Motorized Transportation Planning(NMT), MoHUA > Guidance Documents for Transit Oriented Development(TOD), MoHUA

Activity	Instrument or Other Measures	Resources
Agriculture	> Promotion of skill development in Sustainable agricultural practices within city and immediate surroundings. > R & D in developing cheaper technologies for controlling stubble burning. > Stubble to CNG Technological Interventions in all the States with CNG Infrastructure. > Development of Biogenic Emission Inventory – Agriculture	> National Mission for Sustainable Agriculture (NMSA) > Stubble Decomposing Solution, Indian Agricultural Research Institute (IARI), Pusa, Delhi > Biogenic Emissions, Environmental Protection Agency (EPA)
Industries	> Zoning of Industries based on meteorological datasets, surrounding land uses (influence zones), transportation accessibility and air pollution scenarios. > Relocation & phasing out of polluting units based on CPCB CEPI score & also based on Traffic Demand of Industrial Units. > Study of Traffic Demand of Industrial Units to capture intensity of traffic movement for good and supply. > Regulation of Household industries primarily contributing to Particulate Matter concentration. > Lockdown of industries such as stone crushing, hot mix plants, brick kilns generating dust pollution from October to December.	> Delhi Industrial Policy (2010-2021) > Household Industries, Delhi Master Plan > Comprehensive Environmental Pollution Index (CEPI), CPCB > Comprehensive Mobility Plan
Waste sector	> Strict ban & Regulations on Agricultural Refuse Burning, Biofuels & Solid Waste Burning in Landfills. > Improving efficiency of solid waste segregation, collection & transportation. > Setting up of Waste to Energy Plants > Development of Circular Economy Package. Key sectors include plastics, food waste, critical raw materials, construction and demolition as well as biomass and biobased products. The aim of the action plan is to create an environment that enables a circular economy and to improve the balance between regulation and other measures.	> Calorific Values of Waste http://www.igniss.com/calorific-value-waste
Residential	> Upscaling coverage of LPG Penetration in the city and surrounding areas.	
Commercial	> Fiscal incentives to commercial units > Retail Enterprises to use electric vehicles/clean fuel for procurement and transport of goods and supply. > Siting suitable locations for Storage of goods/warehouses > Control of traffic movement in Sub-City Level Markets, Non-Hierarchical Commercial Centres and District Centres	

Activity	Instrument or Other Measures	Resources
Construction	> Regulation of Construction Activities > Dust Suppression Method > Implementation of control measures for fugitive emissions. > Regulation of Transfer of Development Rights (TDR) used by Developer for construction.	
Dust	> Maintenance of vegetation and covering of loose soil > Creation of green buffers > Maintaining pothole-free roads	

1.4. DELHI SPECIFIC RECOMMENDATIONS TO CURB AIR POLLUTION

Air pollution mitigation techniques and corresponding strategies have been provided in the table below. The recommendations for Delhi city specific have been provided along with planning strategies. These planning strategies can be applied at various scale and at under varying techniques as earmarked on table.

Table 10: Strategies and Techniques to Mitigate Air Pollution

TECHNIQUES	REGIONAL PLAN & MASTER PLAN				ZONAL DEVELOPMENT PLAN AND LOCAL AREA PLAN						
	Alternative Regional Forms	Balanced Communities and Sub-regions	Low Density Development	Regional Open Space Patterns	Location of Stationary Sources	Relocation of Stationary Sources	Control of Land Use around sources	Location of Sensitive Receptors	Location & Design Control of New Towns	Planned Unit Developments	Small Open Spaces
	1	2	3	4	1	2	3	4	5	6	7
Comprehensive & Project Planning	o	o	o	o	□	o	o	□	o	o	o
Localized Zoning (Location & Density)	o	o	□	o	o	o	□	□	o	□	o
Regional Zoning (Location & Density)	□	□	□	□	□	o	□	□	□		
Performance Zoning					o						
Non-Conforming Use						o	o	o			
Zoning Regulations for Site Use										o	□
Air Pollution Zoning (Sensitive Zones)			o		o						
Sub-Division Regulations								o	□	□	
Land Dedication Regulations										□	
Planned Unit Development Regulations								o	□	□	
Building and Housing Codes			o							o	
Urban Renewal		o				o	o	o	o	o	o
Land Acquisition Programs	□		o	□				o		□	
Open Space Tax Incentives	□		o	o							
Location & Relocation Incentives	o	□	o		o				o		
Speculative Public Investment	o	□			o	□			o		
Tax Equalization for Govt. Consolidation	o				□	□			o		
Emission Budget Review	o	o		o	o				□		o
Direct Urban Design		o								o	o
LEGEND											
Source: Source: SPA Delhi											

Table 11: Strategies to mitigate air pollution in Delhi

ACTIVITY	INSTRUMENT	PLANNING STRATEGIES
Urban Development	Development Authorities to study land use implications on Air Pollution. This will help identify future growth directions based on Air Management Zones.	Balanced Communities and Sub-regions
		Low Density Development
		Location of Stationary Sources
		Relocation of Stationary Sources
		Control of Land Use around sources
		Location of Sensitive Receptors
		Location & Design Control of New Towns
		Planned Unit Developments
		Small Open Spaces
	Designing better urban design strategies to improve ventilation of city via better understanding of Local Climatic Zones (LCZ).	Control of Land Use around sources
		Location & Design Control of New Towns
		Planned Unit Developments
	Development Authorities (DA) to prepare of set of supporting reports as a part of Air Act (1986) and SDGs; • Comprehensive Mobility Plan • Environmental Management Plan • Carrying Capacity of City with respect to Air, Water and Land environment. This should be updated every five years and every city to follow and standard SOP for preparation of these reports to enable synergy between different cities.	
	Development of State of Art Climate Modelling and Air Pollution Modelling Centre.	
	The data should be made available publicly to encourage better research in environment domain.	
	Development Authorities to share GIS datasets of city under 'The National Data Sharing and Accessibility Policy (NDSAP)' - • Land use in GIS format with sub-categories. • Building Plots with typology and Heights to enable 3D modelling and wind dispersion modelling. • Existing Land Use (if available for present year) • Location of trees properly georeferenced with details of type of tree, shrub, Leaf Area Index (LAI)	
Energy Production	Preparation of City Emission Budget (allowable emission per land use)	Centre & State Intervention
	Legal mandate for reviewing and updating City Clean Air Action Plans	

ACTIVITY	INSTRUMENT	PLANNING STRATEGIES
Energy Production	Delineation of Airshed for Regional Air Pollution Management	
	Shift of coal-based thermal power plants to Gas based.	Location of Stationary Sources
	All cities to exploit potential of Renewable energy, e.g., Solar Energy for Lighting Purpose, Electricity from Waste to Energy (WTE) Plants.	Location & Design Control of New Towns
	Increase uptake of solar rooftop in Delhi by scaling up the existing schemes.	Planned Unit Developments
	Ban on Diesel GenSets.	
	Uninterrupted Power Supply in NCR towns to avoid requirement of operating DG sets and inconvenience to public.	
Transport	Preparation of Comprehensive Mobility Plan (CMP)	
	Preparation of Annual Transport Survey primarily focused on household traffic surveys.	
	Household traffic surveys are widely used in travel behaviour analysis, especially in travel time and distance analysis (trip modelling process).	
	Adopt BS VI Standards and clean fuel such as H-CNG & CNG	
	Enhance Public Transport – The goal is to Move People, Not Vehicles.	
	Improving road infrastructure to promote bicycle friendly environment. Shading spaces for bicycle networks can prove useful in arid and semi-arid areas.	
	Promoting Walkability, Electric vehicles and Bicycle Usage via developing user-friendly road network.	
	Scaling up of CNG based Public Transport Vehicles	
	Ban on Old Vehicles in All States - all diesel vehicles older than 10 years and all petrol vehicles older than 15 years and Road Transport Offices to de-register such vehicles.	
	Registration of Vehicles (MV Tax) should be based on Vehicle Engine Capacity rather than price slab. This means the vehicles having less mileage (higher vehicle engine capacity) will pay more registration tax. E.g., Singapore Motor Vehicle Tax	
	R & D in the field of Transport sector should be promoted to develop Electric Buses feasible for Indian Road and Climatic Conditions	
	Traffic Calming Measures	Control of Land Use around sources
	Greening of Roads	
	Design of roadside automatic sprinkling system	
	Improving efficiency in Street Sweeping (dust collection system).	
	Retrofitting diesel vehicles (especially trucks for inter-state supply of goods) with particulate filters.	
	Maintaining pothole free roads	

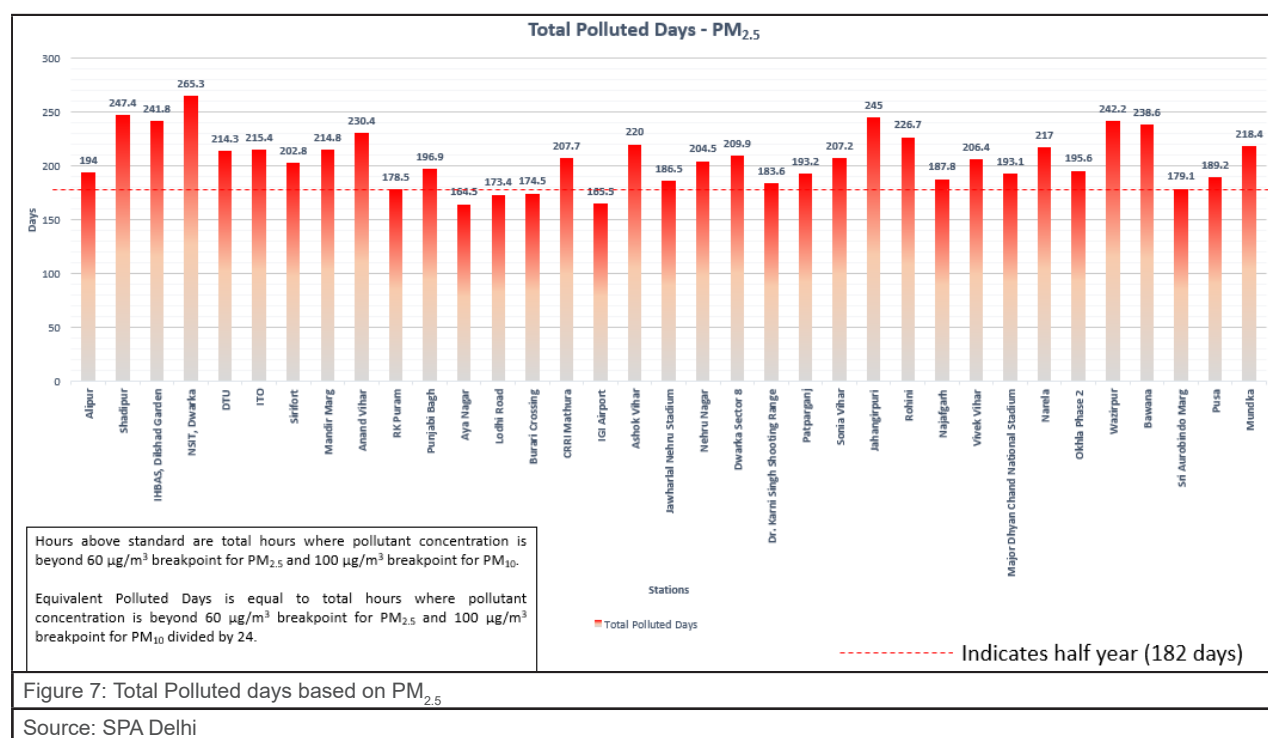
ACTIVITY	INSTRUMENT	PLANNING STRATEGIES
Agriculture	Promotion of skill development in Sustainable agricultural practices within city and immediate surroundings.	
	R & D in developing cheaper technologies for controlling stubble burning.	
	Conversion of Farm Stubble into CNG	
	Development of Biogenic Emission Inventory – Agriculture & Green Belt	
Industries	Zoning of Industries based on meteorological datasets, surrounding land uses (influence zones), transportation accessibility and air pollution scenarios.	Location of Sensitive Receptors
		Location & Design Control of New Towns
		Planned Unit Developments
	Relocation & phasing out of polluting units based on CPCB CEPI score & also based on Traffic Demand of Industrial Units	Location of Stationary Sources
		Location of Sensitive Receptors
		Control of Land Use around sources
	Study of Traffic Demand of Industrial Units to capture intensity of traffic movement for good and supply.	Location & Design Control of New Towns
	Regulation of Household industries primarily contributing to Particulate Matter concentration.	Location of Stationary Sources
		Control of Land Use around sources
Waste sector	Strict ban & regulations on Agricultural Refuse Burning, Biofuels & Solid Waste Burning in Landfills.	
	Improving efficiency of solid waste segregation, collection & transportation.	
	Setting up of Waste to Energy Plants	
	Development of Circular Economy Package. Key sectors include plastics, food waste, critical raw materials, construction and demolition as well as biomass and biobased products. The aim of the action plan is to create an environment that enables a circular economy and to improve the balance between regulation and other measures.	
Residential	> Maintaining continuous engagement with the concerned authorities to maximise LPG/PNG coverage for domestic and commercial cooking with a target of 100 per cent coverage	
Commercial	> Fiscal incentives to dhabas, hotels and restaurants for conversion into PNG from conventional fuel.	
	> Use of LPG/PNG or Wood Charcoal for tandoors. Barbecues to function under controlled environment in all dhabas, hotels and restaurants.	
	> Retail Enterprises to shift to electric vehicles, clean fuel for procurement and transport of goods and supply.	
	> Storage of goods/warehouses to be place at the periphery of cities.	

ACTIVITY	INSTRUMENT	PLANNING STRATEGIES
Commercial	> Control of traffic movement in Sub-City Level Markets, Non-Hierarchical Commercial Centres and District Centres should be done.	
Construction	> All construction activities involving excavation, civil construction (excluding internal finishing/work where no construction material is used) to be closed from onset of October Month to December (in NCR).	
	> Dust Suppression Method	
	> Implementation of control measures for fugitive emissions.	
	A study should be done on sources of fugitive emissions which fails to reflect in source apportionment studies and emission inventories.	
Dust	> Maintenance of vegetation and covering of topsoil	
	> Creation of green buffers	
	> Maintaining pothole-free roads	

Source: SPA Delhi

2. HOTSPOTS IN DELHI

The hotspots have been identified based on the frequency of days with $PM_{2.5}$ above the NAAQ Standards i.e., $60 \mu\text{g}/\text{m}^3$.



The stations have been categorized as follows based on their polluted days count.

Table 12: Hotspot Categories

Category	Polluted Days
Primary Hotspot	> 220 days
Emerging Hotspot	180 – 220 days
Reaching Hotspot	< 180 days

Source: SPA Delhi

The strategies that are mentioned in later stage will apply to strictly to all categories of hotspot in Delhi.

Table 13: Polluted Days of Monitoring Stations in Delhi

Monitoring Stations	Total No. of Polluted Days	Status
NSIT, Dwarka	265.3	Primary Hotspot
Shadipur	247.4	Primary Hotspot
Jahangirpuri	245	Primary Hotspot

Monitoring Stations	Total No. of Polluted Days	Status
Wazirpur	242.2	Primary Hotspot
IHBAS, Dilshad Garden	241.8	Primary Hotspot
Bawana	238.6	Primary Hotspot
Anand Vihar	230.4	Primary Hotspot
Rohini	226.7	Primary Hotspot
Ashok Vihar	220	Emerging Hotspot
Mundka	218.4	Emerging Hotspot
Narela	217	Emerging Hotspot
ITO	215.4	Emerging Hotspot
Mandir Marg	214.8	Emerging Hotspot
DTU	214.3	Emerging Hotspot
Dwarka Sector 8	209.9	Emerging Hotspot
CRRI Mathura	207.7	Emerging Hotspot
Sonia Vihar	207.2	Emerging Hotspot
Vivek Vihar	206.4	Emerging Hotspot
Nehru Nagar	204.5	Emerging Hotspot
Sirifort	202.8	Emerging Hotspot
Punjabi Bagh	196.9	Emerging Hotspot
Okhla Phase 2	195.6	Emerging Hotspot
Alipur	194	Emerging Hotspot
Patparganj	193.2	Emerging Hotspot
Major Dhyan Chand National Stadium	193.1	Emerging Hotspot
Pusa	189.2	Emerging Hotspot
Najafgarh	187.8	Emerging Hotspot
Jawaharlal Nehru Stadium	186.5	Emerging Hotspot
Dr. Karni Singh Shooting Range	183.6	Emerging Hotspot
Sri Aurobindo Marg	179.1	Reaching Hotspot
RK Puram	178.5	Reaching Hotspot
Burari Crossing	174.5	Reaching Hotspot
Lodhi Road	173.4	Reaching Hotspot
IGI Airport	165.5	Reaching Hotspot
Aya Nagar	164.5	Reaching Hotspot

Source: Compiled by SPA Delhi

3. LOCATION SPECIFIC STRATEGIES FOR DELHI

3.1. URBAN DEVELOPMENT STRATEGIES:

3.1.1. LOW DENSITY RESIDENTIAL AREAS (LDRA)

These areas should have a stricter regulation on FAR. The Low-Density Residential plots are permitted in the villages falling within Zones -L, P-1, P-2, N and Low-Density Residential Areas in Urban Extension as specified by Delhi Development Authority. As per the new LDRA Policy, it allows the owners to pay an extra charge for utilising higher FAR than what has been stipulated. Older farmhouses that have utilised higher floor areas than what was sanctioned are now being regularised by paying a penalty. Farmhouses in Delhi are only allowed in the peripheral green belt of the city.

A proper study on local wind movement and air pollution dispersion should be done to back the policy. The failure of which will lead to haphazard development in the outskirts and concentrating the pollutants within the neighbourhood with no space for vertical transport of air pollutants.

Table 14: List of villages in Green Belt where Low Density Residential Plots are permitted

Sl. No.	Planning Zone	Name of Village	
(1)	Zone G	1. Bijwasan (Part) 2. Kapashera	3. Salahpur
(2)	Zone J	4. Rajokri (Part)	
(3)	Zone K-II	5. Bamnoli (Part)	6. Bijwasan (Part)
(4)	Zone L	7. Badusaria 8. Bakargarh 9. Deorala 10. Dhansa 11. Ghalibpur 12. Ghumanhera 13. Isapur 14. Jainpur 15. JharodaKalan (Part) 16. Jhatikara 17. Kair	18. Kanganheri 19. Mitraon (Part) 20. MndhelaKalan 21. MundhelaKurd 22. Nanakheri 23. Raghopur 24. Rauta 25. Shikarpur 26. Surekhpur (Part) 27. TikriKalan (Part)
(5)	Zone P-I	28. Bakaner 29. Ghoga	30. Lampur 31. Mamurpur
(6)	Zone P-II	32. Hamidpur 33. Jhangola 34. Palia	35. Singhu 36. Tajpurkalan
(7)	Zone N	37. Auchandi 38. Mungeshpur 39. Qutabgarh 40. Khor Punjab 41. Chatesar	42. Jaunti 43. GarhiRindhala 44. Nizampur-Rashidpur 45. TikriKalan (Part) 46. Hareoli
(8)	Zone E	47. Mandoli	

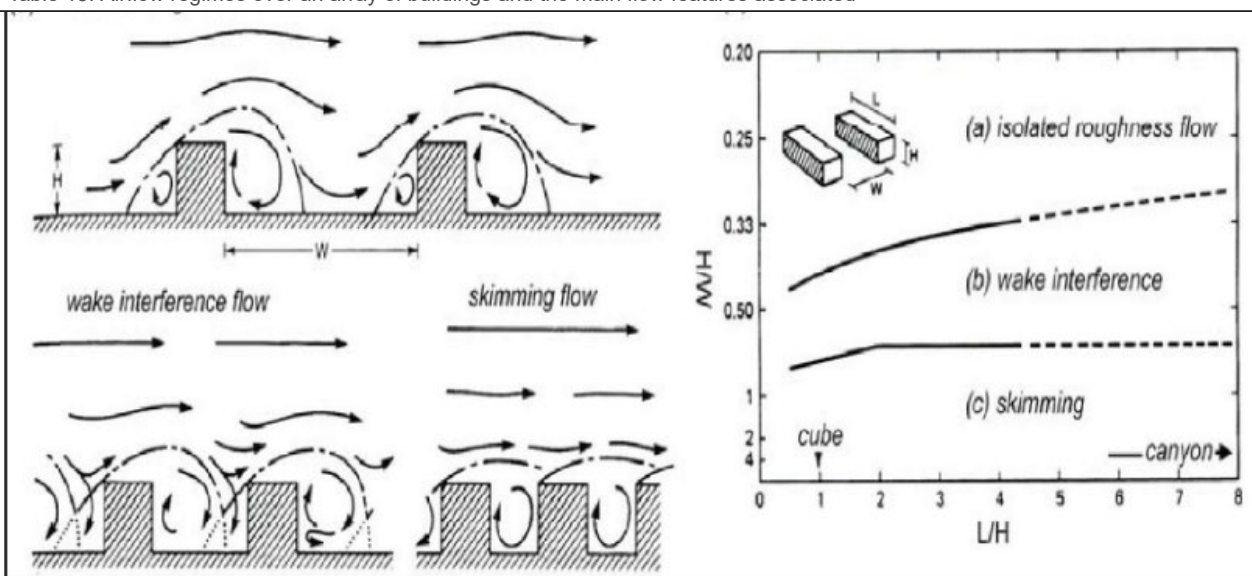
Source: Delhi Master Plan, 2021

The Building Regulations for Special Area, Unauthorized Regularized Colonies and Village Abadis, 2010 Notification (17th January, 2011) stipulates that the number of dwelling units (D.U.s), F.A.R, height of buildings, basement and other conditions shall be as per MPD 2021 norms for residential plotted development. However, full Ground Coverage will be permissible, and Setbacks will not be insisted upon. (Para 4.4.3 A of MPD 2021)

In such cases, a proper air ventilation and air dispersion modelling should be done. A secondary circulation feature driven by urban boundary layer provides airflow in an urban canyon which is strongly affected by the street orientation and geometry (H/W and L/W)^{1 2}. It can also be assessed by identifying the Street Canyon Parameters:

- H/W (i.e., Vertical Height of Building/Width of Access Road)
- L/W (i.e., Length of Canyon/ Width of Access Road)
- L/H (Length of Canyon/ Vertical Height of Building)

Table 15: Airflow regimes over an array of buildings and the main flow features associated



Source: Boundary Layer Climates, T.R. Oke

The urban streets vary in geometry as defined by height/width ratio (H/W) and length/width (L/W) and the orientation that is defined by its long axis. These parameters directly influence the absorption and emission of solar radiation and urban ventilation which have a significant impact on the temperature variations within the street as well as the surrounding environment (UHI).

The geometry of a street canyon is expressed by its 'aspect ratio' including the ratio of the height of the building (H) to width of the street (W). **If the canyon has an aspect ratio of around equal to 1 with no major openings on the walls it is called a uniform street canyon. A canyon with an aspect ratio below 0.5 is a shallow street canyon; and the aspect ratio of 2, represents a deep street canyon.** The length of canyon (L) illustrates the road distance between two main intersections.

The isolated roughness regime takes place between well-spaced buildings, when there is no interaction between windward and leeward flows, similarly to a wind movement around an isolated barrier. By increasing the H/W ratio, the wakes are disturbed leading to a wake interference regime. Further increase of H/W ratio makes the street canyon isolated from the

circulating air in the urban boundary layer and thus, a steady circulatory vortex is created in the canyon. This stable circulatory vortex brings about a skimming regime which is the most frequent in urban areas. Therefore, it could be concluded that there is slower airflow in deep street canyons in comparison with uniform or shallow ones.

CASE STUDY ON STREET CANYON EFFECT:

The impacts of street design on airflow have been investigated in many studies. For instance, Johansson³ studied the influence of street geometry on airflow has been studied in Morocco as case studies with real site measurements for a period over 1.5 years. Both deep and shallow street canyons with aspect ratio of 9.7 and 0.6 respectively were studied in detail. The results illustrated an obvious relationship between street canyon geometry and the microclimate within an urban canyon (1.7 m). This study shows that the wind speeds are slower and more stable in the deep canyon (0.4 m/s) in both winter and summer seasons. While the shallow street canyon had an average wind speed of 0.7 m/s in summer and 0.8 m/s in winter. In another study by Al-Sallal and Al-Rais⁴ in Dubai, it has been proved that narrow street canyons (4 m and less) could increase wind speed passing through it, resulting in a better passive cooling performance yet creating eddies at bending angles. When the wind speed was higher (5 m/s), wind reached deeper inside the traditional narrow streets providing better potential for thermal comfort. Most locations (49-57% of the studied area) with street canyons aspect ratio of 2-0.67 had wind speeds that ranged from light to gentle breeze. In addition, some studies assessed the impacts of building's heights on the airflow within a street canyon.

In this term, Priyadarsini and Wong⁵ found that **strategically placing a few blocks of high-rise towers will improve the velocity within the street canyon when the airflow is parallel or perpendicular to the canyon**. In addition, the temperature was lower when high-rise towers were placed in a street canyon. By placing some high-rise towers, the velocity is increased by up to 90% for parallel flow and the temperature is decreased by up to 1°C. For perpendicular flow, the velocity is increased up to 10 times and the temperature is decreased by 1.1°C.

Moreover, Robins and Macdonald⁶ discovered that additional wakes create additional air exchange and U-shaped vortices could occur by designing a few tall buildings among surrounding buildings restricted in the urban canopy layer. Upstream tall buildings would bring about more vertical flow up from the street canyon to the urban boundary layer. Downstream buildings would create additional vertical flow down from the urban boundary layer into the urban canopy layer.

In addition, providing adequate openings between streets and courts improves air exchange within the urban canopy layer.

Furthermore, it has been proved by Chan et al.⁷ who discovered that better ventilation

3 E. Johansson, "Influence of urban geometry on outdoor thermal comfort in a hot dry climate: a study in Fez, Morocco," *Building and Environment*, vol. 41, pp. 1326-1338, 2006.

4 A. Al-Sallal and L. Al-Rais, "Outdoor airflow analysis and potential for passive cooling in the modern urban context of Dubai," *Renewable Energy*, vol.38, pp. 40-49, 2012

5 R. Priyadarsini and N. Wong, "Parametric studies on urban geometry, airflow and temperature," *International journal on architectural science*, vol. 6, no. 3, pp. 114-132, 2005.

6 A. Robins and R. Macdonald, "Review of Flow and Dispersion in the Vicinity of Buildings," *Atmospheric Dispersion Modeling Liaison Committee Annual Report*, 1999

7 A. T. Chan, E. S. P. So, and S. C. Samad, "Strategic guidelines for street canyon geometry to achieve sustainable street air quality," *Atmospheric Environment*, vol.35, pp. 5681-5691, 2001.

could be provided by different building heights. Therefore, tall buildings do not essentially promote obstacle. Moreover, they found out that better mixing of air is brought about by a wider urban canyon and street geometry should be limited to threshold value for skimming flow and the maximum relative canyon length ratio L/H should not be more than five.

> As per the provision of Master Plan of Delhi 2021 development in urbanisable areas of Planning Zones – J, K-I, L, & P-II is to be taken up through the Land Policy based on the concept of **Land Pooling** wherein the land parcels owned by the individuals or group of owners are legally consolidated by the transfer of developments rights to the designated land pooling agency/DDA which later transfers the ownership of the part of land back to the land owners for undertaking developments for such areas as per the defined norms and categories.

To compensate for the 50-60k acres of land requirement in the upcoming years, areas like Narela, Najafgarh, and Bawana will witness land pooling and development. About 89 of the 95 villages have been listed as urban villages that will accommodate development. This system is a part of the master plan for Delhi-2021 according to which the city of Delhi will be developed. The residential Floor Area Ratio (FAR) of 400 for group housing to be applicable on net residential land exclusive of 15 percent FAR reserved for Economically Weaker Section (EWS) housing. Net residential land to be a maximum of 55 percent of gross residential land. The resultant of this is high rise buildings which may further aggravate the situation of air pollution and lead to more air pollution episodes.

The similar approach of Urban Street Canyon is applicable in this case following that the surrounding land uses has less implications on pollutant concentration and conform to the air pollution standards.

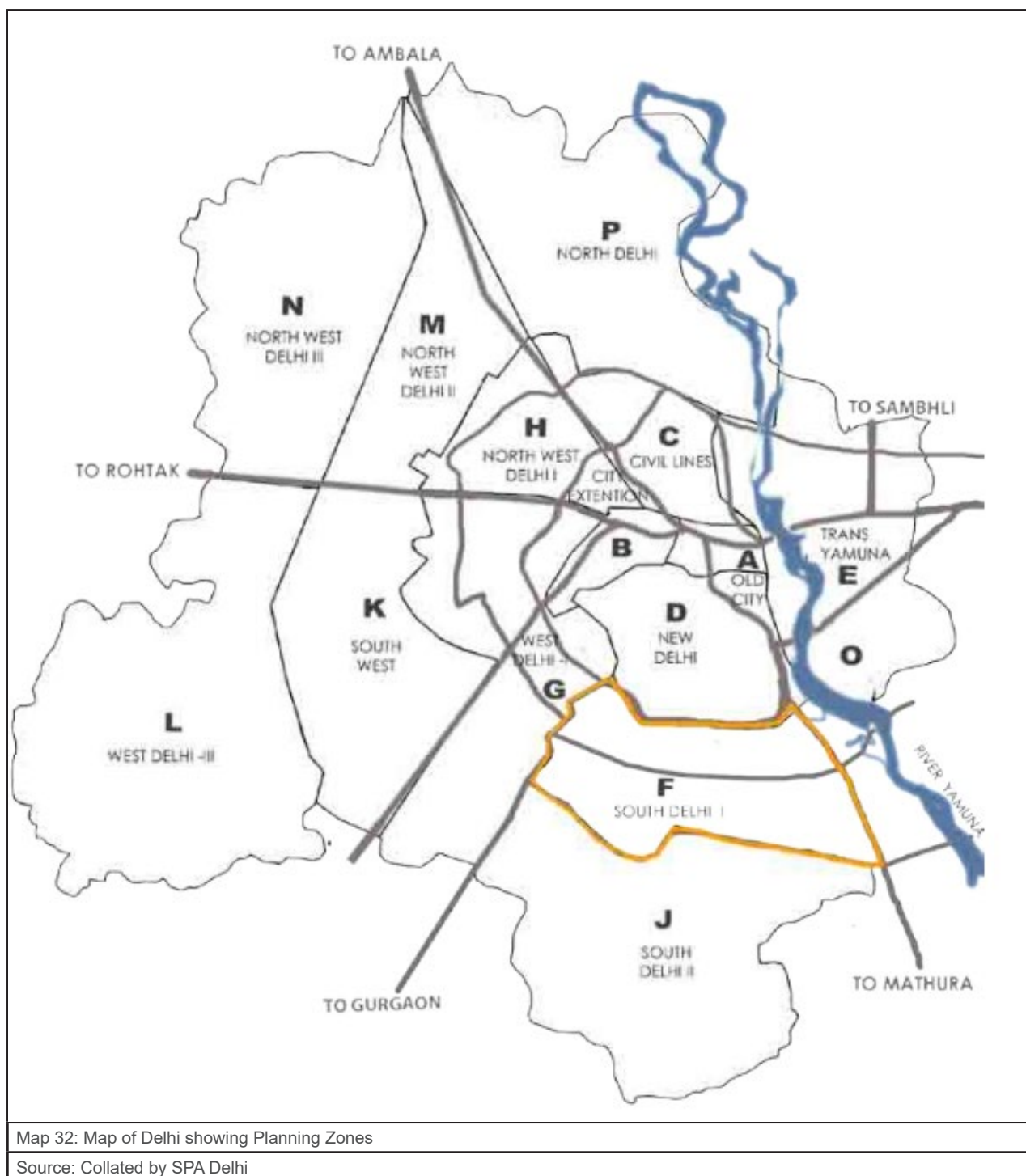
3.1.2. REGULATION ON TRANSFER OF DEVELOPMENT RIGHTS

Transfer of Development Rights (TDR) policy allow landowners to offer their land for development in exchange of development certificate that can be bought by developers to carry out additional construction in their projects as per norms.

Under the new TDR policy, landowners can surrender their land to the state government to set up critical infrastructure, such as sector roads, green and open spaces, and amenities such as hospitals and schools in exchange of a TDR certificate. The land surrendered under this policy shall be transferred to the government to build infrastructure.

A TDR certificate refers to the government awarding extra floor area ratio to the landowner for surrendering part of his land for building critical infrastructure. This certificate can be monetised by the landowner by being sold to a developer for construction of additional area as per rules.

Monitoring of applications of TDR should be necessary to manage building heights. Regulations on use on TDR by developers should be made.



3.1.3. DEVELOPMENT OF STATE OF ART CLIMATE MODELLING AND AIR POLLUTION MODEL-LING CENTRE.

This will enable better climate modelling and establishing local solutions. The data should be made available publicly to encourage better research in environment domain.

3.1.4. DEVELOPMENT AUTHORITIES TO SHARE GIS DATASETS OF CITY UNDER 'THE NATIONAL DATA SHARING AND ACCESSIBILITY POLICY (NDSAP)' –

- Land use in GIS format with sub-categories.
- Building Plots with typology and Heights to enable 3D modelling and wind dispersion modelling.
- Existing Land Use (if available for present year)
- Location of trees properly georeferenced with details of type of tree, shrub, Leaf Area Index (LAI)

3.1.5. PREPARATION OF EMISSION BUDGET (BASE AS ATTAINMENT YEAR)

A city-wide limit on allowable emission (Emission Budget) needs to be set for each activity to control the emissions and adoption of Best Available Technology (BAT). The limit is set based on emissions during attainment year.

The National Clean Air Programme (NCAP) aims to achieve a 20–30 per cent reduction in particulate matter (PM) concentration by 2024 with 2017 as the base year (MoEFCC, 2019).

3.1.6. LEGAL MANDATE FOR REVIEWING AND UPDATING PLANS

Unlike in the United States and the European Union, where states and member nations are legally mandated to periodically update clean air plans for regions that violate air pollution standards, the City Clean Air Action Plans in India were drafted in response to an order by the National Green Tribunal. Therefore, there is cause for concern that the preparation of plans might remain a one-time exercise. The Centre should recommend that preparing and periodically updating plans be mandated under the Air (Prevention and Control of Pollution) Act (1981)".

3.1.7. DELINEATION OF AIRSHED FOR REGIONAL AIR POLLUTION MANAGEMENT

Airshed is roughly analogous to the concept of the watershed and considers air basins as geographical areas that share the same air because of topography, meteorology and climate. To address the problem of air pollution comprehensively, Sagnik Dey, Associate Professor at IIT-Delhi and Coordinator for the Centre for Excellence for Research for Clean Air (CERCA), said, "We need to delineate airsheds based on wind flows and their pollutant reach. The city action plans should be integrated with the larger airshed management strategy to deal with the problem".

A 2012 study by IIT-Delhi mapped the aerosol transfer across the Indo-Gangetic region, making it the world's most polluted hotspot -- stretching from Punjab, Haryana, Delhi, UP, Bihar and all the way to West Bengal.

The constraints that have been found so far in establishment of airshed are:

- Varying meteorological properties i.e., wind speed and direction, rainfall, humidity, etc., and

further estimating pollutant reach – flow of pollutants.

- The modern-day assessments done on AERMOD relies on predicted values for many parameters and is time consuming.

An approach of delineating Airshed have been developed with focus on inflows and outflows. The quality of air is influenced by the intensity of activity(ies). Cities are dependent on each other for goods, raw materials, employment opportunities, etc. Therefore, identifying the intensity of flows will help in building a functional relationship between the dominant centre (focus area) and the surrounding cities/towns.

Gravitation Analysis suggests that the interaction between the two centers is directly proportional to the 'mass' of the centers and inversely proportional to the 'distance' between the centers. The variables used to measure 'mass' and 'distance' depend upon the problem and data availability. **The 'mass' can be represented by variables such as population, employment, income, expenditure etc. and 'distance' can be represented by distance in physical terms i.e. km, time, price etc.** Mathematically this can be represented as:

$$T_{ij} = [p_i p_j / d_{ij}^2]$$

Where T_{ij} is the gravitational force between towns i and j and P_i and P_j are the masses of the two centers and d_{ij} is the distance between them.

By calculating the potential for the centers in a study area, contour lines of equal potential can be plotted on a map, illustrating the relative attractiveness and sphere of influence of various centers.

In the expression, Gravitation Force between two town i and j ,
 $T_{ij} = [P_i P_j / d_{ij}^2]$,

P can be substituted by:

- Population
- Land use/Land Cover (Area/Percentages)
- Export/Import of goods and supplies
- Migration/Tourism
- Infrastructure – Vehicles/Solid Waste Management, etc.
- Emission Load
- Goods Consumption & Production
- Economic Growth

d can be substituted by:

- Distance

By calculating the potential for the centers in a study area, contour lines of equal potential can be plotted on a map, illustrating the relative attractiveness and sphere of influence of various centers. The sphere of influence thus generated will provide the airshed boundaries.

Gravitational Force will be calculated for all the parameters mentioned earlier. A matrix will be developed as shown below for all the parameters. Similar values will be connected to generate contour lines representing areas with similar influences. The result will help us in delineating the airshed boundaries.

EXAMPLE

Table 16: Generic Matrix for Airshed Delineation

Cities	Delhi	Ghaziabad	Noida	Gurgaon	Faridabad	Greater Noida	Agra
Delhi	1	2	1	5	2	2	1
Ghaziabad	3	1	2	3	1	2	2
Noida	2	2	1	3	2	3	1
Gurgaon	1	5	2	1	2	3	4
Faridabad		3	4	4	1	2	1
Greater Noida	5	4	4	3	2	1	5
Agra	2	5	3	1	4	2	1

Source: SPA Delhi

The method can also be used to identify sphere of influence of activity within the city. Later the values can be compared with the emission loads and AQI values of that area within the city to check their accuracy.

3.2. ENERGY PRODUCTION STRATEGIES

- > There are 3 power plants operating in the city which uses fuel mainly PNG/CNG and some operate using diesel and LPG.
- > Delhi has 3 Waste to Energy Plants (WTE Plants) with total capacity 5250 TPD at 3 different locations in Delhi namely Okhla, Ghazipur and Bawana. One New Waste to Energy Plant of capacity about 2000 TPD is proposed at Tehkhand and another in the Integrated Waste Complex at Ghonda Gujran. After commissioning of these 2 proposed WTEs capacity of WTE Plants will increase from 5250 TPD to about 9000 TPD by June 2022.
- > The Delhi Solar Policy, 2016 is applicable for any solar energy generating system with a capacity of 1 KWp or more. The State shall promote the development of grid-connected solar plants on rooftops for meeting own electricity needs and injecting surplus electricity into the distribution grid.
- > Given Delhi's land-locked position, the high cost and paucity of barren land within its borders, and low potential for wind or hydro power, Delhi must focus on rooftop solar as its primary source of renewable energy. Delhi is blessed with almost 300 sunny days and the rooftop space available for solar panels is estimated to be 31 sq. km, giving Delhi a solar energy potential of 2500 MWp (annual Generation approx. 3,500 million kWh). Of this potential, 26% is in the government/public sector, 25% in commercial/ industrial sector, and 49% in domestic sector.
- > The State shall encourage the installation of solar plants with Net Metering on all residential buildings, colonies, townships, housing societies, private bungalows, farmhouses, etc. All urban development and housing agencies (private and public, including DDA and PWD), the Municipal Corporations of Delhi, banks and RWAs shall facilitate the deployment of solar project installations.
- > The State shall offer a limited-time GBI for existing and future Net Metered connections in the domestic/residential segment only.
- > In order to promote clean and green energy and reduce the pollution burden on the capital,

all Municipal Corporations of Delhi shall work towards and notify the exemption of Electricity Tax (currently 5%) for solar energy units generated, whether for self-consumption or supplied to the grid.

INCREASE UPTAKE OF SOLAR ROOFTOP IN DELHI BY SCALING UP THE EXISTING SCHEMES.

The energy sector in Delhi has improved overall and will strengthen its energy security and reduce its reliance on unsustainable fossil fuels in coming years with improved efficiency in Waste to Energy Plants and Solar Policy.

Solar power generation in Delhi has increased from 7 MW to 177 MW in four years and emphasised on its adoption in a mission mode. Delhi government has come out with two policies for its promotion in residential areas and for farming. Recently in October, the Delhi government inaugurated a 218 KW solar plant at Lady Irwin College in Mandi House. Efforts should be made by other institutions to adopt solar energy.

> Ban on diesel GenSets – The operation of electricity generator sets of all capacities running on diesel, petrol or kerosene in Delhi have been imposed with ban in Delhi from October 15 till further orders from DPCC under the Graded Response Action Plan (GRAP).

> Uninterrupted Power Supply in NCR towns to avoid requirement of operating DG sets and inconvenience to public.

The DPCC have directed power companies to ensure an uninterrupted power supply to the consumers. The other NCR districts should adhere to the EPCA orders and make necessary arrangements for supply of power to the public.

3.3. URBAN TRANSPORT STRATEGIES

3.3.1. PREPARATION OF COMPREHENSIVE MOBILITY PLAN (CMP)

The concept of Comprehensive Mobility Plan (CMP) is to have focus on the mobility of people to address urban transport problems and promote better use of existing infrastructure (i.e., improvement of public transport, pedestrian and NMT facilities) which as such leads to the integration of land use and transport development and is essential to building smart cities.

Delhi so far two Transportation Plan available and both based their studies on 2007 traffic data.

a. Functional Plan on Transport for National Capital Region – 2032; NCRPB

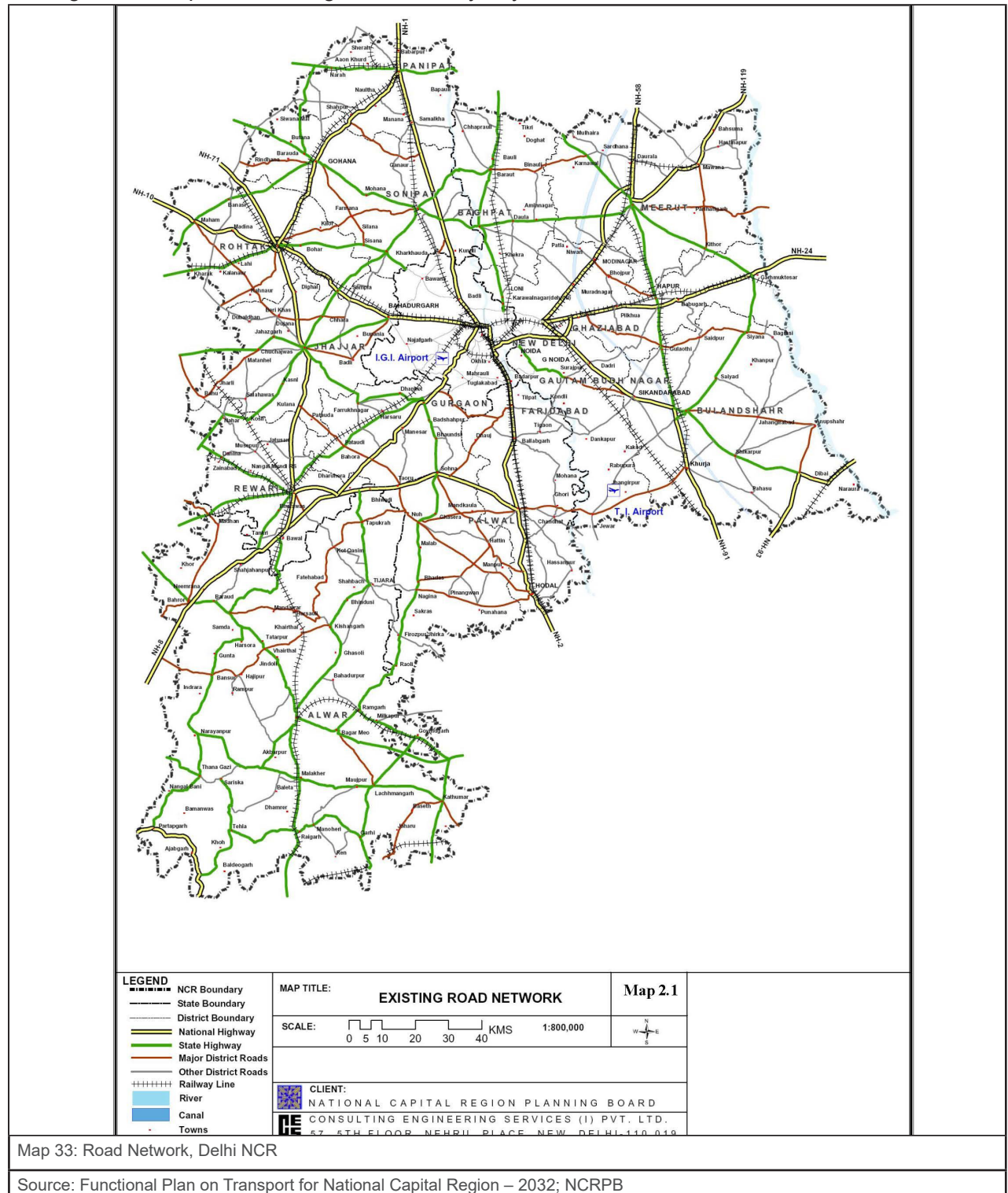
b. Transport Demand Forecast Study and Development of Public Transport Network, April 2010; RITES

Transportation surveys should be done for current year to capture the actual scenario since there have been many recent changes in urban development and land uses. The CMP should be based on the existing recent year Transportation Survey rather than relying on past old dataset.

The Origin Destination Matrix is an essential component for gravitational analysis which will help in Airshed Delineation. As such the current or recent dataset not older than 2 years is required to properly estimate the airshed boundaries based on Gravitational Analysis Technique.

3.3.2. PREPARATION OF ANNUAL TRANSPORT SURVEY PRIMARILY FOCUSED ON HOUSEHOLD TRAFFIC SURVEYS

Household traffic surveys are widely used in travel behavior analysis, especially in travel time and distance analysis (trip modelling process). This will help in better assessment of road network and traffic congestions. This should be mandated as necessity in establishing strategies for air pollution mitigation in every city.



Fuel:

> India has reduced its diesel Sulphur content from 10,000 ppm in most of the country in 1996

to a maximum of 50 ppm in 2017. Another factor that has improved over this period is cetane number, which increased from 45 to 48 in 1998 and 51 in 2005. The proposed BS-VI regulation will reduce diesel Sulphur content to a maximum of 10 ppm, enabling the introduction of advanced emission control technologies, including diesel particulate filters (DPF) and selective catalyst reduction (SCR) systems, which will be needed to meet BS-VI emission standards.

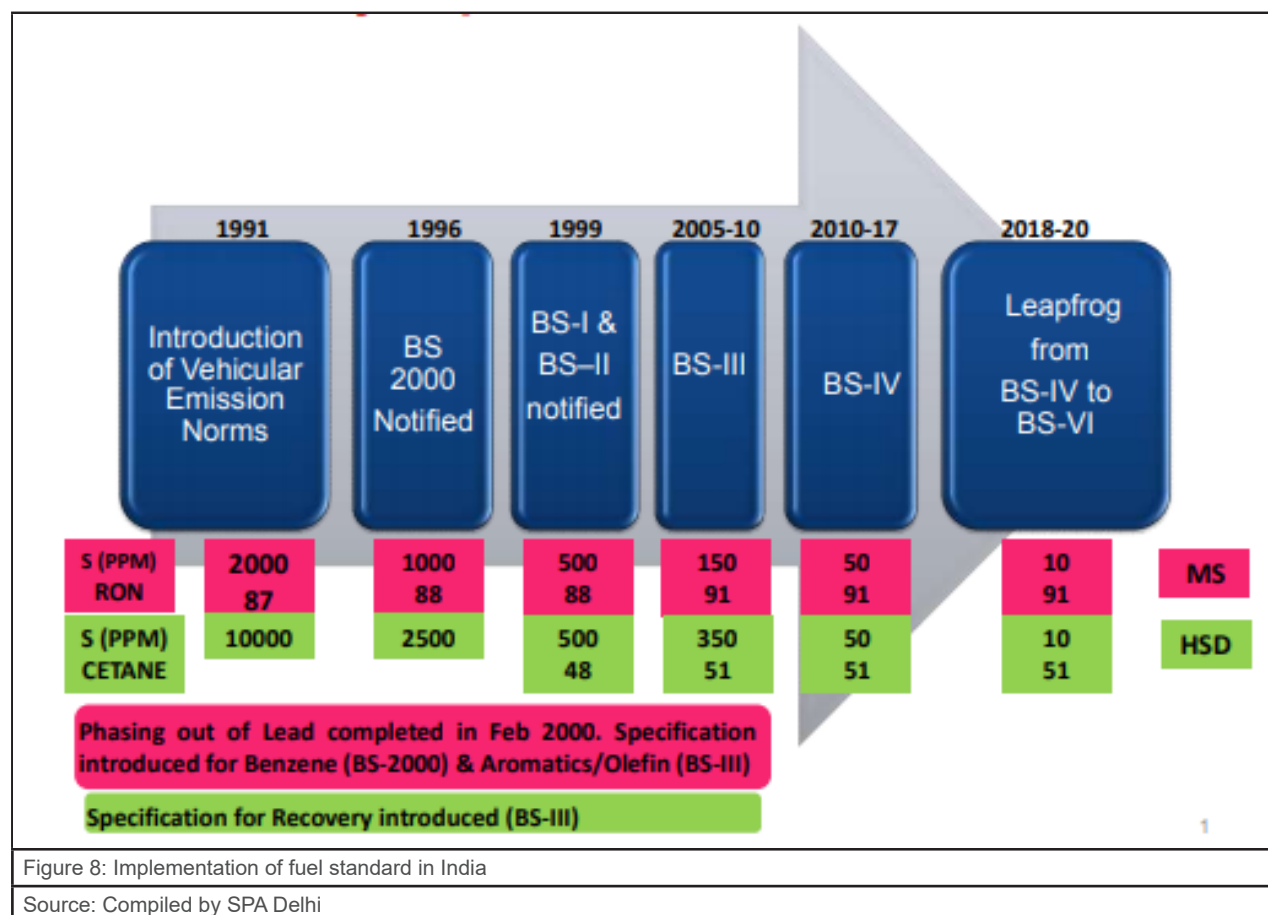


Figure 8: Implementation of fuel standard in India

Source: Compiled by SPA Delhi

Table 17: Implementation of Fuel Sulfur Content Reduction in India

Date	Diesel	Gasoline
1995	10,000 ppm (nationwide)	-
1996	5,000 ppm (Delhi + selected cities)	-
1998	2,500 ppm (Delhi)	-
2000	2,500 ppm (nationwide)	1,000 ppm (nationwide)
	500 ppm in NCR and gradually extended to Metro Cities	
2005	500 ppm (BS II, nationwide)	500 ppm (BS II, nationwide)
	350 ppm (BS III, selected cities)	150 ppm (BS III, selected cities)
2010	350 ppm (BS III, nationwide)	150 ppm (BS III, nationwide)
	50 ppm (BS IV, selected cities)	50 ppm (BS IV, selected cities)
2017	50 ppm (BS IV, nationwide)	50 ppm (BS IV, nationwide)
2018	10 ppm (BS VI, NCT)	10 ppm (BS VI, NCT)
2020	10 ppm (BS VI, nationwide)	10 ppm (BS VI, nationwide)

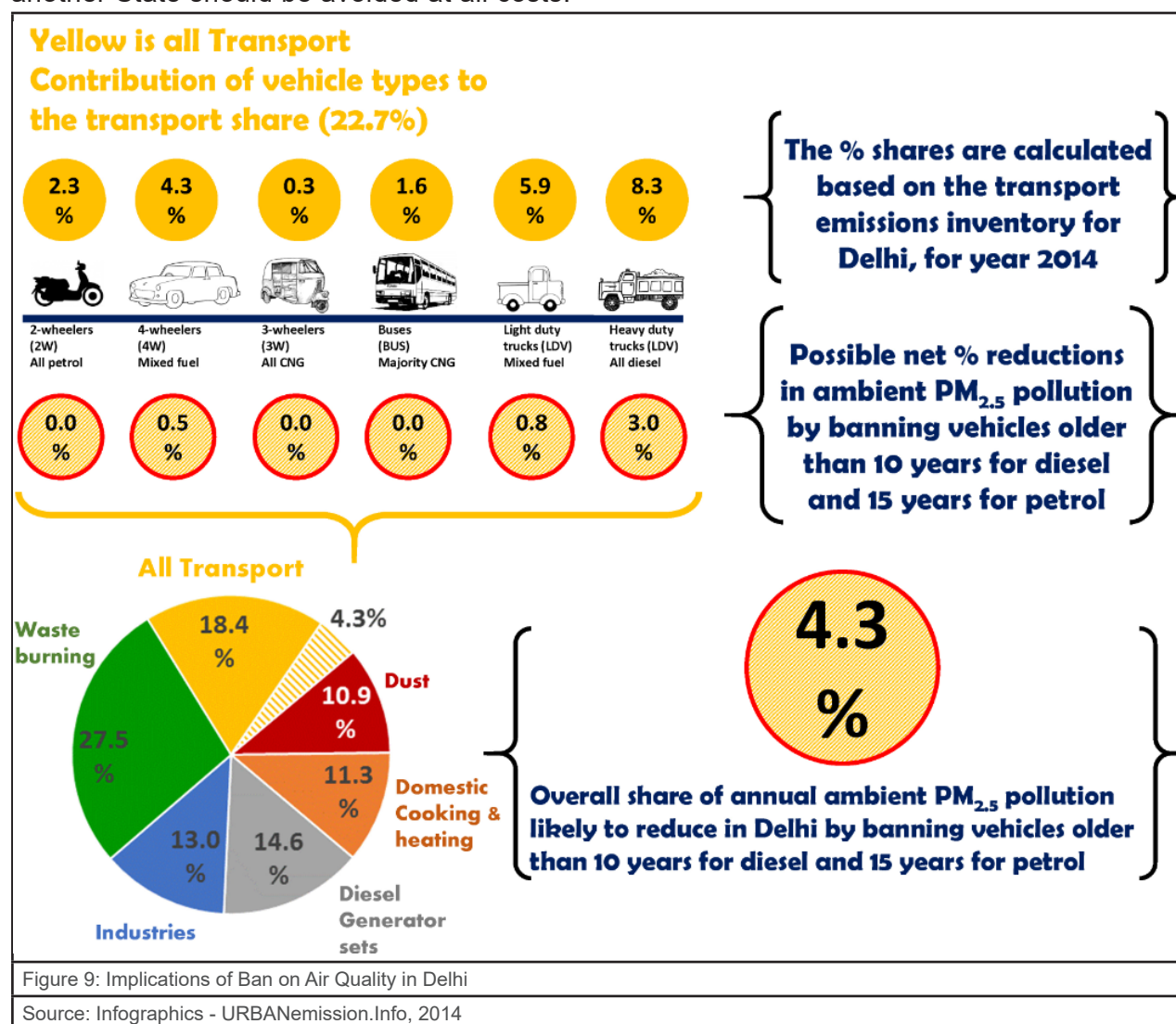
Source: Compiled by SPA Delhi

> The State has adopted the BS VI fuel standard. The city still experiences episodes of high air pollution owing to increase number of private vehicle ownership.

> The Green Tribunal (NGT) in 2015 imposed a ban on all diesel vehicles older than 10 years and all petrol vehicles older than 15 years and Road Transport Offices to de-register such vehicles.

> In order to re-register your old vehicle in another State, one shall first have to obtain a No Objection Certificate ("NOC") from the concerned RTO. Once the NOC is procured, the owner of the vehicle can have it re-registered at such other State where either no such ban is imposed, or where vehicles older than 10 years are permitted.

> The ban should be imposed on all the States and the re-registration of an Old vehicle in another State should be avoided at all costs.



> The Buses in Delhi runs on CNG. Delhi has 3849 buses in the fleet and carries 30.15 lakh passengers daily as shown in the table below. The annual growth of vehicles in Delhi decreased from 8.13 per cent in 2005- 06 to 3.69 per cent in 2018-19. During the same period, the number of vehicles per thousand population increased considerably from 317 to 616.

Table 18: Statistics of Bus in Delhi

ACTIVITIES OF DELHI TRANSPORT CORPORATION: 2016-17 to 2018-19													
Sl. No.	Details	2016-17				2017-18				2018-19			
		Non-AC	AC	Standard	Total	Non-AC	AC	Standard	Total	Non-AC	AC	Standard	Total
1	Total Buses in the Fleet (At the end)	2506	1275	246	4027	2506	1275	170	3951	2506	1275	68	3849
2	Buses on Road (Daily Average)	2238	1065	244	3547	2232	1078	92	3402	2197	1071	27	3295
3	Passengers (in Crore)	87.96	20.63	6.57	115.16	84.86	21.77	2.35	108.98	84.96	24.35	0.74	110.15
4	Daily Average Passengers (in Lakh)	24.13	5.65	1.8	31.55	23.25	5.97	0.64	29.86	23.28	6.67	0.2	30.15

Source: Transport Chapter, Economic Survey of Delhi, 2018-19

Table 19: Growth and Vehicles per 1000 population in Delhi

Sl. No.	Years	Vehicles		Annual Growth (%)	No. of Vehicles Per Number Increase 1000 Population
		Number	Increase		
1	2005-06	4830136	-	8.13	317
2	2006-07	5232426	402290	8.33	337
3	2007-08	5627384	394958	7.55	356
4	2008-09	6026561	399177	7.09	374
5	2009-10	6466713	440152	7.3	393
6	2010-11	6947536	480823	7.44	415
7	2011-12	7452985	505449	7.27	436
8	2012-13	7785608	332783	4.46	446
9	2013-14	8258284	472676	6.07	465
10	2014-15	8827431	569147	6.89	491
11	2015-16	9704741	877310	9.94	530
12	2016-17	10382757	678016	6.99	556
13	2017-18	10986015	603258	5.81	598
14	2018-19	11391551	405536	3.69	616

Source: Transport Chapter, Economic Survey of Delhi, 2018-19

> Scaling up of H-CNG & CNG based Public Transport Vehicles:

A Cedigaz report on India's gas sector (October 2017) states that 11% of total gas consumption is by transport. CNG is now prevalent in around 11 (out of 29) Indian states, with many cities mandating its use in public transport (taxis, auto-rickshaws and buses). The Indian Supreme Court gave the sector a boost when in late 2015 it mandated that all Delhi taxis must convert to CNG and registration of new diesel vehicles in the city will no longer be allowed.

Growth in this sector is severely constrained by infrastructure. India's Petroleum Planning & Analysis Cell reports that as at December 2017, there are 3.045 million natural gas vehicles (NGV) but only 1,282 CNG filling stations. The number of stations has increased by just 379 since 2013. CNG infrastructure (March 2017) is disproportionately skewed towards three states: The National Capital Territory of Delhi (421 stations), Gujarat (396 stations), and Maharashtra (245 stations)⁸.

HCNG is a hydrogen enriched compressed natural gas (CNG). In Delhi, instead of physically blending hydrogen with CNG, hydrogen spiked CNG will be produced using compact reforming process patented by Indian Oil Corporation. HCNG is cleaner and more economical. The power output of HCNG is also better than CNG ones. The HCNG will ensure 70% more reduction in carbon monoxide emissions compared to CNG.

According to Pandit Deendayal Petroleum University website, "It requires only a small hydrogen

storage and a column for the mixing of hydrogen with natural gas at existing CNG stations. Safety components are similar to the CNG. HCNG is easier and safer to use than hydrogen as it contains very low energy content from hydrogen i.e., up to 30% by volume. HCNG reduces the engine's unburned hydrocarbon emissions and speeds up the process of combustion. The engine's fuel efficiency is improved by blending the CNG from hydrogen which lowers the fuel consumption of the vehicle. The thermal efficiency and fuel economy are also increased by HCNG."

HCNG will be used to run 50 buses as part of a pilot project for six months from the Rajghat-1 bus depot. A four-tonne per day compact reformer-based HCNG production plant has come up at the Rajghat-1 bus depot of Delhi Transport Corporation (DTC)

A four-tonne per day compact reformer-based HCNG production plant that has come up at the Rajghat-1 bus depot of Delhi Transport Corporation (DTC) was expected to start operations from March, but the Covid-19 outbreak put a spanner in the works. The Supreme Court had last year suggested looking at hydrogen-run vehicles as a solution for Delhi NCR's poor air quality. Such initiatives can be replicated in other states with CNG infrastructure to further reduce the emission load from vehicles.

> The Delhi Electric Vehicle Policy, 2020 shall seek to drive rapid adoption of Battery Electric Vehicles (BEVs) so that they contribute to 25% of all new vehicle registrations by 2024 and bring about a material improvement in Delhi's environment by bringing down emissions from the transport sector.

Delhi government aims to register at least 5 lakh electric vehicles by 2024 in order to reduce air pollution in the national capital region. In its bid to promote the electric vehicles, the Delhi Government has passed the EV policy. These electric vehicles will mostly include two-wheelers and commercial vehicles.

The Delhi government is targeting induction of 35,000 electric two, three, four wheelers and buses along with 1,000 electric vehicles for last mile deliveries and 250 public charging and battery swapping stations. Also, it has waived road tax and registration fees for all battery electric vehicles for the next three years.

Under this policy, the Delhi government will offer purchase incentive of Rs 5,000 per kWh of battery capacity compared to Rs 5,500 currently offered by Delhi Pollution Control Committee. Besides that, there will be a scrapping incentive of up to Rs 5,000, subject to evidence of matching contribution from the manufacturer or dealer.

Delhi will allow ride hailing service providers to operate electric two-wheeler taxis while all the last-mile delivery companies like food delivery and e-commerce logistics providers are expected to shift to 50 per cent of their fleet to electric by March 2023 and 100 per cent by March 2025.

E-rickshaws and carriers will get an incentive of Rs 30,000 per vehicle and interest subvention of 5 per cent on loans, reveals the policy. Open permit system will apply for individuals who will be given permits on a first-come-first basis, subject to the cap of maximum number of autos

permissible in Delhi.

Electric four wheelers will get a purchase incentive of Rs 10,000 per kWh of battery capacity for first 1,000 cars subject to a cap of Rs 1,50,000 per vehicle. All the leased cars used for commute of Delhi government officers will be transitioned to EVs within next 12 months.

The policy also mandates that new home and workplace parking should reserve 20 per cent parking to EVs. The Delhi government will provide 100 per cent subsidy for the purchase of charging equipment costing up to Rs 6,000 per unit for the first 30,000 charging points at homes and workplaces.

The government will also form an electric vehicle board and an EV cell within transport department that will be responsible for implementing the policy.

- R & D in the field of Transport sector should be promoted to develop Electric Buses feasible for Indian Road and Climatic Conditions. The Feasibility of Electric Bus Operation in Urban Areas, Case Study- Delhi have also been carried by Transport Department of School of Planning and Architecture, Delhi.
- Registration of Vehicles (MV Tax) should be based on Vehicle Engine Capacity rather than price slab. This means the vehicles having less mileage (higher vehicle engine capacity) will pay more registration tax. E.g., Singapore Motor Vehicle Tax
- Delhi needs to reduce its vehicle ownership and ban on old vehicle is just the first step. This high tax slab (Motor Vehicle Tax) on vehicles will also imply that lesser number will opt for owning vehicles in Delhi. The similar strategy should be followed in all Indian cities.
- Restricting odd and even numbered private vehicles on alternate days in Delhi can prove to be useful however the public transport system needs to be efficient in this case.

Table 20: Number of registered vehicles

Sl. No	Details	Number of Registered Vehicles				
		2014-15	2015-16	2016-17	2017-18	2018-19
1	Cars and Jeeps	2790566	2986579	3152710	3246637	3249670
2	Motorcycles & Scooters/ Two wheelers	5681265	6104070	6607879	7078428	7556002
3	Ambulances	1527	2990	3059	3220	2358
4	Auto Rickshaws (Passenger)	81633	198137	105399	113074	113240
5	Taxis	79606	91073	118308	118060	109780
6	Buses	19729	34365	35206	35285	32218
7	Other Passenger Vehicles*	11284	6368	59759	76231	81422
8	Tractors	161821	281159	300437	315080	246861
9	Goods Vehicles (All Type)					
10	Others					
11	Total	8827431	9704741	10382757	10986015	11391551

Sl. No	Details	Number of Registered Vehicles				
		2014-15	2015-16	2016-17	2017-18	2018-19
* Data include the e-rickshaws and maxi cabs etc.						
**Number of vehicles registered are excluding NOC, RC Cancellation, Surrendered, De-registered and Scrapped Vehicles (Record available in Vahan 4.0 database).						

Source: DPCC, Transport Department

As per 2018-19, the odd-even scheme would give the following output:

Table 21: Output of Odd-Even Scheme in Delhi, 2018-19

Vehicle	Registered	% in use	Trips/day	Occupancy/Trip	Total Trips/Day	50% Cut (Trips/Day)
2-Wheeler	7556002	65%	2.5	1.2	1,47,34,204	73,67,102
4-Wheeler	3249670	65%	2.5	1.5	79,21,071	39,60,535

Source: Estimated by SPA Delhi

Therefore, the total new trips required by bus will be = (73,67,102+39,60,535) = 11327637 i.e., 11.33 million trips/day.

Total additional buses required -

= 11327637 trips/day ÷ 10 trips/day (bus) ÷ 50 (occupancy/trip)

= 22,655 additional buses required for odd even to be successful.

At present Delhi has only 3849 buses in fleet and carries 30.15 lakh passengers per day.

Table 22: Performance of Delhi Transport Corporation (DTC)

Sl. No.	Years	Fleet (In No.)	Fleet Utilization (In %)	Vehicle Utilization (Km/Bus/Day)	Load Factor (In %)	Passenger Carried per bus daily (In No.)	Daily Average Passengers (In Lakh)
1	2005-06	3469	90.51	226	74.42	973	30.52
2	2006-07	3444	81.47	199	77.18	951	26.77
3	2007-08	3537	82.47	177	87.82	848	24.04
4	2008-09	3804	77.03	171	68.83	772	22.62
5	2009-10	4725	80.99	184	69.84	776	24.16
6	2010-11	6204	75.03	185	71.43	700	30.32
7	2011-12	5892	84.27	199	77.75	863	44.2
8	2012-13	5445	85.77	202	92.9	973	46.77
9	2013-14	5223	85.51	190	86.63	952	43.47
10	2014-15	4712	83.99	188	85.02	930	38.87
11	2015-16	4352	83.63	191	82	927	35.37
12	2016-17	4027	85.12	199	81.36	890	31.55
13	2017-18	3951	85.69	191	83.83	878	29.86
14	2018-19	3849	84.62	195	81.34	915	30.15

Source: Operational Statistics of DTC

This shows that more users shift towards metros, cab services & autos during odd-even

schemes and thus the usage of cab services and autos increases during those periods. Daily ridership of Delhi Metro is 25 lakhs as of 2018-19⁹.

Table 23: : MRTS average daily ridership and rolling stock

Year	Ridership	Operational Route (Km) Excluding Airport Express line	Rolling Stock (No. of Cars)
2007-08	6,25,000	65.1	280
2008-09	7,22,000	74.55	280
2009-10	9,19,000	95.79	376
2010-11	12,59,000	161.45	844
2011-12	16,60,000	167.33	1022
2012-13	19,26,000	167.33	1094
2013-14	21,90,000	167.33	1282
2014-15	23,86,000	170.56	1306
2015-16	26,00,000	189.747	1392
2016-17	2761,342*	194.844	1426
2017-18	2537,175*	228.78	1818
2018-19	2597,000*	320.968*	2140*

Source: Transport Chapter, Economic Survey of Delhi, 2018-19

Efforts should be made to build efficient cycling networks and pedestrian friendly city in Delhi to reduce the contribution of vehicles towards air pollution.

3.3.3. WALKABILITY:

- At least 125 trees per km for streets with ROW smaller than 12m. At least 125 trees per km per footpath on streets with ROW greater than 12m. Spacing of trees at no place should be greater than 12m except at intersections.¹⁰
- Pedestrian refuge with a minimum width of 1m at each street crossing location after crossing 7m of one-way motor vehicle carriageway or 10m of two-way motor vehicle carriageway at non signalized midblock crossings. Pedestrian refuge width may be expanded to 1.75m where possible to accommodate a bicycle.
- The trees and shrubs plantation alongside roads should conform to minimal biogenic emission and reduction capacity of particulate matter (particulate deposition is relative to leaf area index).
- Adaptive Reuse of Spaces under Flyovers should be promoted.¹¹
- Elevated walkways for pedestrian connectivity should be developed. Such project will aim to support efforts to make the city accessible, create potential for pedestrians to move without being compromised by vehicles in the road space.

9 Economic Survey of Delhi, 2018-19

10 National Mission on Sustainable Habitat

11 DUAC Annual Report, 2018-19

3.3.4. CYCLING:

- Dedicated and physically segregated bicycle tracks with width of 2m or more, one in each direction, should be provided on all streets with total motor vehicle carriageway larger than 10m (not ROW) after providing adequately sized footpaths in each direction based on pedestrian traffic.
- At least 5 safe street crossing per km for bicycles with spacing between two crossings not more than 250m.
- Citywide cycle network of segregated lanes or traffic calmed streets that provides access to at least 80% of built plots (should tend to 100%).
- At least one cycle sharing system with $\geq 5,000$ cycles and automated payment in cities with a population of over 5 lakhs (benchmark census year 2011). Ridership of the system should be in excess of 1000 trips per bicycle per year.¹²
- Shading infrastructure or trees as a means of shading should be provided for comfort in cycling and to enable more users to shift from motorised vehicles to cycling.

3.3.5. TRAFFIC CALMING MEASURES:

Congestion on urban roads is caused due to multiple factors that include but are not limited to –

- Land use,
- High volume to capacity ratio (V/C),
- Development of suburbs leading to greater directional splits,
- Bottlenecks on links due to varying carriageway or encroachment,
- Bottlenecks/ low navigability of nodes (junctions),
- Driving behaviour, etc.
-

Magnitude of effect due to each of these factors varies to a great extent based on context. In a city like Delhi, which on one hand enjoys privileges and facilities of global cities and on the other faces numerous third world issues like rampant encroachment, poor policing, exponential increase of private transport, inefficient and insufficient public transport; almost all of the previously mentioned congestion factors come into play.

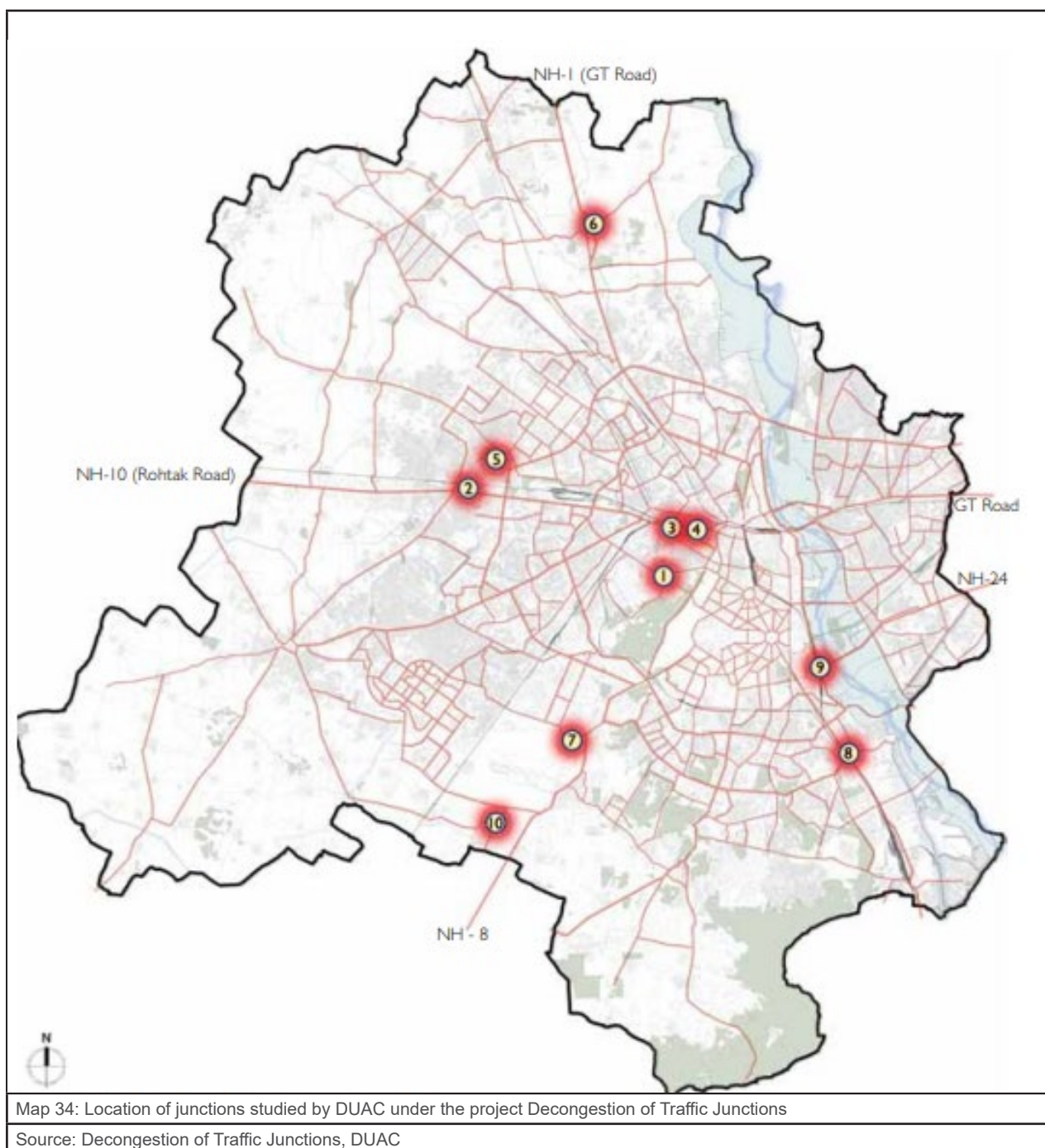
According to a study done by IIT Madras (Harry Raymond Joseph, Gaurav Raina and Krishna Jagannathan, 2015, Cost estimates for road congestion in Delhi: projections and recommendations, traffic congestion on Delhi roads costs about Rs 60,000 crore annually. The contributing factors to this assessment are - fuel waste due to idling of vehicles, productivity loss, air pollution and road crashes. Apart from these factors, other negative externalities of congestion are - a) Financial loss due to wear and tear of vehicles, b) Loss of life resulting from hindered movement of emergency vehicles, c) Inconvenience caused due to inability to forecast travel time, and d) Indiscriminate flouting of traffic rules which, ironically is often both cause and effect of congestion.

A study done by DUAC on Decongestion of Traffic Junctions: Ten Junctions Identified by Delhi Traffic Police (see Map 34), published on January 2018 have identified both short term

¹² National Mission on Sustainable Habitat

measures and long-term measures also identifying various urban design strategies.

> **Greening of Roads** should be done with proper study on type of shrubs and trees to be used along roadside. Such measures should keep in mind of both biogenic emissions due to vegetation and particulate matter reduction efficiency of such plants and trees.



3.3.6. ROADSIDE AUTOMATIC SPRINKLING SYSTEM

Design of roadside automatic sprinkling system should be developed. A study done by Shiyong Liu, Konstantinos Triantis and Lan Zhang on “The Design of an Urban Roadside Automatic Sprinkling System: Mitigation of $PM_{2.5}$ – PM_{10} in Ambient Air in Megacities”¹³ have described the system architecture for an urban roadside automatic mist-generating system. Its primary

purpose is to mitigate particulate matter especially $PM_{2.5}$ – PM_{10} . The unique design of the road automatic sprinkling system renders itself a prominent option.

Similar designs are made in Japan for melting snow accumulated on road with hot water sprinkler. The figures have been shown below. Such unique strategies can be applied in Indian context and especially provided the better utilization of wastewater for such purpose is properly worked out.



Table 24: Snow melting system using warm-water sprinklers in Japan

Source: Google

> **Street Sweeping via Mechanical Road Sweeping machines** should be frequently carried out and should be done once in a week (i.e., the approximate life span of black carbon particulate matter).

A Typical Classification of Streets and the Frequency of Sweeping have been provided by MoHUA

Table 25: Street Cleaning Frequency, MoHUA

Class	Character of Street	Frequency of Sweeping
A	City centre shopping	Daily
B	Market areas	Daily
C	City centre and minor streets	Daily
D	Sub-urban shopping streets	Daily
E	Residential streets (high and low income)	Daily
F	Roads and streets having no households/ establishments on either side	Once a week
G	Sub-urban main streets	Twice a week
H	Open space	Occasionally, when required. (minimum once in a fortnight)

Source: Street Cleansing, MoHUA; [http://mohua.gov.in/upload/uploadfiles/files/chap11\(1\).pdf](http://mohua.gov.in/upload/uploadfiles/files/chap11(1).pdf)

> Retrofitting diesel vehicles (especially trucks for inter-state supply of goods) with particulate filters. This will help in minimizing the emissions from truck vehicles to much higher extent.

> Maintaining pothole free roads: This will minimize the amount of abrasion (wear and tear) of tyres which contribute to the particulate matter concentration. Efforts should be made by PWD and DDA to maintain the road infrastructure to higher standards.

3.4. AGRICULTURAL STRATEGIES:

3.4.1. PROMOTION OF SKILL DEVELOPMENT IN SUSTAINABLE AGRICULTURAL PRACTICES AND CROP ROTATION WITHIN CITY, NCR ESPECIALLY INDO-GANGETIC BELT.

The rice-wheat system is primarily irrigated and its 85% lies in the Indo-Gangetic Plains, encompassing Northern India, Pakistan, Nepal and Bangladesh and covering about 32% of the total rice area and 42% of the total wheat area in these four countries and accounted for between 1/4th and 1/3rd of total rice and wheat production in these countries (Timsina and Connor, 2001; Hobbs and Morris, 1996).

Lack of research and development (R&D) in increasing the productivity of other crops and lack of minimum support price (MSP) for all crops are forcing farmers in Punjab to fall for the paddy-wheat cycle, despite the alarmingly falling water table in the state. The farmers get maximum yield per hectare and maximum price per hectare in the paddy-wheat crop pattern.

Since procurement of other crops under MSP operations is limited as there is no assured outlet for disposal unlike rice and wheat, market prices remain below MSP. In order to address this constraint, **‘Price Deficiency Payment Scheme (PDPS)’**, where difference between MSP and market price (with some ceiling on market price) could be paid to farmers in case market price fall below MSP, can be implemented on pilot basis in major producing regions.¹⁴

3.4.2. R & D IN DEVELOPING CHEAPER TECHNOLOGIES FOR CONTROLLING STUBBLE BURNING.

The burning of paddy stubble left in the fields after harvest has been a cause of concern for the past several years as it contributes to air pollution in the northern Gangetic plains and its already polluted cities like Delhi.

It is a common practice in October and November across North West India, but primarily in Punjab, Haryana, and Uttar Pradesh to quickly clear crop residue from their fields before planting the rabi wheat crop.

Several solutions have been proposed over the years to tackle the issue. The most recent one, which has been billed as a game-changer if found successful, is the ‘Pusa Decomposer’ capsule developed by IARI.

Pusa Decomposer is essentially a fungi-based liquid solution that can soften hard stubble to the extent that it can be easily mixed with soil in the field to act as compost. This would then rule out the need to burn the stubble and help in retaining the essential microbes and nutrients in soil that are otherwise damaged when the residue is burned. The window of time required for the solution to work, which is currently the main concern of farmers, is around 20 to 25 days, as per the IARI.

Farmers argue that this window is too long for them, as they ideally wait about a week or 10 days after harvesting the non-basmati variety of rice — which leaves hard stubble — to sow

¹⁴ Price Policy for Kharif Crops, The Marketing Season, 2019-20.

the wheat crop. IARI scientists, however, say that farmers do not necessarily have to plant the next crop in a rush — and that 20-25 days is enough waiting time.

A 25-litre solution is advisable for use in one hectare of land after being mixed with 500 litres of water. It can be sprayed over the field and left to do its work. IARI scientists explained that the decomposer will work even in fields where stubble has not been finely chopped with a Super Straw Management System (Super SMS) machine. The Super SMS is attached with a combine harvester machine to cut paddy stubble into small pieces and spread it uniformly in the field. This in itself is a stubble management process, as chopped stubble can be removed from the field or wheat can be sowed in the field even without removing the chopped stubble, however, not all farmers currently have this machine, which is offered on 50% subsidy to individual farmers.

About the decomposer, IARI scientists have also said that farmers do not necessarily have to wait for the entire 20-25-day window before getting to work on the field. They can start ploughing and preparing the land 10-15 days after spraying the decomposer.

Union Environment Minister Prakash Javadekar has said that the decomposer will be used on a trial basis this year in Punjab, Haryana, Uttar Pradesh and Delhi. Ministry officials said the technology would be used over 100 hectares of land in Punjab and Haryana, 800 hectares in Delhi and 10,000 hectares in Uttar Pradesh, which they said has been experimenting with a similar technology for the last three years.

IARI has been conducting experiments for a year-and-a-half on the decomposer. The technology was licensed for commercial use to four companies in 2019, and to two other companies in 2020.

Delhi has started preparing the solution with help from IARI and would begin spraying it over fields.

3.4.3. CONVERSION OF FARM STUBBLE INTO CNG

India's first plant to convert paddy straw into biogas that can be used as CNG in automobile will come up at Karnal in Haryana as agencies double effort to prevent burning of crop stubble. The plant will deploy special machines that will chop and bundle paddy straw for transportation to a storage. This storage will be used through the year to produce Compressed Biogas (CBG). This unit will have the capacity to convert stubble generated from 20,000 acres of farmland in a year into gas, which will then be sourced by Indraprastha Gas Limited (IGL) for its City Gas Distribution (CGD) network in Karnal.

This unit, which will come up by 2020, has been set up by Ajay Bioenergy Pvt. Ltd., under 'SATAT' (Sustainable Alternative Towards Affordable Transportation) scheme on CBG launched by the Ministry of Petroleum and Natural Gas.

IGL currently supplies CNG and piped cooking gas to households in Delhi, Noida, Greater Noida, Ghaziabad, Rewari, Gurugram, Karnal and Muzaffarnagar.

The plant will produce maximum of 10,000 kg of CBG every day. The input of plant is majorly paddy straw. The plant has the capacity of consuming around 40,000 tonnes of paddy straw in a year which will be taken from 20,00 acres of farmland in Karnal district.

Bio-manure produced from the plant as a by-product will be organic and can be used to grow organic food and vegetables.

It will not only solve the problem of stubble burning but also provide additional income to farmers in neighbouring Punjab and Haryana.

Similar strategies can be replicated in other States with CNG infrastructure with aim to achieve 100% shift of public transport to CNG in NCR and cities falling within Indo-Gangetic Belt.

3.4.4. DEVELOPMENT OF BIOGENIC EMISSION INVENTORY – AGRICULTURE & GREEN BELT

Biogenic emission sources are emissions that come from natural sources and need to be accounted for in photochemical grid models, as most types are widespread and ubiquitous contributors to background air chemistry.

Agriculture and land use change contribute significantly to the anthropogenic emissions of GHGs.

Biogenic Volatile Organic Compounds (BVOCs) participate in ozone and aerosol formation and comprise a substantial fraction of reactive VOC emission inventories. In the agriculturally intensive areas, emissions from crops may substantially influence regional air quality, but emission potentials have not been extensively studied with advanced instrumentation for many important crops. Because crop emissions may vary according to the species, and India does not have biogenic emission inventories for agricultural sector, a better knowledge of the emission rate at the species-specific level is critical for reducing uncertainties in emission inventories and evaluating emission model performance.

3.5. INDUSTRIAL STRATEGIES

3.5.1. ZONING OF INDUSTRIES

Zoning of Industries based on meteorological datasets, surrounding land uses (influence zones), transportation accessibility and air pollution scenarios.

Central Pollution Control Board have published 'The Zoning Atlas for Siting of Industries' for various States. The atlas helps to identify industries suitable to the identified sites.

Based on the methodology provided in Zoning Atlas, suitable sites for industries have been identified.

Table 26: Categorization of Industries

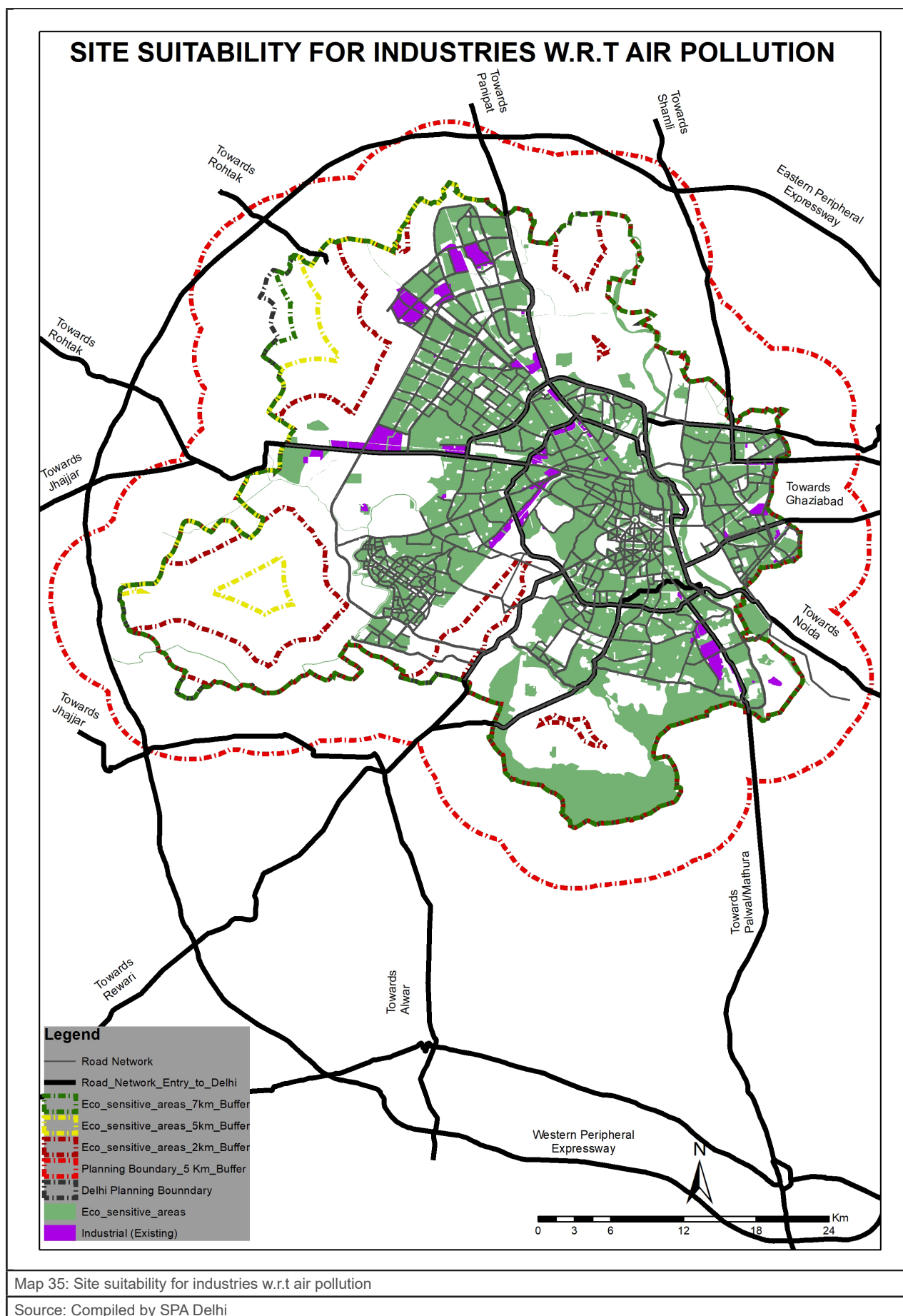
Industry Category	Impact Potential*
A1	> 7 Km
A2	5 to 7 Km
A3	2 to 5 Km
A4	< 2 Km
* impact potential considered without pollution control equipment in operation	

Source: Zoning Atlas of Industries, CPCB

Table 27: Land Use Sensitivity

Feature	Zone - 1	Zone - 2	Zone - 3	Zone - 4
National Parks /Sanctuaries/ Mangrove area/ Wetlands	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Tiger reserve/ elephant reserve/ turtle nesting ground, breeding grounds/ game reserve				
Core zone of biosphere reserve				
Notified protected tribal settlements/ critical/ high air polluted areas/ agricultural research stations/ airports				
Areas with threatened (rare, vulnerable, endangered) flora/ fauna, protected corals/ habitat for migratory birds				
Botanical gardens, Zoological gardens, gene banks				
Monuments of national significance/ world heritage sites				
Any other closed/protected area under the Wildlife (Protection) Act, 1972				
Core areas of scenic areas/tourism areas/ hill resorts/ religious places/ pilgrim centres with more than 5 lakh visitors/tourists/pilgrims per year				
Hilly stretches that act as barriers for dispersion of emissions, areas with frequent inversion conditions				
Any other feature as specified by the State or local government/ or locally applicable				

Source: Zoning Atlas of Industries, CPCB



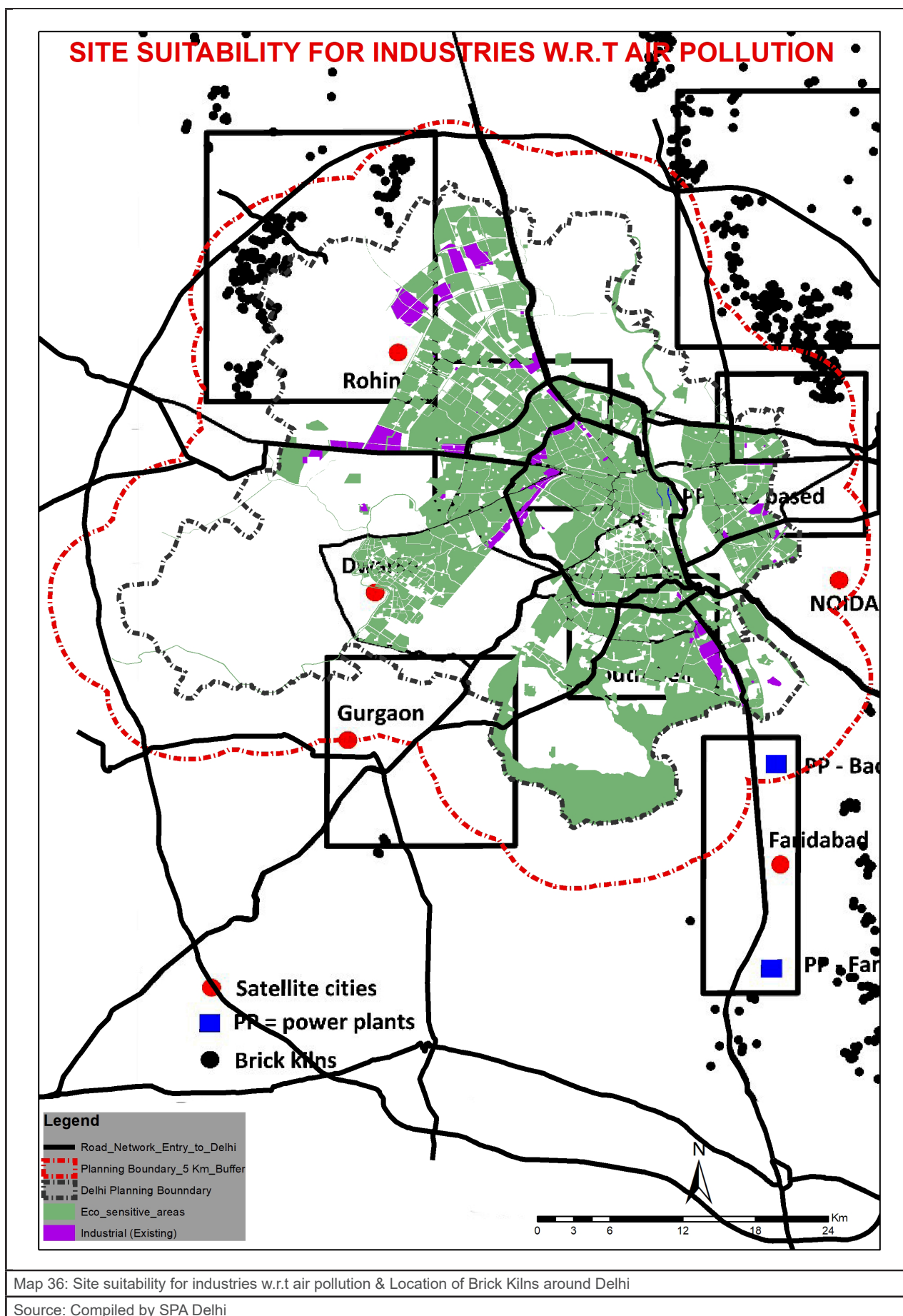


Table 28: Site Suitability to Air Polluting Industries (without considering water pollution)

Industry Category	Env. Sensitive Zone/ Areas to be avoided	Zone – 1 (< 2 Km)	Zone – 2 (2 to 5 Km)	Zone – 3 (5 to 7 Km)	Zone – 4 (> 7 Km)
A1(> 7Km)	Not Suitable	Not Suitable	Not Suitable	Not Suitable	Possible
A2 (5 to 7 Km)	Not Suitable	Not Suitable	Not Suitable	Possible	Suitable
A3 (2 to 5 Km)	Not Suitable	Not Suitable	Possible	Suitable	Suitable

Source: Zoning Atlas of Industries, CPCB

Industries with impact potential less than 2 km (A4 category) may be considered for siting anywhere in the district based on micro-level conditions, except in the areas that are to be avoided. However, in all the cases micro-level assessments are essential before taking final decision on site suitability. Also, 'consent to establish' is required in all cases.

Category of Industries:

- A1 category - industries with emission from combustion of fuels using coal 125 t/hr or equivalent fuel, or industries having process emission emitted through organised let out system (stack) or having fugitive emission or odour nuisance, or industries generating noise levels of 90 dBA and above
- A2 category - industries with combustion emission from usage of coal 125 t/hr or equivalent, or generating noise levels between 70-90dBA, or having diesel generator sets 50 KVA
- A3 category - industries having emission only from boilers of steam generation capacity less than 2t/hr but not using coal, or using DG sets up to 50 KVA

The resulting maps of Zoning Atlas include the sensitive zones where no industrial siting should be allowed and the possible alternate sites showing risks due to siting of industries with various types of pollution. The maps shown above are based only on-air pollution parameters.

> Relocation & phasing out of polluting units based on CPCB CEPI score & also based on Traffic Demand of Industrial Units

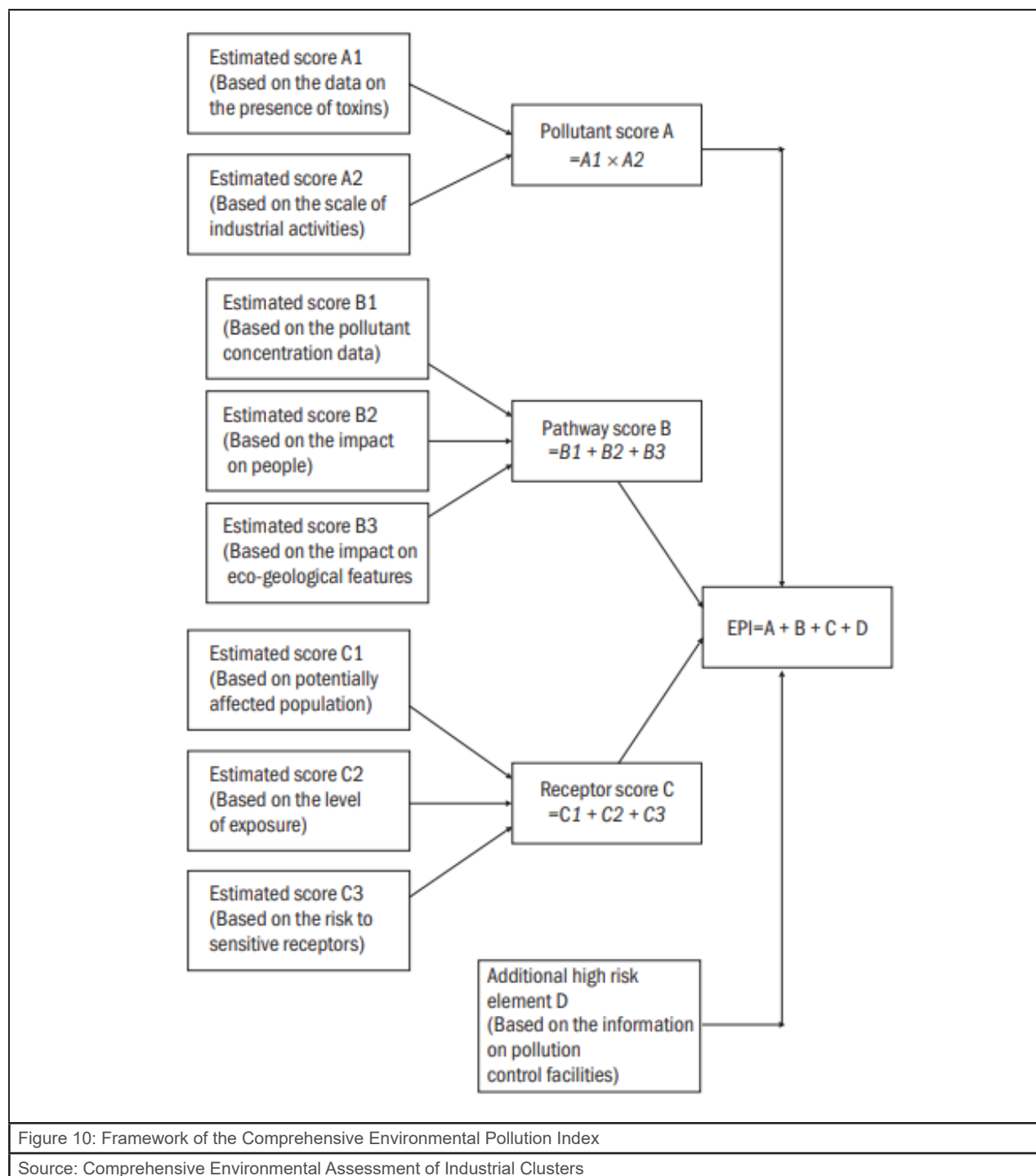
A Comprehensive Environmental Pollution Index (CEPI), which is a rational number to characterize the environmental quality at a given location following the algorithm of source, pathway and receptor have been developed by Central Pollution Control Board (CPCB). The index captures the various health dimensions of environment including air, water and land.

The present CEPI is intended to act as an early warning tool, which is handy to use. It can help in categorizing the industrial clusters/areas in terms of priority of planning needs for interventions. The process of evolution of method and mechanisms that yielded results are dynamic in nature. Improvements and alterations for enhancing more efficiency will be a continuous task.

The effective implementation of the remedial action plan will help in pollution abatement and to restore the environmental quality of respective industrial clusters. The polluted industrial clusters/areas shall be further explored in order to define the spatial boundaries as well as the extent of eco-geological damages. The outcome shall be subjected to structured consultation

with the stakeholders for determining comparative effectiveness of alternative plans and policies. The preparation of effective remedial action plan will yield desired results in terms of sustainable use of the carrying capacity of the respective industrial cluster/ area.

The framework of the CEPI is based on three factors—pollutant, pathway, and receptor.



Revised CEPI will comprise of following components:

Table 29: Revised CEPI

Component	Weightage
Scale of Industrial Activity	20
Scale of exceedance of Environmental Quality (Level of exposure)	50
Health related statistics	10
Compliance status of industries	20
Total	100

Source: http://www.indiaenvironmentportal.org.in/files/file/Directions_on_Revised_CEPI.pdf

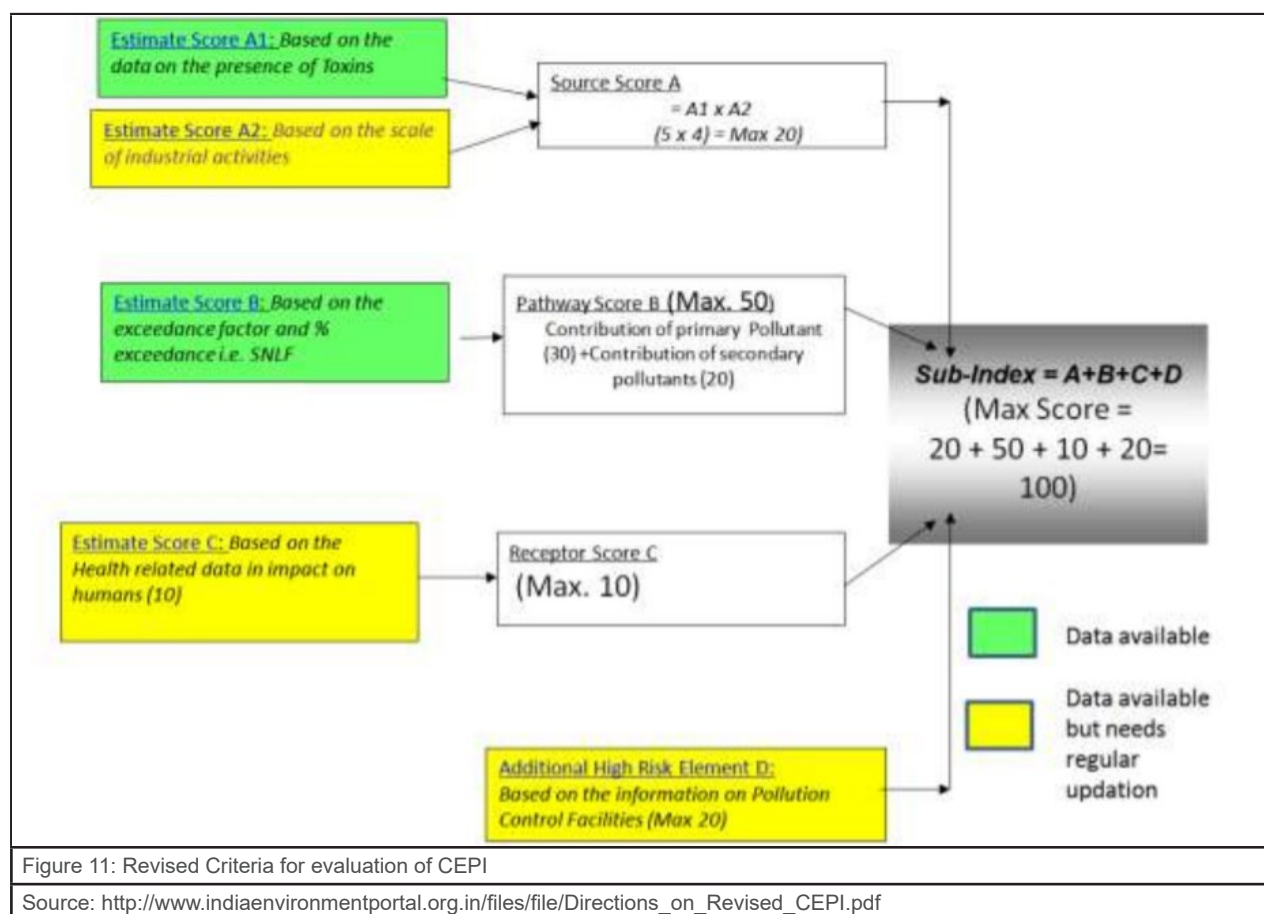


Figure 11: Revised Criteria for evaluation of CEPI

Source: http://www.indiaenvironmentportal.org.in/files/file/Directions_on_Revised_CEPI.pdf

Here we shall focus on air pollution. Air EPI will be calculated on a scale of 0-100.

3.5.2. REVISED CEPI EVALUATION METHODOLOGY

SOURCE

- Factor #A1 - Presence of Toxin
 - Group A – Pollutants / chemicals that are not assessed as acute or systemic = 1
 - Group B – Organics / Pollutants / chemicals that are probable carcinogens (USEPA Class 2 and 3) or substances with some systemic toxicity. e.g. VOC's, PAHs, PCBs, air pollutants

such as PM_{10} and $PM_{2.5} = 2$

- Group C - Known carcinogens or chemicals with significant systemic or organ system toxicity. e.g. vinyl chloride, benzene, lead, radionuclide, hexa-chromium, cadmium, organophosphate pesticides. = 3

Max value of Source = 3

Selection of criteria pollutants:

Option 1: 3 pollutants relevant with the Area depending on the nature of industrial activity (preferable option /method)

Option 2: up to 3 most critical pollutants depending on the concentration and exceedance.

Contribution of remaining two secondary pollutants will be based on the nature of the toxins as mentioned below:

Group of toxicity of each of the Secondary Pollutants	Contribution Value for each of the pollutant
Group A	0.25
Group B	0.50
Group C	1.00

Max. Contribution of secondary pollutants=2.00

Max. score of A1 = 3+2 = 5

Factor #A2 – Scale of industrial activities

Large = 4 (if there are

- > 10 R17 per 10 sq.km area or fraction OR
- 2 R17 + 10 R54 per 10 sq.km area or fraction OR
- 100 R54 per 10 sq.km area of fraction

Moderate = 2.5 (if there are

- 2 to 10 R17 per 10 sq.km area or fraction OR
- 10 to 100 R54 per 10 sq.km area or fraction

Limited = 1 (else there is any industry within 10 sq.km area or fraction)

Score A = A1 x A2 (max score = 5 x 4) = 20

R17 corresponds to 17 highly polluting industries as per CPCB and R54 corresponds to red category industries as per CPCB. The list of industries is provided in Annexure.

PATHWAY

Factor B- Level of exposure

A surrogate number which will represent Level of Exposure (SNLF) is calculated using % violation of ambient pollutant concentration, which is calculated as

$SNLF = (\text{No. of samples exceeded} / \text{total no. of samples}) \times (\text{Exceedance factor})$

The ambient environmental (ambient air/surface water/ground water) quality has been

categorized into four broad categories based on an exceedance factor (the ratio of annual (or 24-hour) mean concentration of a pollutant with that of a respective standard). The Exceedance Factor (EF) is calculated as follows:

$$\text{Exceedance Factor} = \frac{\text{Observed mean concentration of criteria pollutant}}{\text{Prescribed standard for the respective pollutant and area class}}$$

The four environmental quality categories are:

- Critical pollution (C): when EF is more than 1.5;
- High pollution (H): when the EF is between 1.0 and 1.5;
- Moderate pollution (M): when the EF between 0.5 and 1.0; and
- Low pollution (L): when the EF is less than 0.5.

Range of SNLF	Category	Value
0 (For EF< 0.75)	Low	0
0 (For 0.75<EF>0.8)	Low	1.5
0 (For 0.80<EF>0.85)	Low	3
0 (For 0.85<EF>0.9)	Low	4.5
0 (For 0.90<EF>0.95)	Low	6
0 (For 0.95<EF<1	Low	7.5
< 0.05	Moderate	8.25
0.05 to <0.1	Moderate	9
0.1 to <0.15	Moderate	9.75
0.15 to <0.2	Moderate	10.50
0.2 to <0.25	Moderate	11.25
0.25 to <0.3	Moderate	12
0.3 to <0.35	Moderate	12.75
0.35 to <0.4	Moderate	13.5
0.4 to <0.45	Moderate	14.25
0.45 to <0.5	Moderate	15
0.5 to <0.55	High	15.75
0.55 to <0.6	High	16.50
0.6 to <0.65	High	17.25
0.65 to <0.7	High	18.0
0.7 to <0.75	High	18.75
0.75 to <0.8	High	19.5
0.8 to <0.85	High	20.25
0.85 to <0.9	High	21.0
0.9 to <0.95	High	21.75
0.95 to <1	High	22.5
1.0 and above	Critical	30

Max. Contribution of primary pollutant = 30

Contribution of remaining two secondary pollutants will be based on their category of exceedance

as mentioned below:

Level of SNLF of each of the Secondary Pollutants	Level of SNLF	Contribution Value for each of the secondary pollutants
0 (For $EF < 0.75$)	Low	0
0 (For $0.75 < EF < 0.8$)	Low	0.5
0 (For $0.80 < EF < 0.85$)	Low	1
0 (For $0.85 < EF < 0.9$)	Low	1.5
0 (For $0.90 < EF < 0.95$)	Low	2
0 (For $0.95 < EF < 1$)	Low	2.5
<0.05	Moderate	2.75
0.05 to <0.1	Moderate	3
0.1 to <0.15	Moderate	3.25
0.15 to <0.2	Moderate	3.50
0.2 to <0.25	Moderate	3.75
0.25 to <0.30	Moderate	4
0.30 to <0.35	Moderate	4.25
0.35 to <0.4	Moderate	4.5
0.4 to <0.45	Moderate	4.75
0.45 to <0.5	Moderate	5
0.5 to <0.55	High	5.25
0.55 to <0.6	High	5.50
0.6 to <0.65	High	5.75
0.65 to <0.70	High	6.0
0.7 to <0.75	High	6.25
0.75 to <0.80	High	6.50
0.80 to <0.85	High	6.75
0.85 to <0.90	High	7
0.9 to <0.95	High	7.25
0.95 to <1	High	7.5
1 and above	Critical	10

Max. Contribution of secondary pollutants = 20

Maximum value of B = 30 + 20 = 50

RECEPTOR

Component C (Impact on Human Health)	
Main - 10	
% increase in cases	Marks
< 5%	0
5 – 10%	5
> 10%	10

- % increase is evaluated based on the total no. of cases recorded during two consecutive years.
- For Air Environment, total no. of cases related to Asthma, Bronchitis, Cancer, Acute respiratory infections etc. are to be considered.

- For the above evaluation, the previous 5 years records of 3-5 major hospitals of the area shall be considered

ADDITIONAL HIGH-RISK ELEMENT

Factor D - Additional High-Risk Element (Inadequacy of pollution control measures for large scale, medium and small-scale industries and due to unorganized sector). It is cumulative of ETPs, CETPs, Air Pollution Control Devices (APCDs) and unorganized waste disposal. Max. Score = 20

- If all the industries in the area have adequately designed/ operated and maintained pollution control facilities and common facilities such as CETP/ FETP/ CHWDF are having adequate capacity and are having state of art technology = 0
- If all the large industries in the area have adequately designed/ operated and maintained pollution control facilities but small and medium industries are defaulting. Common facilities such as CETP/FETP/CHWDF are having adequate in capacity or operation/ maintenance = 5
- If all the industries in the area have adequately designed/ operated and maintained pollution control facilities but the common facilities such as CETP/FETP/CHWDF are having inadequate in capacity or operation/ maintenance = 10
- If all the large industries in the area have adequately designed/ operated and maintained pollution control facilities but small and medium industries are defaulting. Common facilities such as CETP/FETP/CHWDF are having inadequate in capacity or operation/ maintenance = 15
- Inadequate Facilities of individual as well as common facilities, full penalty = 20

Sl. No.	Large Scale Industries	Small/Medium Scale Industries	Common Facilities for Pollution Control	Score
1	Adequate	Adequate	Adequate	0
2	Adequate	Inadequate	Adequate	5
3	Adequate	Adequate	Inadequate	10
4	Adequate	Inadequate	Inadequate	15
5	Inadequate	Inadequate	Inadequate	20

Inadequate Facilities:

- 10% units deficient in terms of design/ operation and maintenance of pollution control in case of small and medium scale industries OR
- 2% units' deficiency in terms of design/ operation and maintenance of pollution control in case of Large-scale industries or common facilities

The status report (last two years) shall be used for the purpose of deciding the score for adequacy.

Evaluation of the Ambient Air Index:

After calculating A, B, C and D; calculate the sub index score (Air) as:

$$\text{Sub-Index Score} = (A + B + C + D)$$

Sub index scores are to be calculated for each of the individual environmental components that is, Air Environment, Surface Water Environment, and Soil & Ground Water Environment separately.

Table 30: Status of Pollution based on CEPI - Air CEPI

Air CEPI (Sub-Index) Score	Level of Pollution
< 50	Not Polluted
50-60	Severely Polluted
> 60	Critically Polluted

Source: http://www.indiaenvironmentportal.org.in/files/file/Directions_on_Revised_CEPI.pdf

The problems and solutions in CEPI application are:

Table 31: Problems of application of CEPI

Factor	Problem	Solution
A1	Determining critical pollutants	An exhaustive classification of industrial pollutants into the groups A, B, and C
A2	Lack of classified data about industries present	SPCB/ industrial association/industry development corporations should classify industries based on R17 and R54
B1	- Lack of data especially for groundwater - Various data sets for surface water - Inconsistency in measurements within an area	- Maintenance of records with all local or state authorities - CETP effluents discharged should be preferably monitored - Proper and regular data collection drives at all points considered
B2, B3	Lack of evidence of adverse impact	Local health bodies/NGOs/legal authorities (PILs), and so on, should be contacted
C1	No data of population within 2 km of the source; also the definition of source is not clear	Consider total population to get a conservative value
C2	24 hours exceedence factor is not applicable for water and land pollution	Normal exceedence factor based on average annual data can be used
C3	No information about sensitive areas	ASI/IMA/municipal bodies to be involved

Source: http://www.indiaenvironmentportal.org.in/files/file/Directions_on_Revised_CEPI.pdf

The CEPI with respect to Air for Industrial Clusters of Delhi have been worked out in similar pattern to understand their status. Some assumptions and changes in calculating the parameters have been undertaken due to lack of extensive data.

IT industries should be introduced in Delhi. All the industries which carry heavy traffic or are dependent on it should be moved to outskirts in order to control the emissions from the transport sector associated with it.

Table 32: CEPI with respect to Air for Industrial Clusters of Delhi

INDUSTRIAL AREAS							POLLUTING UNITS	CEPI FACTOR A			EF (PM _{2.5})	SNLF (PM _{2.5})	EF (PM ₁₀)	SNLF (PM ₁₀)	CEPI FACTOR B				CEPI FACTOR C	CEPI FACTOR D	SCORE	STATUS
S NO.	NAME OF INDUSTRIAL AREA	RED	ORANGE	GREEN	WHITE	TOTAL		A1	A2	TOTAL A					TOTAL C	TOTAL D	TOTAL (A+B+C+D)					
																		B1		B2	TOTAL B	
														PM _{2.5}	PM ₁₀	SO2						
1	Badli Industrial Area	27	182	255	138	602	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
2	Bawana Industrial Area	88	878	3443	894	5303	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
3	Friends Colony Industrial Area	17	352	535	72	976	0	0.5	0	0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
4	GT Karnal Road Industrial Area	18	193	225	207	643	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
5	Jhandewalan FFC Industrial Area	0	9	9	411	429		0.5		0	0.68	0.00	0.79	0.00	0	0	0	0	5	15	20	Not Polluted
6	Jhimil Industrial Area	22	328	473	219	1042	0	0.5	0	0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
7	Keshopur Industrial Area	1	11	3	24	39		0.5		0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
8	Kirti Nagar Industrial Area	22	198	223	234	677	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
9	Lawrence Road Industrial Area	18	121	688	48	875	0	0.5	5	2.5	0.68	0.23	0.79	0.27	0	0	0	0	5	15	23	Not Polluted
10	Mangolpuri Industrial Area	18	93	685	334	1130	0	0.5	5	2.5	0.68	0.05	0.78	0.06	0	0	0	0	5	15	23	Not Polluted
11	Mayapuri Industrial Area	90	451	656	1004	2201	0	0.5	0	0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
12	Mohan Co-operative Industrial Area	7	88	27	93	215	0	0.5	5	2.5	0.57	0.02	0.78	0.03	0	0	0	0	5	15	23	Not Polluted
13	Moti Nagar DLF Industrial Area	5	46	75	50	176	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
14	Najafgarh Road Industrial Area	21	274	281	182	758	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted

INDUSTRIAL AREAS							POLLUTING UNITS	CEPI FACTOR A			EF (PM _{2.5})	SNLF (PM _{2.5})	EF (PM ₁₀)	SNLF (PM ₁₀)	CEPI FACTOR B				CEPI FACTOR C	CEPI FACTOR D	SCORE	STATUS
S NO.	NAME OF INDUSTRIAL AREA	RED	ORANGE	GREEN	WHITE	TOTAL		A1	A2	TOTAL A					B1		B2	TOTAL B				
															PM _{2.5}	PM ₁₀			SO2			
15	Nangloi Industrial Area	12	103	250	117	482	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
16	Naraina Phase-I Industrial Area	33	196	205	261	695	0	0.5	0	0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
17	Naraina Phase-II Industrial Area	14	164	47	93	318	0	0.5	0	0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
18	Narela Industrial Area	127	1031	2199	172	3529	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
19	Okhla FFC Industrial Area	0	13	5	172	190		0.5		0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
20	Okhla Industrial Area	72	770	346	1341	2529	0	0.5	5	2.5	0.57	0.01	0.78	0.02	0	0	0	0	5	15	23	Not Polluted
21	Okhla Estate Industrial Area	11	29	41	105	186		0.5		0	0.57	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
22	Patparganj Industrial Area	18	323	267	206	814	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
23	Rajasthan Udhog Nagar Industrial Area	3	46	56	15	120	0	0.5	0	0	0.68	0.00	0.79	0.00	0	0	0	0	5	15	20	Not Polluted
24	SMA Industrial Area	11	63	85	39	198	0	0.5	0	0	0.68	0.00	0.79	0.00	0	0	0	0	5	15	20	Not Polluted
25	SSI Industrial Area	7	54	63	23	147	0	0.5	0	0	0.68	0.00	0.79	0.00	0	0	0	0	5	15	20	Not Polluted
26	Shahzada Bagh Industrial Area	12	80	827	185	1104		0.5		0	0.68	0.00	0.79	0.00	0	0	0	0	5	15	20	Not Polluted
27	Tilak Nagar Industrial Area	0	42	17	13	72	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
28	Udyog Nagar Industrial Area	15	139	427	120	701	0	0.5	0	0	0.68	0.00	0.78	0.00	0	0	0	0	5	15	20	Not Polluted
29	Wazirpur Industrial Area	46	179	827	780	1832	0	0.5	5	2.5	0.68	0.12	0.79	0.14	0	0	0	0	5	15	23	Not Polluted
Total		735	6456	13240	7552	27983	0															

Source: Prepared by SPA Delhi

Where,

A1 = Presence of Toxin; A2 = Scale of industrial activities; B1 = Contribution of primary pollutants; B2 = Contribution of secondary pollutants; C = Impact on Human Health; D = Additional High-Risk Element; E.F = Exceedance Factor; SNLF = Surrogate Number of Level of Exposure

Considerations in estimation of CEPI with respect to Air for Industrial Clusters of Delhi:

Factor A1 = Data have been provided by DPCC indicating type and number of industrial units in a cluster using diesel/petrol/wood/charcoal/etc. These fuels are known to emit $PM_{2.5}$ and PM_{10} considerably and thus is a useful indicator of presence of toxins Group B.

Factor A2 = The scale of industries have been estimated from the data provided by DPCC indicating industries grouped into R17 category corresponding to 17 highly polluting industries as per CPCB and R54 category corresponds to red category industries as per CPCB and the areal extent have been estimated from google imagery.

Total Factor A = A1 x A2

Factor B1 = Three pollutants have been considered based on nature of industrial activity with $PM_{2.5}$ and PM_{10} being primary pollutant and SO_2 as secondary pollutant.

The values have been estimated based on calculation of Exceedance Factor first. The total hours for $PM_{2.5}$ & PM_{10} exceeding the specified NAAQ limit i.e., $60 \mu g/m^3$ and $100 \mu g/m^3$ in a year have been taken into consideration for calculation of Exceedance Factor. The following map of the same have been shown below.

Surrogate Number of Level of Exposure (SNLF) = ((Total number of polluting units in the cluster)/(Total number of Red & Orange industrial units in the cluster)) x Exceedance Factor (i.e., $PM_{2.5}$ & PM_{10})

Total B1 = Contribution Value of $PM_{2.5}$ + Contribution Value of PM_{10}

Factor B2 = Here SO_2 is considered secondary pollutants. Thus, the corresponding value of Contribution considered for Secondary Pollutant, SO_2 is given for the estimated Level of SNLF of SO_2 .

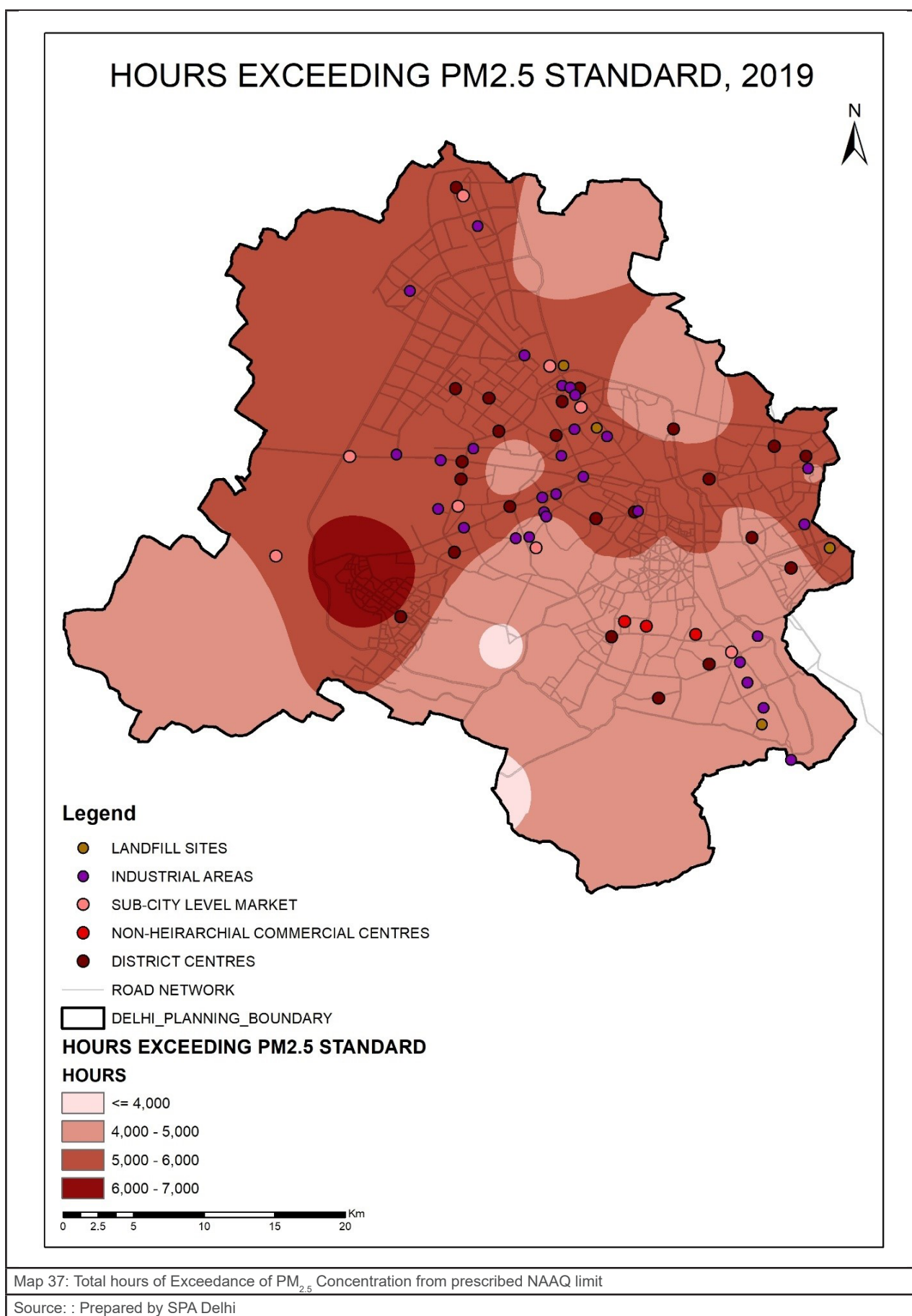
Therefore, Factor B2 = Contribution value of SO_2 is negligible in our case study and thus is considered as 0.

Total Factor B = B1 + B2

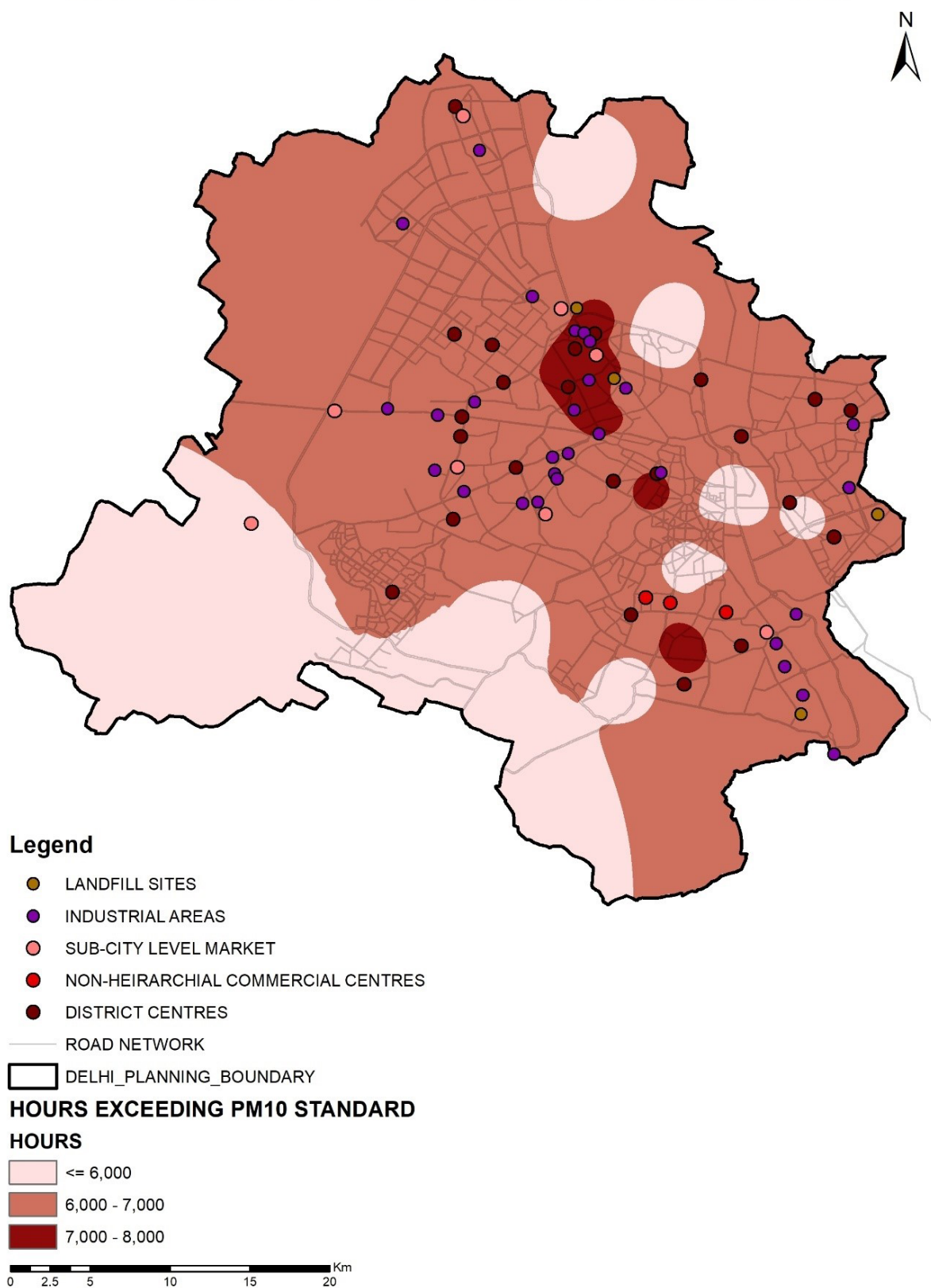
Factor C = The impact on human health from the industries is assumed to be 5-10% and thus a marking of 5 points have been given to all industrial cluster. The assumption is based on partially available data regarding percentage increase is evaluated based on the total no. of cases recorded during two consecutive years.

Factor D = All the large industries in the area have adequately designed/operated and maintained pollution control facilities but small and medium industries are defaulting. Common facilities such as CETP/FETP/CHWDF are having inadequate in capacity or operation/maintenance. Thus, a value of 15 have been provided to corresponding industrial clusters.

Score = The score represents the total score = Total Factor A + Total Factor B + Factor C + Factor D



HOURS EXCEEDING PM10 STANDARD, 2019



Map 38: Total hours of Exceedance of PM_{10} Concentration from prescribed NAAQ limit

Source: Prepared by SPA Delhi

The Exceedance Factor is calculated as:

Table 33: Exceedance Factor Calculation

Hours Exceeding PM _{2.5} Standard	Total Hours in a Year	Exceedance Factor (E.F.)	Corresponding Value of level of Exposure PM _{2.5} & PM ₁₀	Industries
Value of level of Exposure PM _{2.5} & PM ₁₀	Industries	C = A/B	Values are provided in CEPI document	Identified from map
< 4000	8760	0.46		
4000 – 5000	8760	0.57		
5000 – 6000	8760	0.68		
6000 - 7000	8760	0.78		
7000 - 8000	8760	0.79		

Source: SPA Delhi

We observe that the pollution from industrial cluster is very negligible from the point of CEPI Air Score. This also implies that the standards of industries in Delhi have been improved with respect to design, operation and maintaining pollution. This is also attributed to recent year changes in policies and penalties imposed on industries.

This also helps us to establish the fact that the siting of industries at present have minimal impact on air pollution.

So, the other factors that can be the cause of pollutant concentration exceedance may be attributed to transportation factored with low wind speed especially the goods vehicle entry into these clusters causing congestion and traffic thus increasing the intensity of concentration.

As per study Emissions Inventory for Delhi-NCR conducted by SAFAR in 2018 finds that industrial emissions contributed to only 18.6% of PM 2.5 emissions in Delhi. However, the inventory for NCR shows the contribution from industry is about 22.3%. Industrial emissions increased by 48% in 2018 compared to 2010, mainly due to increase in industrial activities in fringe areas of Delhi and not inside Delhi. Most industries were shifted out of Delhi in the 90s.

The siting of new industries can be provided based on the Site Suitability Analysis done for Delhi which is provided in the map earlier.

3.5.3. STUDY OF TRAFFIC DEMAND OF INDUSTRIAL UNITS TO CAPTURE INTENSITY OF TRAFFIC MOVEMENT FOR GOOD AND SUPPLY.

The findings of CEPI Air Sub-Index Score Analysis have shown that traffic intensity around Industrial clusters due to goods movement factored with lower wind speed is a major issue of increase in pollutant concentration. Thus, a detail study on the traffic demand of these industrial clusters need to be carried out.

SAFAR had conducted an emissions inventory for Delhi-NCR in 2018. The study says lower vehicle speed due to an increase in traffic congestion could be a reason for reduction in windblown dust which gets exacerbated when vehicles speed on roads.

The study finds that local paratransit, particularly cabs, have significantly high vehicle kilometre

travelled (VKT) of about 1.45 lakh km per year per car in Delhi. Everyday vehicle load at the eight entry points of Delhi, mainly from other states, is about 11 lakhs, while the average speed of vehicles in Delhi on major roads is only 20 to 30 kmph leading to poor vehicle mileage and resultant emissions from idling vehicles.

3.5.4. REGULATION OF HOUSEHOLD INDUSTRIES PRIMARILY CONTRIBUTING TO PARTICULATE MATTER CONCENTRATION.

Some of the activities can contribute to particulate matter concentration if not worked in controlled environment. All such activities are unaccounted source of pollution and should be monitored carefully.

3.5.5. LOCKDOWN OF INDUSTRIES SUCH AS STONE CRUSHING, HOT MIX PLANTS, BRICK KILNS GENERATING DUST POLLUTION IN DELHI AND NCR DISTRICTS FROM OCTOBER TO DECEMBER.

Air pollution in Delhi and the whole of the Indo Gangetic Plains is a complex phenomenon that is dependent on a variety of factors. The first and foremost is the input of pollutants, followed by weather and local conditions.

Delhi experiences episodes of high air pollution starting from October to December. These months are considered to be critical from the point of meteorology too. October usually marks the withdrawal of monsoons in Northwest India. During monsoons, the prevalent direction of wind is easterly. These winds, which travel from over the Bay of Bengal, carry moisture and bring rains to this part of the country. Once monsoon withdraws, the predominant direction of winds changes to north westerly. During summers, too, the direction of wind is north westerly and storms carrying dust from Rajasthan and sometimes Pakistan and Afghanistan. According to a peer reviewed study conducted by scientists at the National Physical Laboratory, 72 per cent of Delhi's wind in winters comes from the northwest, while the remaining 28 per cent comes from the Indo-Gangetic plains.

A 2015 source-apportionment study on Delhi's air pollution conducted by IIT-Kanpur also states that 17-26% of all particulate matter in Delhi in winters is because of biomass burning. Over the years, the System of Air Quality and Weather Forecasting and Research (SAFAR) has developed a system to calculate the contribution of stubble burning to Delhi's pollution. Last year, during peak stubble burning incidents, its contribution rose to 40%. Over the past few days, it has been 2%-4%, indicating that a variety of factors, not just stubble burning, are responsible for the dip in quality. As November draws closer, the percentage contribution is set to go up.

The stubble burning season is around 45 days long. Air in Delhi, however, remains polluted till February.

As per the IIT Kanpur Source Apportionment Study of Delhi, Dust and vehicular pollution are

the two biggest causes of dipping air quality in Delhi in winters. Dry cold weather means dust is prevalent in the entire region, which does not see many rainy days between October and June. Dust pollution contributes to 56% of PM₁₀ and the PM_{2.5} load at 59 t/d, the top contributors being road 38 % of PM_{2.5} concentration.

As per SAFAR Emission Inventory of Mega City Delhi, 2018, approx. 13 tons of biomass (Tudi) and rubber is being used as a fuel to generate 1 lakh bricks in semi-ZIGZAG technology as compared to 10 tons of coal for producing the same number of bricks. Jhajjar region of Haryana is one of single big source of pollutants due to 300 number of brick industries in one cluster. Outskirts of NCT are preoccupied with approximately 360 brick kilns majorly scattered in Jhajjar, Faridabad and Ghaziabad regions.

Outskirts of NCT are preoccupied with numerous brick kilns, which primarily use 70% coal, 25% of tudi (mustard husk) and rest 5% uses rubber as alternative fuel along with coal as primary fuel. The total amount of coal, tudi and rubber consumed in this sector is 125650 tons, 71800 tons and 8975 tons in a season respectively.

Emissions from brick kiln has a seasonal pattern due to peak business month starting from December to June.

Thus, activities not just in Delhi but also the surrounding areas, NCR including Punjab should ideally put a lockdown on activities such as stone crushing, hot mix plants, brick kilns generating dust pollution in NCR districts from **October to December**.

3.6. WASTE STRATEGIES

3.6.1. STRICT BAN & REGULATIONS ON AGRICULTURAL REFUSE BURNING, BIOMASS BURNING, SOLID WASTE BURNING AND LANDFILL FIRES.

Heavy penalties to be set on agricultural refuse burning, biomass burning, solid waste burning and landfill fires. With the paucity of land for solid waste dumping efforts must be made to build compost pits within residential societies and commercial areas.

Such interventions can be legally imposed through Building Byelaws and providing fiscal incentives to set up compost pits. Skill development should be provided to public regarding the same.

3.6.2. IMPROVING EFFICIENCY OF SOLID WASTE SEGREGATION, COLLECTION & TRANSPORTATION.

Solid waste management should be made efficient through **Decentralised or semi-decentralised systems**.

Under section 8 of the byelaws, preference will be given to decentralised waste processing like bio methanation, composting, and any other method for bio stabilisation of biodegradable

waste so that transportation cost and environmental impacts are minimised. For waste-to-energy plants, absolute segregation of waste has been made mandatory. The MCDs need to ensure that horticultural, park and garden waste is processed in parks and gardens as far as possible. All the inert and residual waste must be disposed in a manner prescribed under the Solid Waste Management Rules, 2016.

Neighbourhood level composting pits can be developed along Dhalaos and in newer planning units. This will minimize the load from newer planned residential areas.

Some of the models have been described in Composting Chapter published by Ministry of Housing and Urban Affairs.¹⁵

A compendium of good practices in solid waste management has been documented by National Institute of Urban Affairs published on January 2015. Such best practices can be taken up as a pilot project in the city and then scaled up to city level.¹⁶

3.6.3. SETTING UP OF WASTE TO ENERGY PLANTS

Delhi has three working landfills at present with 28 million tons of legacy waste. With growing population and demands, the numbers are going to increased. Thus, establishing an efficient waste to energy plant will also reducing the amount of material that would have been accumulated on landfill and also generate electricity to power the residential areas in Delhi.

Delhi has shown great success in Waste to Energy Plants setup and operations. This should further be scaled up to incorporate the waste that will be generated from newly planned areas.

3.6.4. DEVELOPMENT OF CIRCULAR ECONOMY PACKAGE.

Key sectors include plastics, food waste, critical raw materials, construction and demolition as well as biomass and biobased products. The aim is to create an environment that enables a circular economy and to improve the balance between regulation and other measures.

Waste to Wealth:

Organic Agriculture: With greater sensitivity to issues related to sustainable development, agro-ecological farming methods are gaining in popularity. These rely on ecological processes to sustain the health of soil as well as treating farming as an integrated, holistic, interconnected process of food production by optimizing the farm in design and closely knit nutrient and resource recycling. Instead of synthetic fertilizers and pesticides, compost, green manure and bone meal are key ingredient in organic farming and on non-chemical modes of pest and disease control. Consciousness towards healthy lifestyle has seen organic farm production and trade emerging as an important sector in India as in other parts of the developing world.

Biofuels: Another important direction in bid for sustainability is use of biofuels from biomass or bio-waste. Biogas production is a clean low carbon technology for conversion of organic waste into clean renewable biogas and a source of organic fertilizer. Biogas obtained by anaerobic digestion of cattle dung and other loose and leafy organic matter/ wastes can be used as energy

¹⁵ [http://mohua.gov.in/upload/uploadfiles/files/chap14\(1\).pdf](http://mohua.gov.in/upload/uploadfiles/files/chap14(1).pdf)

¹⁶ https://pearl.niua.org/sites/default/files/books/GP-IN3_SWM.pdf

source for cooking, lighting, refrigeration, electricity generation and transport applications.

Biomass has always been an important source of energy in our country. According to the Ministry of New and Renewable Energy (MNRE), about 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs. MNRE is promoting development of efficient technologies for its use in various sectors of economy. Biomass materials used for power generation include bagasse, rice husk, straw, cotton stalk, coconut shell, soya husk, de oiled cakes, coffee waste, jute waste, groundnut shells, saw dust etc.

Applications range from use of biofuel in rural/urban kitchens to grid power generation to meet varied energy demands of a sugar mill, an entire village and even a smart city. This is an industry that attracts an investment of Rs. 600 crore every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in rural areas. Maharashtra leads by example generating about 1220 MW of Biomass power.

Waste Management and Sustainable Wealth Creation:

Consider a typical community with 1 lakh population.

- Average waste produced is 50 tonnes per day with 70% wet waste, i.e. 35 tonnes
- If all of wet waste is composted directly or after producing methane gas, it reduces to 1/5th of its weight. Hence it will produce 7 tonnes of compost per day and 210 tonnes per month.
- If the compost is sold at Rs. 3/kg, it will yield Rs. 6,30,000 per month.
- Additionally, about 3 tonnes of dry waste can be sold or converted into useful products every day.
- The Urban Local Body can earn Rs. 7,50,000 per month or Rs. 90,00,000 annually. On the other hand, for untreated waste, mixed solid waste management requires the municipality or corporation to spend about Rs. 700 per tonne, which is a minimum expenditure of Rs. 12,60,000 annually without any return on investment except pollution and ill health.

Some of the best practices on Waste to Wealth have also been provided in Annexure.

3.7. RESIDENTIAL STRATEGIES

3.7.1. 100% USAGE OF LPG/PNG FOR DOMESTIC AND COMMERCIAL COOKING

Maintaining continuous engagement with the concerned authorities to maximise LPG/PNG coverage for domestic and commercial cooking with a target of 100 per cent coverage in Delhi and NCR.

Millions of households across the country burning solid fuels like firewood in their homes for cooking, heating and other energy services. The resulting pollution not only has an enormous health impact on the households themselves, but it accounts for a quarter to a third of ambient air pollution across the country.¹⁷

¹⁷ The Contribution of Household Fuels to Ambient Air Pollution in India, Policy Brief, Collaborative Clean Air Policy Centre, New Delhi, May 2019

PM_{2.5} is emitted directly from household fuel combustion and contributes both “primary PM_{2.5}” including black carbon (BC) and organic carbon (OC) and “secondary PM_{2.5}” formed as emissions of Sulfur dioxide (SO₂), nitrogen oxides, volatile organic compounds, and semi-volatile organic compounds react in the air downwind from the stove (Fleming et al., 2018; Reece et al., 2017).

As per SAFAR Emission Inventory of Mega City Delhi, 2018, preparation and storing of Cow Dung cake across the outskirts of Delhi and Haryana/UP/Punjab is very common practice. A single household of size 5-6 members used approx. 30Kg of cow dung per month as a source of fuel for cooking and heating of water in winter. This accounts for huge particulate matter emission in neighbouring areas.

Unlike 2010, LPG is being widely used for cooking in slums accounting for 95% followed by wood (3%) and coal (2%). In winters, relative contribution of wood as fuel increases (for heating of water). The used of fuel in slum areas must be monitored.

It is thus mandatory for the neighbouring states to scale up the LPG/PNG coverage in both urban and rural areas to fully negate the PM_{2.5} emissions from solid fuels. The concern of long-range transport of particulate matter should be kept in mind.

3.8. COMMERCIAL STRATEGIES

3.8.1. FISCAL INCENTIVES TO DHABAS, HOTELS AND RESTAURANTS FOR CONVERSION INTO PNG FROM CONVENTIONAL FUEL.

A study of 27 vending areas across the Delhi by SAFAR during 2018 found out that 83% of street vendors are using LPG, followed by coal (15%) and wood (2%). It is noticed that coal is being used by many street vendors near various tourists' places like India Gate, Jama Masjid, Lal Qila, etc. Kerosene is not been in use as a source of fuel anywhere.

Currently, the prices of non-subsidised LPG refills vary in different parts of the country and are revised every month. With effect from September 1, the price of non-subsidised LPG has remained steady at ₹ 594 per cylinder (14.2 kilograms) each in Delhi and Mumbai, according to data from Indian Oil Corporation, which supplies LPG under brand Indane.

Figure 12: Current Price of Indane Non-Subsidised LPG

City	Price In Rupees Per 14.2 KG Cylinder	
	With Effect From September 1	Existing
Delhi	594.00	594.00
Kolkata	620.50	621.00
Mumbai	594.00	594.00
Chennai	610.00	610.50

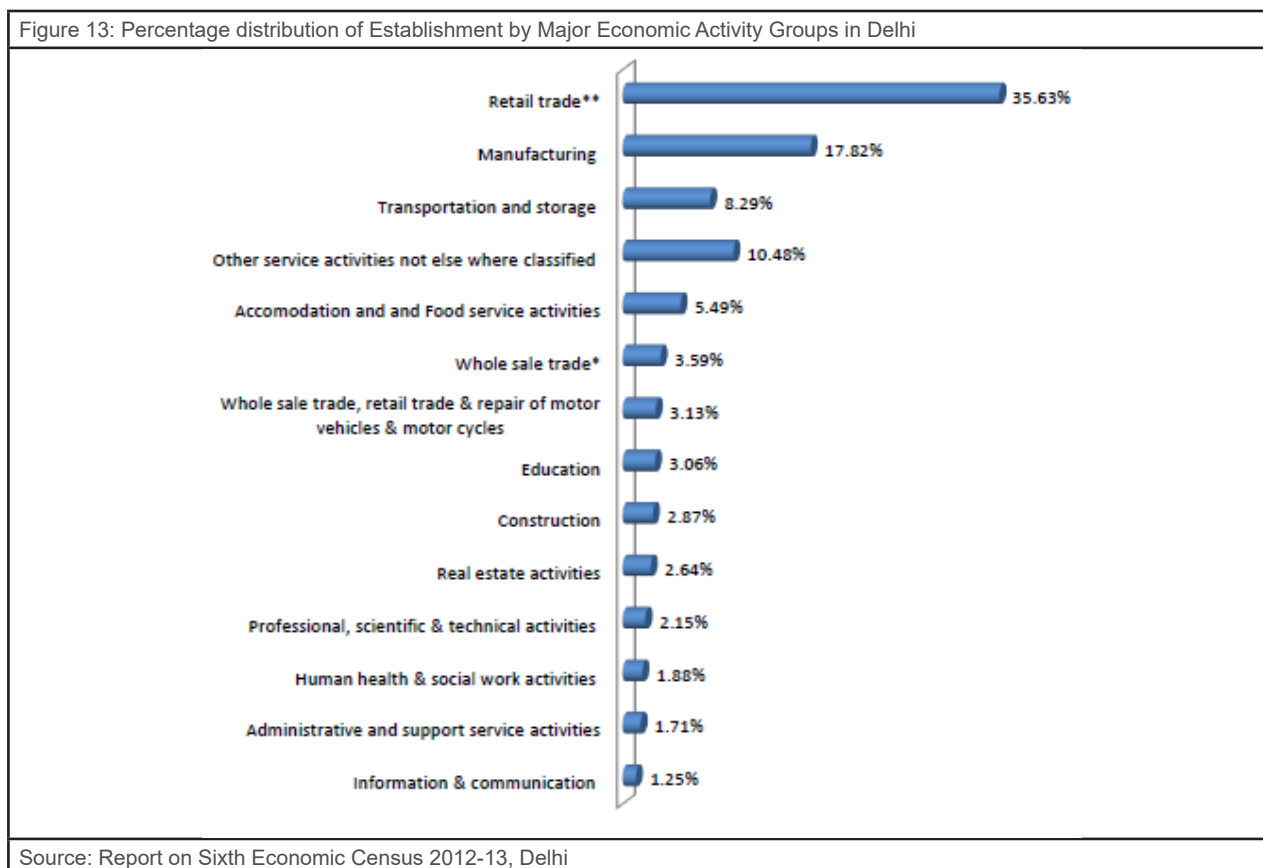
Source: iocl.com

The government currently subsidises 12 cylinders of 14.2 kilograms each per household every year. The consumer must make any additional purchases of LPG cylinders at the prevailing market price.

- Use of LPG/PNG or Wood Charcoal for tandoors. Barbecues to function under controlled environment in all dhabas, hotels and restaurants.
- Retail Enterprises to use electric vehicles/clean fuel for procurement and transport of goods and supply.

The retail trade and manufacturing show a higher share with 35.6% and 17.82% in terms of percentage distribution of economic activity groups in Delhi.

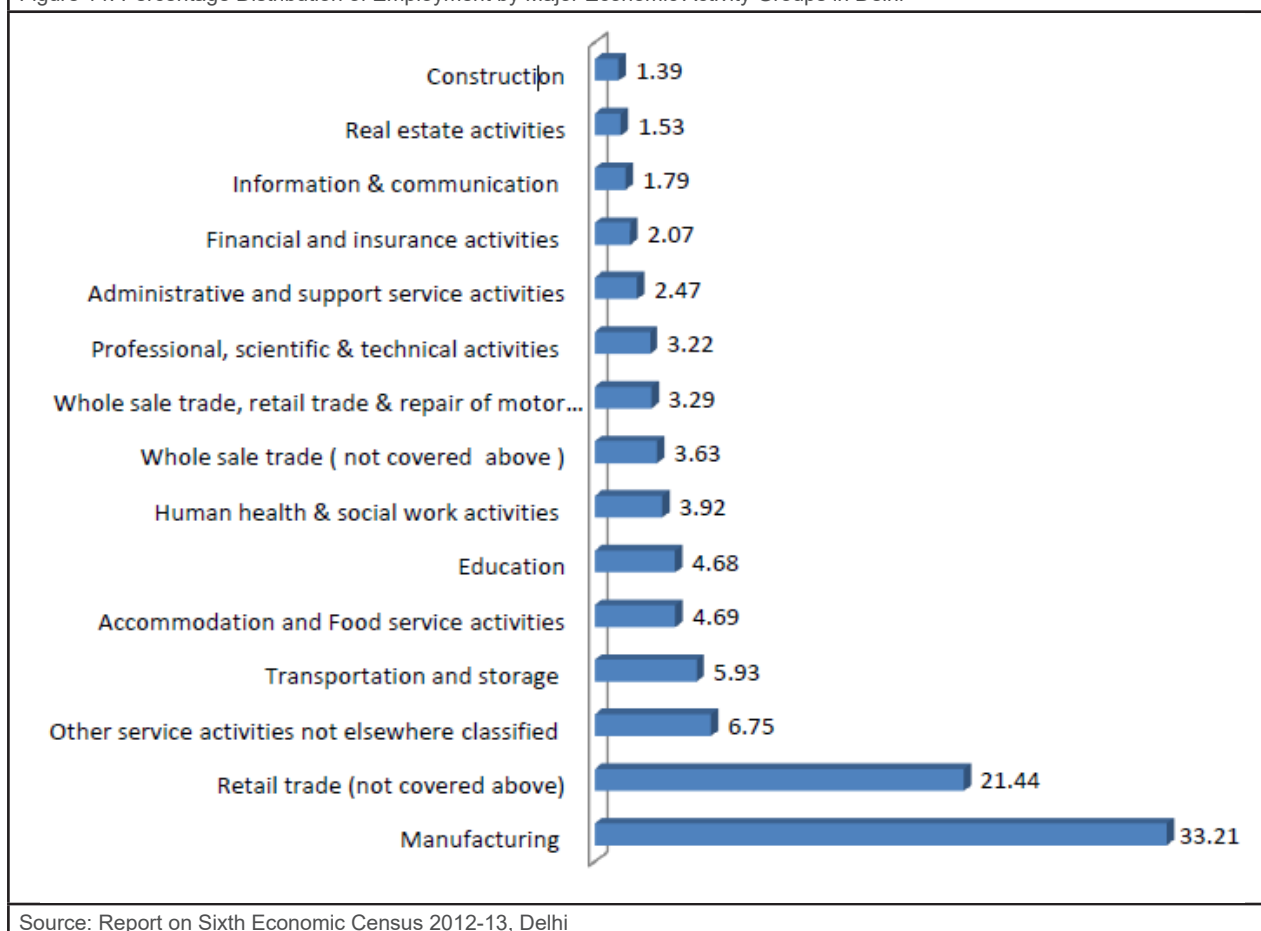
Figure 13: Percentage distribution of Establishment by Major Economic Activity Groups in Delhi



Source: Report on Sixth Economic Census 2012-13, Delhi

The employment in Retail trade and Manufacturing also exceeds by large margin i.e., 21.44% and 33.21% as shown in figure below.

Figure 14: Percentage Distribution of Employment by Major Economic Activity Groups in Delhi



As per the new Electric Vehicle Policy, Delhi will allow ride hailing service providers to operate electric two-wheeler taxis while all the last-mile delivery companies like food delivery and e-commerce logistics providers are expected to shift to 50 per cent of their fleet to electric by March 2023 and 100 per cent by March 2025.

The focus on retail enterprises is due to their large inflow and outflow of goods from and into the city. Measure must be taken up to control the traffic especially in terms of fuel.

3.8.2. STORAGE OF GOODS/WAREHOUSES

Storage of goods/warehouses to be placed at the periphery of city based on local wind direction and traffic movement. The goal is to divert the goods traffic from entry into city core area. Site suitability for location of industries have been provided in Industrial strategies. This should be coupled with identifying suitable locations for Transport Nagar and Warehouses. The Eastern and Western Peripheral Highway eases the traffic passing through the city and thus becomes a potential accessibility points and criteria for locating infrastructure such as warehouses and Transport Nagar.

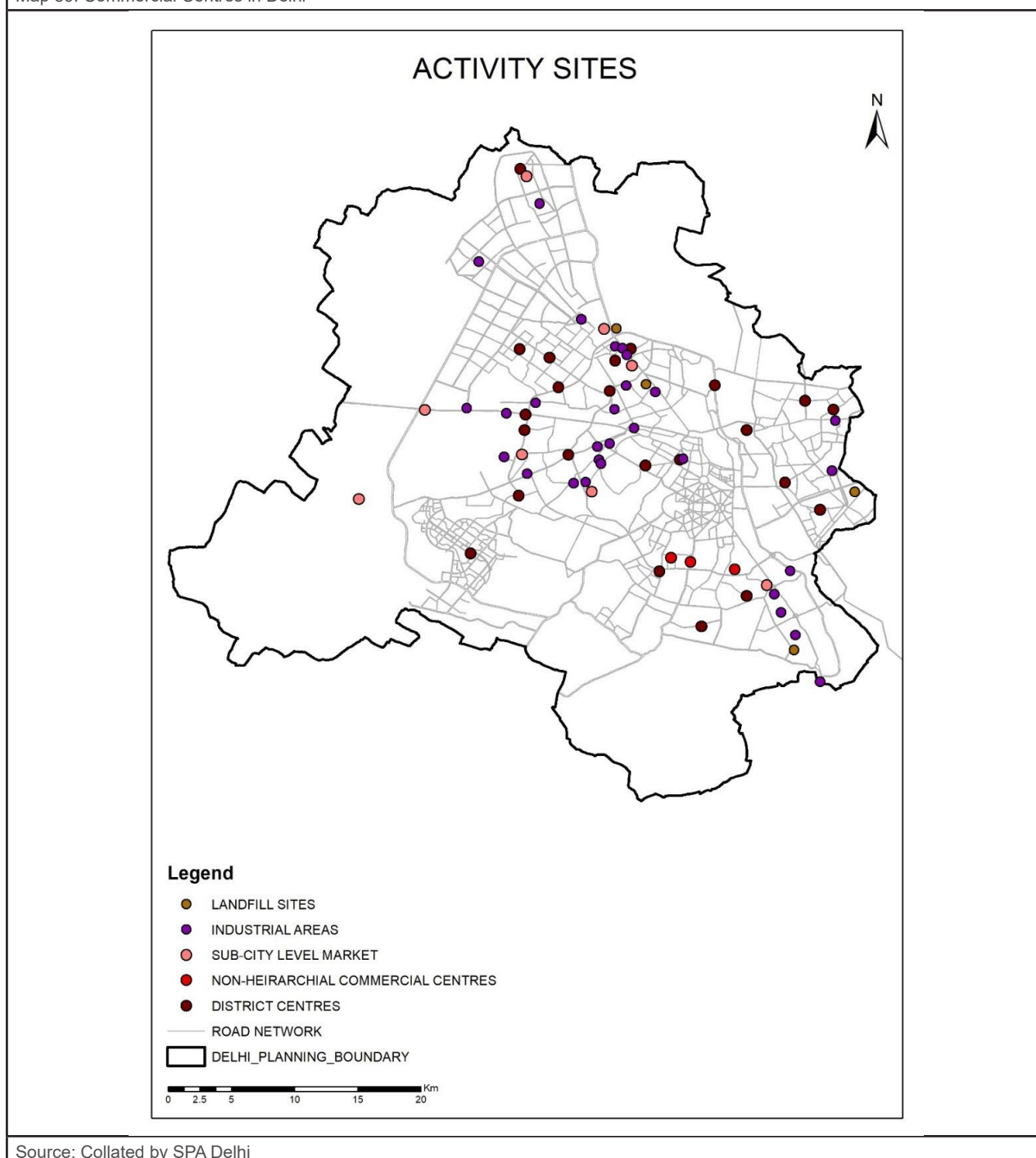
3.8.3. CONTROL OF TRAFFIC MOVEMENT IN SUB-CITY LEVEL MARKETS

Control of traffic movement in Sub-City Level Markets, Non-Hierarchical Commercial Centres and District Centres should be done.

As per the SAFAR Emission Inventory of Mega City Delhi, 2018, it is found that average car parking capacity is 1200 in weekdays and 2000 in weekends in 20 large malls across Delhi. Average parking capacity was calculated to be approximately 550.

Restricted entries to avoid congestion and public transport especially metros, buses, cycling, etc., for leisure and recreational activities should be promoted.

Map 39: Commercial Centres in Delhi



3.9. CONSTRUCTION STRATEGIES

All construction activities involving excavation, civil construction (excluding internal finishing/work where no construction material is used) to be closed from onset of October Month to December.

3.9.1. DUST SUPPRESSION METHOD

Dusts can cause serious health problems including dermatitis, asthma, Chronic Obstructive Pulmonary Disease (COPD) and silicosis.

Silica is one of the most abundant minerals on earth and found naturally in masonry, stone, sand and aggregates. It's also used in the manufacturing of a huge range of building materials including bricks, blocks, mortar, roof tiles and concrete products. Materials containing silica are perfectly safe, but when the materials containing silica are subjected to everyday site activities such as cutting, drilling, grinding and sanding, very fine dust particles can be released into the air. These fine silica dust particles known as Respirable Crystalline Silica or RCS are so small, they cannot be seen with the naked eye and can remain suspended in the air for hours after being created. Wind and air movement can also spread this invisible hazard around a construction site affecting not just the person who created the hazard but also those working around them and even people living and working nearby. These RCS particles are extremely hazardous and extensive or prolonged exposure to them is known to cause a debilitating lung disease called silicosis, CPOD including chronic bronchitis and emphysema.

Although dust barriers are provided in construction activities, the Construction and Demolition (C&D) wastes is a huge issue and most often can be seen piling up along the roads in Delhi. Strict enforcement and penalties must be imposed on violators for delay of disposing of C&D wastes.

Sprinkling of water should be curtailed as per humidity because increase in humidity leads to trapping of pollutants and when the water dries up, the pollutants again mix with the air.

> Implementation of control measures for fugitive emissions.

Fugitive emissions are often not accounted into emission inventories and thus a detail study on fugitive emissions from all land use activities must be made.

3.10. DUST STRATEGIES

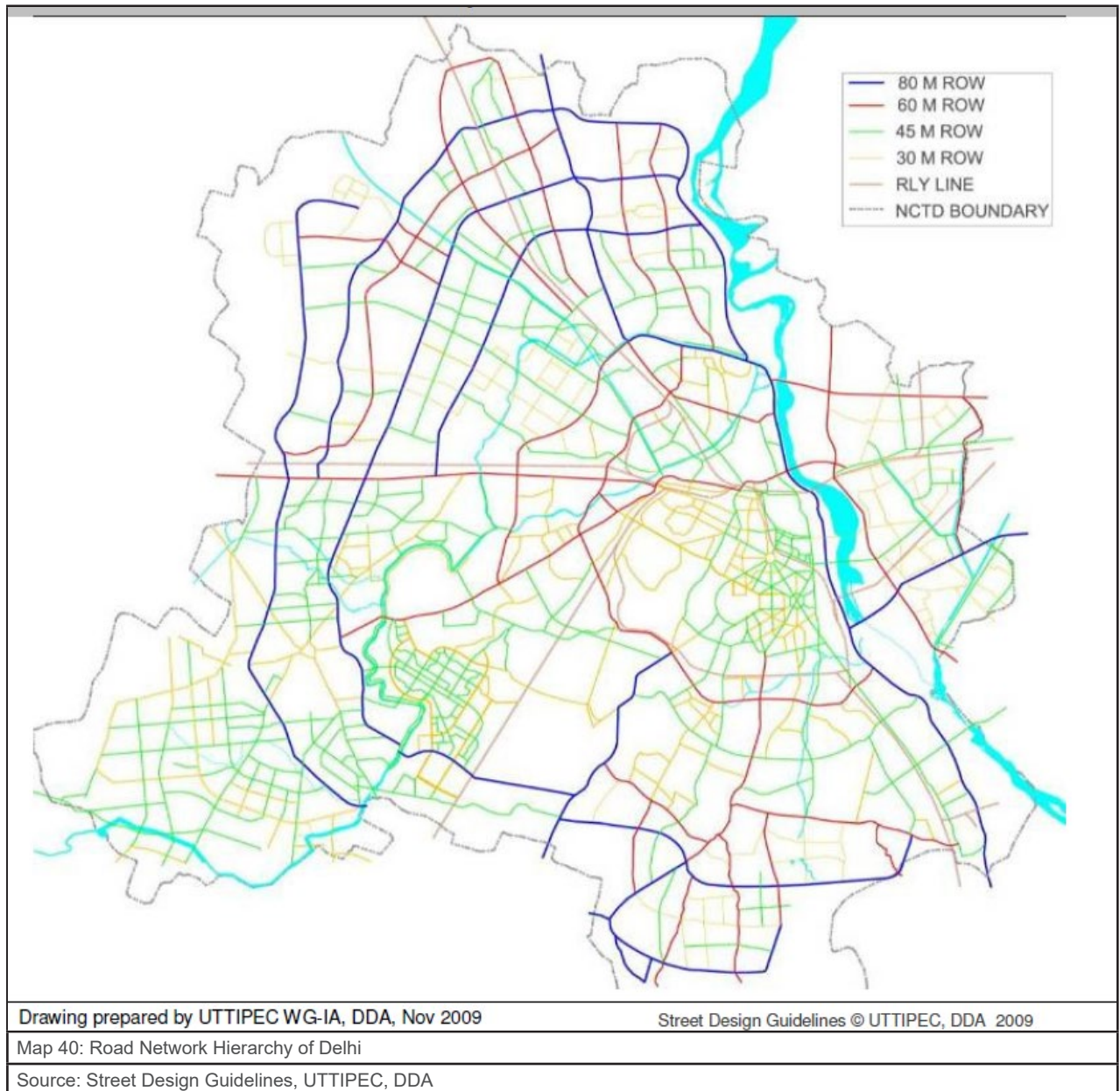
3.10.1. MAINTENANCE OF VEGETATION AND COVERING OF LOSE SOIL

The expose of topsoil poses a huge issue of dust in Delhi. Plantation on massive scale must be taken up to cover areas with open soil.

The other issues are the presence of brick kiln industries around Delhi. These industries are known for exposing the topsoil for the raw materials and are not often covered up. At-site interventions must be taken to prevent long distance transport of lose dust from such sites.

Plantation of trees as specified earlier i.e., at least 125 trees per km for streets with ROW

smaller than 12m. At least 125 trees per km per footpath on streets with ROW greater than 12m. Spacing of trees at no place should be greater than 12m except at intersections.¹⁸



Road Hierarchy in Delhi:

1. National Highways: minimum ROW 90 m

2. Arterial Roads:

- Primary Roads: 60-80m (minimum 80 m. in the proposed urban extension.)
- Other Primary Roads: 45-60m (minimum 60 m. in the proposed urban extension.)

3. Sub Arterial (Collector) Streets.

- Primary Collector: 20-40 m (minimum 45 M. in the proposed urban extension)
- Secondary Collector: 18-24m (minimum 30 M. in the proposed Urban extension)

4. Local Streets

The suggested ROW is 12 to 20 m. in the existing and proposed urban area.

5. Exclusive Pedestrian Only Streets: 6 M and less; as per the provisions in MPD 2021 be

identified area by area, by the local bodies/ road owning agencies.

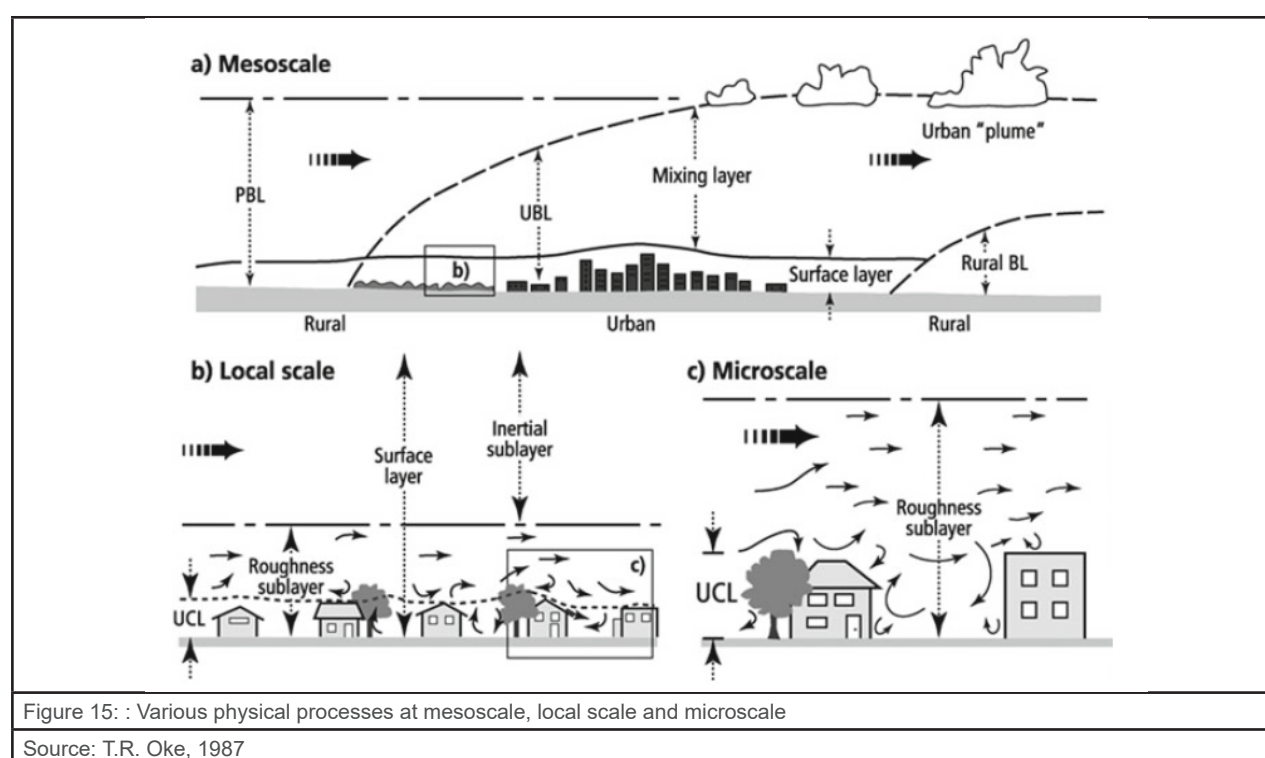
The following standards must be maintained to achieve dispersion of pollutants on road coupled along with arrangement of tall and mid-rise buildings and plantation strategies.

Table 34: Urban Street Canyon Standards

Road ROW (m)	Street Canyon (m)		Vertical Wind Ratio	Distance between two buildings (m)
	H/W	L/H	VRw	
30	< 1.2	< 5	$0.5 < VR_w < 1$	H/1.2
45				
60				
80				

Source: Collated by SPA Delhi

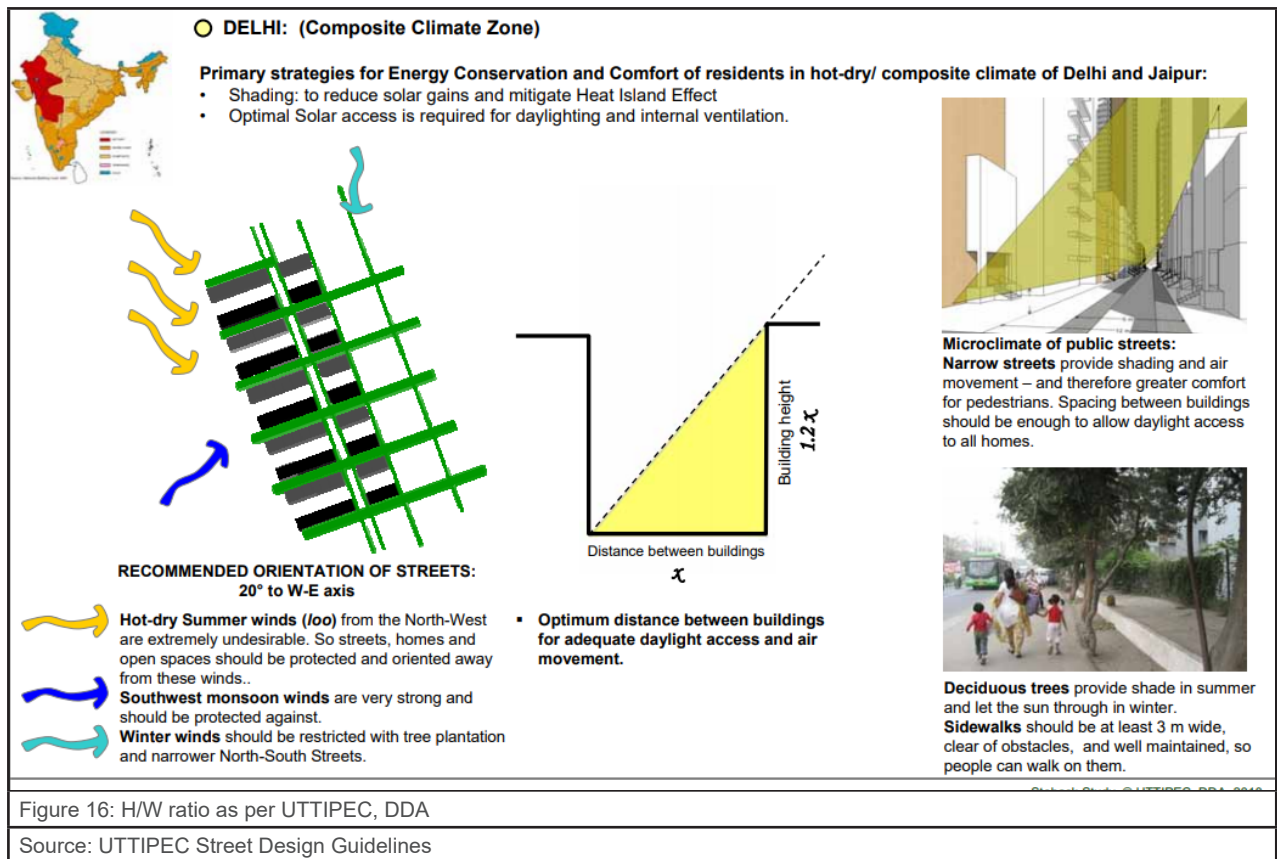
The wind velocity VR_w serves as a simple indicator of ventilation, defined as the ratio of mean wind speed at pedestrian level, 2m above ground, and the velocity at the top of the model domain, well above the roof tops.



The study of urban aerodynamic properties normally requires dynamics modelling from regional scale to building scale, where the subjects of urban flow and dispersion with different physical processes vary.

The turbulent mixing at the urban canyon layer is essential to improve urban air ventilation, alleviate air pollution, and dissipate the anthropogenic heat.

UTTIEPEC Guidelines suggest the H/W ratio to be 1.2. Various researchers have also studied the canyon effect and found the best suitable range is between 0.67 – 2.



Using H/W as the measure, a relationship between Urban Heat Island and H/W have been developed by T.R. Oke:

$$\Delta T_{u-r(max)} = 7.54 + 3.97 \ln (H/W),$$

this relationship demonstrates that urban geometry is a fundamental control on the urban heat island. Urban geometry and the density of development are known to influence processes such as the trapping of both incoming solar and outgoing long-wave radiation, the reduction of turbulent transport due to wind shelter and the amount of anthropogenic heat released.¹⁹

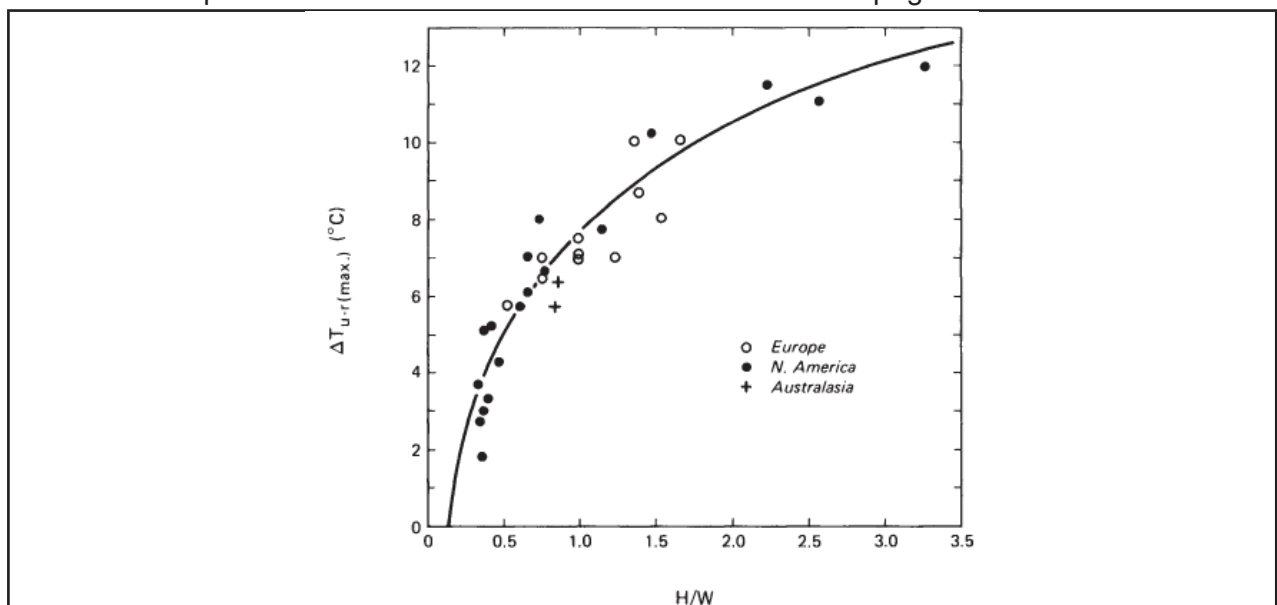


Figure 17: Relation between the maximum heat island intensity ($\Delta T_{u-r(max)}$) and the height to width ratio (H/W) of the street canyons in the centres of 31 cities

Source: Boundary Layer Climates, Second Edition, T.R. Oke

In Delhi we observe deep street canyons all around the city i.e., the H/W ratio is > 1.2 . Such conditions lead to accumulation of particulate matter on ground due to reduced turbulence in canyons with already existing heavy traffic conditions leading to slower speeds.

This suggest that plantation along the streets i.e., 125 trees per km is necessary. This will also help in mitigation of Urban Heat Island effect to some extent.

3.10.2. CREATION OF GREEN BUFFERS

Creation of green buffers and vertical greens can help in deposition of particulate matter reducing the concentration by some amount. However, proper planning should be made as to planting the right type of trees and the quantity of trees.

Non-methane volatile organic compounds [NMVOCs] play an important role in determining the oxidizing capacity and aerosol burden of the atmosphere [Fehsenfeld et al., 1992]. They exert a strong influence on chemical composition of the atmosphere and on global climate change [Hewitt and Street, 1992; Steinbrecher et al., 1997]. There are many sources of the atmospheric NMVOCs. Isoprene emission from vegetation is the world's largest known source of non-methane volatile organic compounds, which represents a direct transfer of reactive carbon from plants to the atmosphere. It is estimated that over 90 per cent of isoprene emissions are from vegetation [Guenther et al., 1995]. Isoprene is highly reactive NMVOCs having atmospheric lifetime of 0.2 days. The oxidation of isoprene in the atmosphere (a) produces large quantities of CO [Zimmerman et al., 1978]; organic acids [Chameides et al., 1992] and ozone [Jacob and Wofsy, 1988] (b) increases the lifetime of methane in the atmosphere [Wuebbles et al., 1989]. Isoprene emission from vegetation is influenced by many factors, including ambient temperature [Tingey et al., 1979], sun light [Harley et al., 1996], CO₂ concentration [Monson and Fall, 1989], genetics [Monson et al., 1994], leaf development, growth stage of plants [Monson et al., 1994; Street et al., 1996], phenological events [Robertson et al., 1995], time of the day and the season [Guenther, 1997]. Accordingly, NMVOCs emission from plants is highly sensitive to land cover (plants composition and dominance) and environmental conditions.

Tree planting has many positive effects upon air quality, but it is important to select tree species that have the most air quality beneficial characteristics. As part of their normal growth and survival processes, many trees emit small quantities of precursor organic compounds that contribute to the formation of harmful ground-level ozone. There is great variation in emissions rates among species, great variation in response to ambient temperature changes, and some variation in the chemical structure and photochemical reactivity of the emitted compounds.

A research study on Isoprene emissions from Indian trees by C. K. Varshney and Abhai Pratap Singh School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India, have found that the following five families namely, Anacardiaceae, Casuarinaceae, Fabaceae, Moraceae, Myrtaceae, and Proteaceae were moderate to high isoprene emitter on the basis of limited number of taxa of each families screened during the study. On other the hand, Bignoniaceae, Bombacaceae, Ehretiaceae, Rutaceae, and Sterculiaceae were found to be negligible or low isoprene emitters. Isoprene emission was found to be below detection limit (BDL) in all species belonging to family Combretaceae and Meliaceae. Certain families such as Bombacaceae, Fabaceae, Lauraceae, Mimosaceae, Moraceae, Myrtaceae and Sapotaceae exhibited a wide variation of isoprene emission rates.

Many of the tree species viz. Albizzia lebbeck, Ceiba petendra, Dalbergia sissoo, Eucalyptus

globulus, *Ficus benghalensis*, *Ficus glomerata*, *Ficus infectoria*, *Ficus religiosa*, *Grevillea robusta*, *Heterophragma adenophyllum*, *Kigelia pinnata*, *Morus alba*, *Pithecellobium dulce*, *Pongamia pinnata*, *Terminalia arjuna* and *Syzygium jambolanum* have been preferentially selected for avenue plantation and green belt development in urban and industrial areas in India. Among these, *Dalbergia sissoo*, *Eucalyptus globulus*, *Ficus benghalensis*, *Ficus glomerata*, *Ficus infectoria*, *Ficus religiosa*, *Grevillea robusta*, *Morus alba*, *Pithecellobium dulce*, *Pongamia pinnata*, *Syzygium jambolanum* are high isoprene emitters. Prevalence of high isoprene emitting species in avenue plantations and green belt development has obvious repercussion for urban air quality. The high values of ground level ozone reported for the urban/peri-urban environment of Delhi [Varshney and Aggarwal, 1992; Singh et al., 1997; Varshney and Rout, 1998], appears to be largely on account of wide spread plantations of high VOC emitting tree species in urban areas. In view of the implication of high isoprene emitting species for air quality, it is important that isoprene-emitting potential should also be given serious consideration along with other features while selecting tree species for planting in urban and industrial areas.

Construction of biogenic VOC emission model requires emission factors for each individual species of the landscape. However, it is not feasible to measure emission rate of each species particularly in the tropical ecosystem on account of high species diversity. Consequently, actual VOC emission data on many species remains unavailable. To overcome this hurdle, Benjamin et al. [1996] have proposed a method of assigning emission rate on genus and family basis to plant species, for which emission rates are not known. Subsequently, many of the workers have used the taxonomic approach of Benjamin et al. [1996] for assigning emission rates to unexplored species for constructing regional or global emission inventories [Guenther et al., 1994; Geron et al., 1995; Rasmussen and Khalil, 1997]. The results of this study show that emission rate assignment to a particular species at family level may suffer from >50% uncertainty. However, assignment at genus level is relatively more dependable (<50% uncertainty).

3.10.3. MAINTAINING POT-HOLE FREE ROADS

The standards of urban and rural roads need to be maintained preventing occurrences of potholes and debris which leads to wear and tear of tyres contributing to particular emission. Vehicle-related particulate matter (PM) emissions may arise from both exhaust and non-exhaust mechanisms, such as brake wear, tire wear, and road pavement abrasion, each of which may be emitted directly and indirectly through resuspension of settled road dust. Several researchers have indicated that the proportion of $PM_{2.5}$ attributable to vehicle traffic will increasingly come from non-exhaust sources.

The contribution of tire wear to ambient PM_{10} and $PM_{2.5}$ has been estimated to be between 0.8– 8.5% and 1–10% by mass respectively, although the data are sparse, and most estimates are indirectly calculated with only a few observational studies.^{20 21 22 23}

20 Fauser, P. Particulate Air Pollution with Emphasis on Traffic Generated Aerosols. Ph.D. Thesis, Technical University of Denmark, Lyngby, Denmark, 1999.

21 Grigoratos, T.; Martini, G. Non-Exhaust Traffic Related Emissions. Brake and Tyre Wear PM; Literature Survey; JRC Science and Policy Reports; EC Joint Research Centre: Ispra, Italy, 2014

22 Panko, J.M.; Chu, J.; Kreider, M.L.; Unice, K.M. Measurement of airborne concentrations of tire and road wear particles in urban and rural areas of France, Japan, and the United States. *Atmos. Environ.* 2013, 72, 192–199.

23 Weinbruch, S.; Worringer, A.; Ebert, M.; Scheuvers, D.; Kandler, K.; Pfeffer, U.; Bruckmann, P. A quantitative estimation of the exhaust, abrasion and resuspension components of particulate traffic emissions using electron microscopy. *Atmos. Environ.* 2014, 99, 175–182

Table 35: Mean Isoprene Emission Rate ($\mu\text{g/g/h}$) from 40 Indian tree species

Scientific Name	Local Name	Isoprene Emission Rate	No. of Enclosure Run	Avg. Temp., $^{\circ}\text{C}$	Avg. PAR, $\mu\text{mol m}^{-2}\text{s}^{-1}$
<i>Anacardiaceae</i>					
Mangifera indica Linn.	Aam	26.0 ± 7	6	27	440
<i>Bignoniaceae</i>					
Heterophragma adenophyllum Benth & Hook.	Maronfali	0.50 ± 0.02	8	25	350
Kigelia pinnata DC.	Kigelia	1.0 ± 0.03	6	39	800 ^a
<i>Bombacaceae</i>					
Ceiba petendra Linn.	Ceiba	BDL	6	42	1200 ^a
Chorisia speciosa St. Hill.	Kuregia	BDL	6	41	1000 ^a
Salmaal malabarica DC.	Semul	4.20 ± 1.00	6	35	500
<i>Casuarinaceae</i>					
Casuarina equisetifolia Linn.	Vilayti- Jhau	20.4 ± 5.20	6	39	850 ^a
<i>Combretaceae</i>					
Terminalia arjuna Roxb.	Arjun	BDL	8	34	600
Terminalia bellirica Roxb.	Bahera	BDL	8	35	600
<i>Ehretiaceae</i>					
Cordia obliqua Willd.	Lasora	1.50 ± 0.23	6	38	800 ^a
<i>Fabaceae</i>					
Butea monosperma Lamk.	Dhak	11.60 ± 1.75	6	43	1500 ^a
Dalbergia sissoo Linn.	Shisham	81.5 ± 17.78	8	35	550
Pongamia pinnata Linn.	Papari	33.0 ± 6.25	8	30	400
<i>Lauraceae</i>					
Cinnamomum tamala T.Nees & E. Bern.	Tejpat	27.1 ± 5.67	7	39	900 ^a
Cinnamomum zeylanicum Bereyn.	Dalchini	BDL	6	38	700 ^a
<i>Meliaceae</i>					
Azadirachta indica A.Juss.	Neem	BDL	6	40	1000 ^a
Melia azedarach Linn.	Buckain	BDL	8	38	750 ^a
Chukrasia tabularis A.Juss.	Chikrasi	BDL	7	33	500
<i>Mimosaceae</i>					
Acacia nilotica Willd.	Desi babool	BDL	6	44	1600 ^a
Albizia lebbek Linn.	Siras	0.66 ± 0.11	6	40	1000 ^a
Pithecellobium dulce Roxb.	Jangal Zalebi	21.5 ± 3.23	6	39	750 ^a
<i>Moraceae</i>					
Ficus benghalensis Linn.	Bargad	37.0 ± 8.20	8	34	560
F. glomerata Roxb.	Gular	47.6 ± 6.80	6	35	500
F. infectoria Willd.	Pilkhan	52.0 ± 13.86	8	32	400
F. religiosa Linn.	Peepal	76.5 ± 15.0	8	36	550
Morus alba Linn.	Sahtoot	21.6 ± 6.93	8	37	600
<i>Myrtaceae</i>					
Eucalyptus globulus Labill.	Safeda	55.6 ± 12.35	4	39	870 ^a
Psidium guajava Linn.	Amrood	31.5 ± 5.62	8	41	1100 ^a
Syzygium jambolanum DC.	Jamun	25.0 ± 3.84	7	27	350
<i>Proteaceae</i>					
Grevillea robusta A. Cunn.	Silk-Oak	16.2 ± 3.00	8	38	700 ^a
<i>Rutaceae</i>					
Aegle marmelos Linn.	Bel	BDL	7	35	500
Citrus reticulata	Santara	0.92 ± 0.12	8	32	450
Citrus limon Linn.	Nimbu	0.61 ± 0.10	8	36	550
Citrus sinensis Linn.	Mausambi	0.70 ± 0.15	8	26	330
Murraya koenigii Linn.	Meethi Neem	BDL	9	32	400
<i>Rhamnaceae</i>					
Zizyphus jujuba Lamk.	Ber	1.65 ± 0.18	8	36	540
<i>Sapotaceae</i>					
Manilkara hexandra Roxb.	Khirmi	BDL	9	25	240
Achras zapota Linn.	Chiku	38.0 ± 6.50	6	39	880 ^a
<i>Sterculiaceae</i>					
Sterculia alata Roxb.	Estercolia	BDL	6	38	700 ^a
Pterospermum acerifolium Willd.	Knakchampa	1.20 ± 0.25	8	32	450

^aEmission measurements in summer months (April, May, June). Values without footnotes indicate measurements during Autumn (Sept., Oct., Nov. months). BDL: below detection limit.

Source: Isoprene emission from Indian trees, C. K. Varshney and Abhai Pratap Singh, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D24, 4803, doi:10.1029/2003JD003866, 2003

4. CRITERIA FOR LAND USE BASED INTERVENTIONS IN DELHI

CRITERIA (ADAPTED FROM “AIR POLLUTION CONTROL PERMIT”, USEPA)

“Major stationary source”²⁴ means:

Any stationary source or group of stationary sources located within a contiguous area and under common control that emits or has the potential to emit, in the aggregate, **10 tons per year (tpy) or more of any hazardous air pollutant, 25 tpy or more of any combination of such hazardous air pollutants**, or such lesser quantity as CPCB/SPCBs may establish by rule. Notwithstanding the preceding sentence, emissions from any oil or gas exploration or production well (with its associated equipment) and emissions from any pipeline compressor or pump station shall not be aggregated with emissions from other similar units, whether or not such units are in a contiguous area or under common control, to determine whether such units or stations are major sources; or

Any stationary source which has the potential to increase emissions of a listed toxic air contaminant by greater than the minimum quantity for that contaminant; or

Any other stationary source or process except for those outlined by CPCB having the potential to emit 45 kgs or more per day, or 4.5 kg or more per hour of any air contaminant or combination of air contaminants into the atmosphere, including but not limited to the following categories:

- (a) Surface coating, spray and dip painting, roller coating, knife coating and electrostatic depositing;
- (b) Metal cleaning or surface preparation, degreasing, bright dipping, stripping, galvanizing and chrome plating;
- (c) Textile dyeing and finishing, including tenter frames, dryers, printers and solvent dyers;
- (d) Glass or fiberglass manufacturing, including melting furnaces, forming lines, curing ovens and product cooling lines;
- (e) The production of asphalt concrete, including rotary dryers, screening and conveying systems and mixers;
- (f) The production of metal castings, including cupolas, reverberatory furnaces, electric furnaces, crucible furnaces and sand handling systems; or

A major stationary source of air pollutants that directly emits, or has the potential to emit, 100 tpy or more of any air pollutant (including any major source of fugitive emissions of any such pollutant). The fugitive emissions of a stationary source shall not be considered in determining whether it is a major stationary source unless the source belongs to one of the following categories of stationary source:

²⁴ <https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=0574cb3eeb8bbf281bcebf74d2901131&rgn=div5&view=text&node=40:16.0.1.1.7&idno=40>

- Coal cleaning plants (with thermal dryers);
- Kraft pulp mills;
- Portland cement plants;
- Primary zinc smelters;
- Iron and steel mills;
- Primary aluminium ore reduction plants;
- Primary copper smelters;
- Municipal incinerators capable of charging more than 250 tons of refuse per day;
- Hydrofluoric, sulfuric, or nitric acid plants;
- Petroleum refineries;
- Lime plants;
- Phosphate rock processing plants;
- Coke oven batteries;
- Sulfur recovery plants;
- Carbon black plants (furnace process);
- Primary lead smelters;
- Fuel conversion plants;
- Sintering plants;
- Secondary metal production plants;
- Chemical process plants—The term chemical processing plant shall not include ethanol production facilities that produce ethanol by natural fermentation;
- Fossil-fuel boilers (or combination thereof) totalling more than 73267.76 kW hour heat input;
- Petroleum storage and transfer units with a total storage capacity exceeding 300,000 barrels;
- Glass fibre processing plants;
- Charcoal production plants;
- Fossil-fuel-fired steam electric plants of more than 73267.76 kW hour heat input; or

For ozone nonattainment areas, sources with the potential to emit 100 tpy or more of volatile organic compounds or oxides of nitrogen in areas classified or treated as classified as “Marginal” or “Moderate,” 50 tpy or more in areas classified or treated as classified as “Serious,” 25 tpy or more in areas classified or treated as classified as “Severe,” and 10 tpy or more in areas classified or treated as classified as “Extreme”;

For carbon monoxide nonattainment areas: stationary sources which contribute significantly to carbon monoxide levels, sources with the potential to emit 50 tpy or more of carbon monoxide; and

For particulate matter (PM-10) nonattainment areas classified or treated as classified as “Serious,” sources with the potential to emit 70 tpy or more of PM-10. Potential to emit means the maximum capacity of a stationary source to emit any air pollutant under its physical and operational design. Any physical or operational limitation on the capacity of a source to emit an air pollutant, including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design if the limitation is enforceable by the Administrator.

Table 36: Emissions from landfill sites

Sl.No.	Location	Area (in ha.)	%age share	Waste Collected in tcpd	Waste Burned = 3% of total waste (tcpd)	PM _{2.5} Emission load (kg/day)	PM ₁₀ Emission load (Kg/day)
				A	B = 0.03 x A	C = B x 5.44	D = B x 8
1	Site near Ghazipur Dairy Farm	70	46.2	1450	43.5	236.64	348
2	Site near Jhangipur / Bhalswa	36	23.6	2000	60	326.4	480
3	Okhla Phase I	46	30.2	1826	54.78	298	438.24
	Total	152		5276	158.28	861.04	1266.24

Source: Compiled by SPA Delhi; DPCC

Emission from Solid Waste Burning in Landfill sites per year:**1. Site near Ghazipur Dairy Farm:**

- PM_{2.5} = 236.64 kg/day = 86,373.6 kg/year = **86.37 tonnes/year**
- PM₁₀ = 348 kg/day = 127020 kg/year = **127.02 tonnes/year**

2. Site near Jahangirpuri/Bhalswa:

- PM_{2.5} = 326.4 kg/day = 118990 kg/year = **118.99 tonnes/year**
- PM₁₀ = 480 kg/day = 175200 kg/year = **175.20 tonnes/year**

3. Okhla Phase I:

- PM_{2.5} = 298 kg/day = 108770 kg/year = **108.77 tonnes/year**
- PM₁₀ = 438.24 kg/day = 159957.6 kg/year = **159.96 tonnes/year**

The emission of PM_{2.5} and PM₁₀ pollutants from solid waste dumping sites **exceed the cap of 10 tonnes per year limit and exceed by large amount in combination i.e., 776.46 tonnes per year.**

2. Waste to Energy:

Delhi has 3 Waste to Energy Plant (WTE Plants) with total capacity of 5250 TPD. Total Waste produced is around 10,470 TPD. Capacity of WTE Plants should be increased in order to prevent accumulation of waste in landfill sites and thus preventing waste burning.

3. Road Dust:

- PM_{2.5} Emission = 2871.56 kg/day = 10,48,119.4 kg/year = 1048.12 tonnes/year
- PM₁₀ Emission = 22751.02 kg/day = 83,04,122.3 kg/year = 8304.12 tonnes/year

4. Commercial – Hotels and Restaurants

- PM_{2.5} Emission = 1591.41 kg/day = 5,80,864.65 kg/year = 580.86 tonnes/year

5. Street Vendors/Open Eat Outs

- PM_{2.5} Emission = 108.24 kg/day = 39507.6 kg/year = 39.51 tonnes/year
- PM₁₀ Emission = 688.8 kg/day = 2,51,412 kg/year = 251.41 tonnes/year

6. Domestic

- $PM_{2.5}$ Emission = 989.36 kg/day = 3,61,116.4 kg/year = 361.12 tonnes/year
- PM_{10} Emission = 6295.98 kg/day = 2,298,032.7 kg/year = 2298.03 tonnes/year

7. Building Construction

- PM_{10} Emission (Infrastructure project < 1 crore) = 185.4 tonnes/year
- PM_{10} Emission (Infrastructure project > 1 crore) = 207 tonnes/year

8. Crematorium

- $PM_{2.5}$ Emission = 120.8 kg/day = 44,092 kg/year = 44 tonnes/year
- PM_{10} Emission = 1232.69 kg/day = 4,49,931.85 kg/year = 449.93 tonnes/year

9. Waste Incinerators

- Exempted

10. Soil Dust

- $PM_{2.5}$ Emission = 48640.49 kg/year = 48.64 tonnes/year
- PM_{10} Emission = 24320.136 kg/year = 24.32 tonnes/year

11. Airport

- PM_{10} Emission = 1410319.35 kg/year = 1410.32 tonnes/year

12. Diesel Gen Set

- PM_{10} Emission = 785.50 kg/day = 2,86,707.5 kg/year = 286.71 tonnes/year

13. Biogenic emissions

- N_2O Emission from Agricultural Land = 29.21×10^6 tonnes/year
- N_2O Emission from Green areas = 215784.3268 Kg/year = 215.78 tonnes/year

Many VOCs form ground-level ozone by “reacting” with sources of oxygen molecules such as nitrogen oxides (NO_x), and carbon monoxide (CO) in the atmosphere in the presence of sunlight.

The Biogenic emission from agricultural land in Delhi itself exceeds the standard limit of 50 tonnes per year.

14. Industries

- PM_{10} Emission = 62492.75 kg/day = 22,809,853.75 kg/year = 22809.85 tonnes/year

15. Power Plants

- PM_{10} Emission = 46816.6 kg/day = 17,088,059 kg/year = 17088.06 tonnes/year

16. Agricultural Burning

- $PM_{2.5}$ Emission = 1041.09 kg/day = 3,79,997.85 kg/year = 379.99 tonnes/year
- PM_{10} Emission = 1301.36 kg/year = 4,74,996.4 = 474.99 tonnes/year

17. Refuse Burning

- $PM_{2.5}$ Emission = 861.04 kg/day = 3,14,279.6 kg/year = 314.28 tonnes/year
- PM_{10} Emission = 1266.24 kg/day = 4,62,177.6 kg/year = 462.18 tonnes/year

18. Transport

- $PM_{2.5}$ Emission from vehicles = 1224.18 kg/year = 1.22 tonnes/year

Sl. No.	Land Use	Source/ Activity	%age	Area (Sq. Km.)	Emissions (tonnes/year)		Emissions (tonnes/year/ Sq.Km.)	
					PM _{2.5}	PM ₁₀	PM _{2.5}	PM ₁₀
1	Residential	Cooking	45 – 55	306.17	361.12	2298.03	1.18	7.51
		Refuse Burning			314.28	462.18	1.03	1.51
2	Agricultural	Waste Burning	Balance	214.34	379.99	474.99	1.77	2.21
		Biogenic			29.21 x 10 ⁶ of N ₂ O		13.63 x 10 ⁴ of N ₂ O	
3	Industrial	Industrial	4 – 5	35.39		22809.85		644.53
		Construction				392.4	11.09 (Based on location)	
4	Commercial	Hotels & Restaurants	4 – 5	25.12	580.86		23.12	
		Open Eat Outs			39.51	251.41	1.57	10.01
		DG Sets				286.71		11.41
5	PSP	Crematorium	8 – 10	57.59	44	449.93	0.76	7.81
6	Circulation	Transport Vehicles	10 – 12	32.32	1.22		Based on traffic intensity	
		Road Dust			1048.12	8304.12	32.43	256.93
		Airport				1410.32	Based on location	
7	Green/ Recreational	Biogenic	15 – 20	184.59	215.78 of N ₂ O		1.17 of N ₂ O	
8	Utilities	Power Plant		13.42		17088.06	Based on location	
		Land Fill Waste Burning			412.14	462.18		
9	Special Area			23.65				
10	Government			48.49				
11	Sub-Total			941.08				
12	Vacant Land	Soil Dust		541.92	48.64	24.32	0.089	0.043
13	Total			1483				

Source: Compiled by SPA Delhi

Table 37: Classification of sources (based on PM_{2.5} & PM₁₀ Pollutants)

Classification of sources (based on PM_{2.5} & PM₁₀ Pollutants)	
Significant Source (potential to increase)	5tpy ≤ Pollutant Emission <10tpy 5tpy ≤ Combined Pollutant Emission <10tpy
Major Source	Pollutant Emission ≥ 10tpy Combined Pollutant Emission ≥ 25tpy

Source: Compiled by SPA Delhi

Important Note:

Impose conditions on the design, construction or operation of the source, including but not limited to:

- (1) limitations on the hours of operation
- (2) limitations on allowable emissions from the stationary source
- (3) operation and maintenance criteria that are necessary to ensure that the maximum allowable emissions from the stationary source are not exceeded
- (4) require the use of instrumentation to monitor and record emission data
- (5) conditions to ensure the attainment or maintenance of applicable state or national ambient air quality standards
- (6) conditions to ensure that compliance with all applicable state and national air pollution control rules and regulations is attained and maintained.

5. SITE LEVEL ANALYSIS

5.1. ALIPUR MONITORING STATION

Table 38: Emission sources around Alipur Monitoring station

Table 38: Emission sources around Alipur Monitoring station							
Alipur	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial		0.00	0.00	0.00	0.00	
	Industrial	Industries	19.11	0.60		386.72	
	Transportation	Vehicles	5.41	0.17	Not accounted		
		Road Dust			5.51	43.68	
	Recreational		0.00	0.00	0.00	0.00	
	Residential	Cooking	6.37	0.20	0.24	1.50	
		Refuse burning			0.21	0.30	
	PSP		0.00	0.00			
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	69.43	2.18	3.86	4.82	
		Biogenic			Not accounted		
Total					9.81	437.02	

Source: Compiled by SPA Delhi

Source: Compiled by SPA Delhi

The major source around Alipur is attributed to industries and road dust. The area is predominantly agricultural and thus there is emerging potential from agricultural activities to contribute to PM_{2.5} and PM₁₀ concentration. The area also consists of large number of warehouses. This means large inflow of heavy vehicle traffic for goods storage. As per the Local Climate Zone, the area is predominantly occupied by green belt (agricultural land) and large low rise and open low rise which is suitable for dispersion of pollutants.

The wind direction is predominantly North-East coming from Loni, Ghaziabad which consist of large number of illegal industrial units.²⁵ 121 Polluting units have been demolished in Loni, Ghaziabad since October 15, 2020.²⁶ The pollutant transport from surrounding areas can be attributed to Alipur falling under class of '**reaching hotspot**'.

Recommendations (Details are mentioned for each recommendation in earlier section):

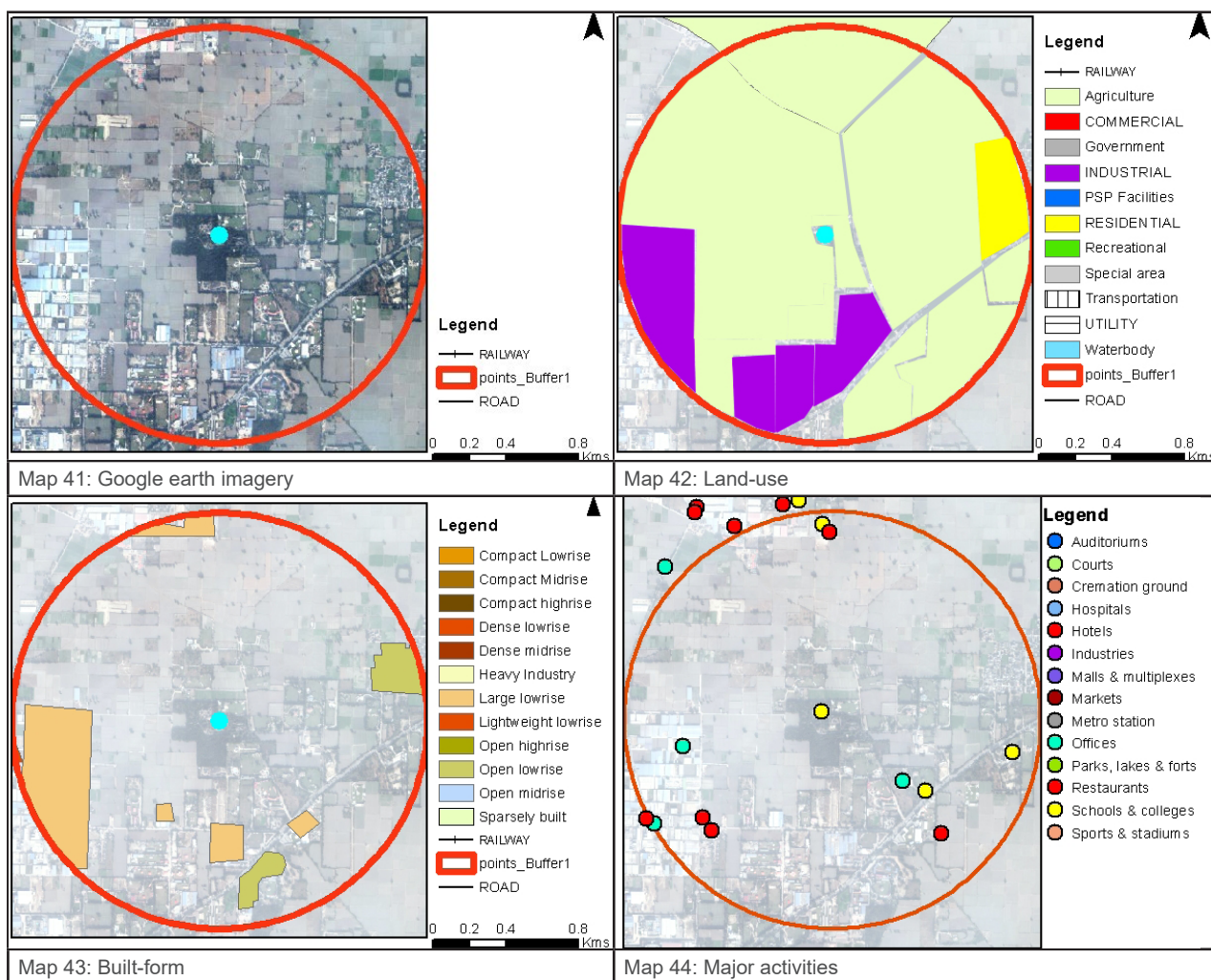
- Lockdown of industries such as stone crushing, hot mix plants, brick kilns generating dust pollution in Delhi and NCR districts from **October to December**.
- Regulation of Household industries primarily contributing to Particulate Matter concentration.

²⁵ <http://www.indiaenvironmentportal.org.in/files/file/e-waste-units-Loni-report-NGT.pdf>

²⁶ <https://www.ndtv.com/ghaziabad-news/121-polluting-units-demolished-in-ghaziabad-since-october-15-2316698#publisher=newsstand>

- Study of Traffic Demand of Industrial Units to capture intensity of traffic movement for good and supply.
- Relocation & phasing out of polluting units based on CPCB CEPI score & also based on Traffic Demand of Industrial Units
- Retail Enterprises to shift to electric vehicles, clean fuel for procurement and transport of goods and supply.
- Storage of goods/warehouses to be place at the periphery of cities.
- Maintenance of vegetation and covering of topsoil
- Creation of green buffers
- Maintaining pothole-free roads

Note: Vehicle emission have not been accounted due to non-availability of latest traffic volume data. However, as per observations and study of source apportionment reports, the emission from vehicular sources will contribute significantly and thus should be considered as a major source in any case.



LCZ			LANDUSE			ALTITUDE	POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%		MONTHS	PM2.5	PM10		
Dense lowrise	0.002	0.06	COMMERCIAL	0	0.0	200-220	January	193.3	285.736		
Dense midrise	0.000	0.00	INDUSTRIAL	0.6	19.1		Febrauray	145.28	232.592		
Open midrise	0.000	0.00	TRANSPORTATION	0.17	5.4		March	88.56	166.387		
Open highrise	0.000	0.00	RECREATIONAL	0	0.0		April	92.02	235.218		
Open lowrise	0.081	2.58	RESIDENTIAL	0.2	6.4		May	85.28	244.477		
Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0		June	63.58	213.692		
Compact Midrise	0.000	0.00	GOVERNMENT	0	0.0		July	44.58	118.648		
Compact Highrise	0.000	0.00	UTILITY	0	0.0		August	31.56	57.6946		
Large lowrise	0.283	9.02	SPECIAL AREA		0.0		September	36.73	72.4616		
Sparsely built	0.000	0.00	WATERBODY		0.0		October	128.16	220.637		
Green belt	2.600	82.80	GREEN BELT	2.18	69.4		November	203.76	305.871		
Open area	0.000	0.00					December	194.85	279.997		
Waterbody	0.000	0.00									
Road	0.170	5.41									
Heavy Industry	0	0.00									

Table 39: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

5.2. SHADIPUR MONITORING STATION

Table 40: Emission sources around Shadipur Monitoring station

Shadipur	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	3.50	0.11	2.54		
		Eat Out			0.17	1.10	
		DG Set				1.26	
	Industrial	Industries	24.60	0.77		496.29	
	Transportation	Vehicles	11.30	0.36	Not accounted		
		Road Dust			11.51	91.21	
	Recreational	Biogenic	8.70	0.27	Not accounted		
	Residential	Cooking	32.70	1.03	1.22	7.74	
		Refuse burning			1.06	1.56	
	PSP		0.00	0.00			
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		6.70	0.21			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	12.70	0.40	0.71	0.88	
		Biogenic			Not accounted		
Total					17.21	600.03	

The major source around Shadipur is attributed to industries and transport sector including residential areas. The area consists of large number of slum clusters which can be the reason. (Refer to Map 45) Shadipur is also a 'primary hotspot area'.

While in-situ redevelopment of slums at Kathputli Colony and Kalkaji are yet to be completed, the Delhi Development Authority (DDA) is planning to undertake rehabilitation of 96 Jhuggi Jhopri (JJ) clusters on similar lines of a public-private partnership (PPP) basis.

The planning on similar projects — Dilshad Garden, Kirti Nagar, Rohini's sectors 18 and 19, Shalimar Bagh, and Kusumpur Pahadi in Vasant Vihar covering 30 slum clusters — has already begun.

There are 675 slums in Delhi out of which 499 are on central government's land, including

DDA's. DDA will be carrying out rehabilitation work in 23 slum clusters in phases.

The area is beside Kirti Nagar. Kirti Nagar is one of the most affluent neighbourhoods in all of Delhi, India. Part of the Punjabi Bagh subzone of West Delhi, it primarily a residential colony. Kirti Nagar is home to India's largest furniture market housing showrooms of multi-national home remodelling and fittings companies, the most reputed interior design boutiques, imported kitchen and bath brands as well as traditional carpentry furniture makers. Kirti Nagar also hosts the biggest golf course and country club in North India.

The adjacent neighbourhood of Rajouri Garden is a popular market, comprising the Main Market, Nehru Market and many western style indoor shopping malls including TDI Mall, Moments mall, TDI Paragon Mall, Shoppers Stop, City Square, West Gate Mall, and Paradise Mall. Together, this area is now the largest single locality shopping conglomeration in Delhi ahead of South Delhi.

Considered one of the upmarket areas in Delhi, the twin localities of Mansarovar Garden and Kirti Nagar are indeed one of the posh areas in West Delhi. The colony mostly consists of private houses and so called "Kothis", housing rich Sikh businessmen and people who migrated from Pakistan after partition constitute a significant part of the population. This accounts for large number of individual private vehicle ownership.

This can be reason for heavy traffic situation and road dust around Shadipur along with traffic movement into industrial clusters nearby.

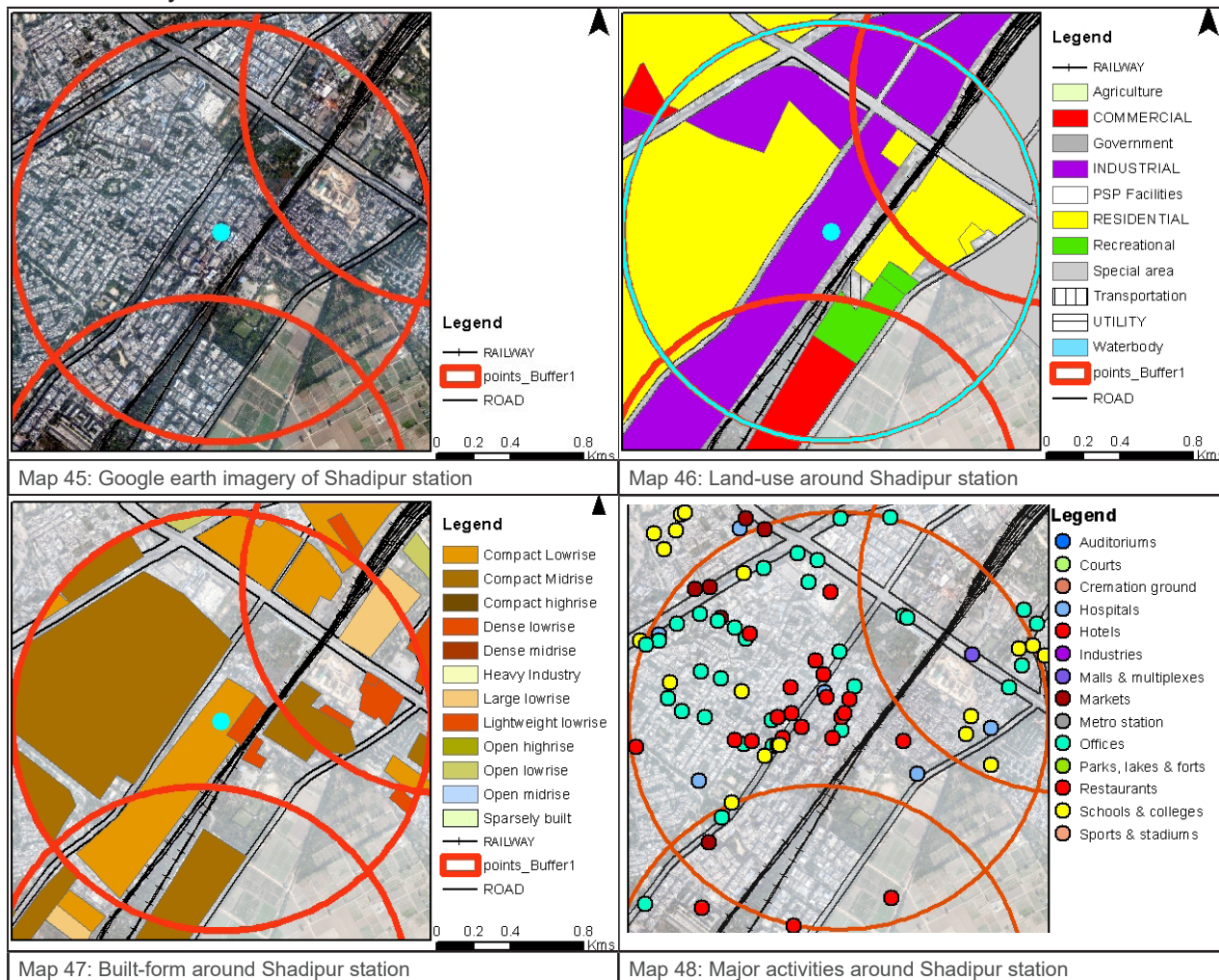
As per the Local Climate Zone, the area is predominantly occupied by green belt followed by compact midrise, compact low rise, open low-rise and dense low-rise. Large contiguous space of compact mid-rise surrounding the compact low rise pose an issue of dispersion in this case. The vertical wind ratio at local level goes beyond 1, H/W ratio greater than 1.2 and distance between two buildings are less which is unsuitable for ventilation as narrow roads surrounded by large structures prevents motion thereby further aggravating the situation. In such cases it is better to regulate traffic movement flowing through such areas; promote walkability and cycling; regulate goods traffic movement via certain standard operating procedures (SoPs).

Recommendations (Details are mentioned for each recommendation in earlier section):

- Study of **Traffic Demand of Industrial Units** to capture intensity of traffic movement for good and supply.
- **Control of traffic movement** in Sub-City Level Markets, Non-Hierarchical Commercial Centres and District Centres should be done.
- Retail Enterprises to **shift to electric vehicles**, clean fuel for procurement and transport of goods and supply.
- **In-situ development** of slum clusters.
- **Regulation of Household industries** primarily contributing to Particulate Matter concentration.
- Maintaining continuous engagement with the concerned authorities to maximise **LPG/PNG coverage for domestic and commercial cooking** with a target of 100 per cent coverage
- Promoting **Walkability, Electric vehicles and Bicycle Usage** via developing user-friendly road network.
- **Greening** of Roads
- Design of roadside **automatic sprinkling system**

- Improving **efficiency in Street Sweeping (dust collection system)**.

Note: Vehicle emission have not been accounted due to non-availability of latest traffic volume data. However, as per observations and study of source apportionment reports, the emission from vehicular sources will contribute significantly and thus should be considered as a major source in any case.



LCZ			LANDUSE			ALTITUDE	POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)	MONTHS	PM2.5	PM10		
Dense lowrise	0.074	2.35	COMMERCIAL	0.11	3.5	200-240	January	204.69	0	135.064	0.873729
Dense midrise	0.000	0.00	INDUSTRIAL	0.7737	24.6		Februray	209.79	0	162.791	0.929286
Open midrise	0.000	0.00	TRANSPORTATION	0.355	11.3		March	107.61	0	211.154	1.117419
Open highrise	0.000	0.00	RECREATIONAL	0.2717	8.7		April	129.17	0	160.931	1.160667
Open lowrise	0.012	0.37	RESIDENTIAL	1.0265	32.7		May	126.76	0	155.299	1.145645
Compact Lowrise	0.452	14.39	PSP FACILITIES	0	0.0		June	112.3	0	162.534	1.236667
Compact Midrise	0.994	31.66	GOVERNMENT	0	0.0		July	67.36	0	208.254	1.115645
Compact Highrise	0.000	0.00	UTILITY	0	0.0		August	46.86	0	193.113	0.998
Large lowrise	0.057	1.80	SPECIAL AREA	0.209	6.7		September	50.15	0	120.12	0.9295
Sparsely built	0.000	0.00	WATERBODY		0.0		October	105.34	0	77.2908	0.587258
Green belt	1.000	31.85	GREEN BELT	0.4	12.7		November	148.77	0	83.0508	0.649667
Open area	0.200	6.37					December	179.94	0	57.195	0.616935
Waterbody	0.000	0.00									
Road	0.34	10.83									
Heavy Industry											

Table 41: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

5.3. IHBAS

Table 42: Emission sources around IHBAS Monitoring station

IHBAS	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.20	0.01	0.12		
		Eat Out			0.01	0.05	
		DG Set				0.06	
	Industrial	Industries	13.50	0.42		273.28	
	Transportation	Vehicles	9.60	0.30	Not accounted		
		Road Dust			9.73	77.08	
	Recreational	Biogenic	3.60	0.11	Not accounted		
	Residential	Cooking	45.90	1.44	1.70	10.81	
		Refuse burning			1.48	2.17	
	PSP		27.50	0.86	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.40	0.71	0.88	
		Biogenic			Not accounted		
Total					13.75	364.35	

It is located within Delhi Planning Zone E. The station recorded 242 days of pollution in a year during 2019 which makes it a primary hotspot of air pollution in Delhi.

IHBAS is located near posh areas in West Delhi i.e., Mansarovar Garden. This accounts for large number of individual private vehicle ownership. And such posh colonies are often attributed to higher usage of emission from cooking.

The presence of industries in North and South of the Shadipur station accounts for higher share of emission of particulate pollutants coupled with very low vegetation along roads. The presence of public-semi-public facilities which attract a lot of traffic can be attributed to higher share of vehicular emission and road dust. (Refer to Map 44)

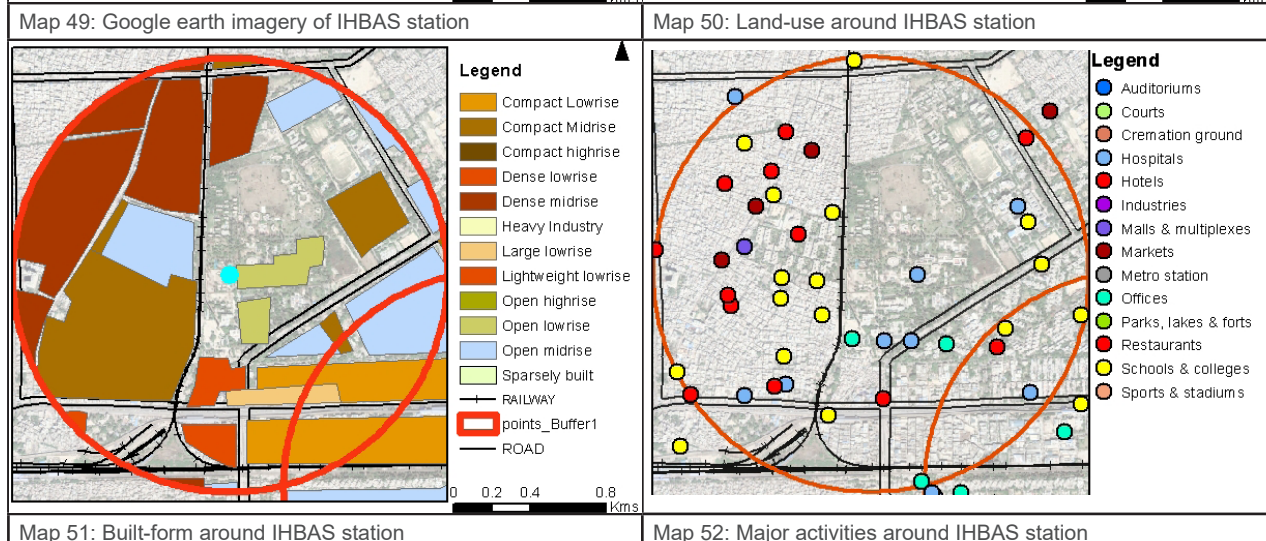
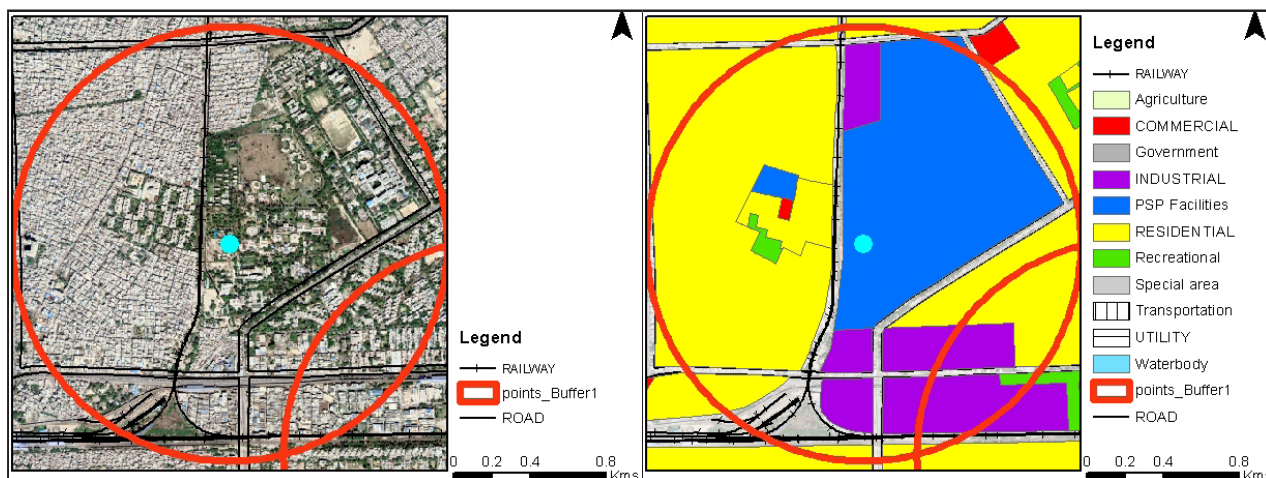
The Local Climate Zone of IHBAS is predominantly occupied with open area and green belt followed by dense mid-rise, compact mid-rise, open-mid rise and few dense low-rise and open low-rise. (Refer to Map 51)

The large contiguous space of dense mid-rise and compact low-rise poses an issue of dispersion with narrow streets for ventilation and very few green infrastructures. The presence of arterial road on one side and railway line on other side further aggravates the situation of stagnation of pollutants. (Refer to Map 49)

All these physical attributes contribute IHBAS towards becoming a '**primary hotspot area**'.

Note: Vehicle emission have not been accounted due to non-availability of latest traffic volume data. However, as per observations and study of source apportionment reports, the emission from vehicular sources will contribute significantly and thus should be considered as a major source in any case.

Recommendations (Details are mentioned for each recommendation in earlier section):



LCZ			LANDUSE			ALTITUDE	POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%		MONTHS	PM2.5	PM10		
Dense lowrise	0.084	2.66	COMMERCIAL	0.0053	0.2	200-220	January	208.58		176.798	1.1437097
Dense midrise	0.591	18.82	INDUSTRIAL	0.4243	13.5		Febrauray	128.12		274.374	1.56625
Open midrise	0.379	12.08	TRANSPORTATION	0.3	9.6		March	92.62		333.86	1.7667742
Open highrise	0.000	0.00	RECREATIONAL	0.1134	3.6		April	111.27		157.257	1.1341667
Open lowrise	0.083	2.64	RESIDENTIAL	1.4398	45.9		May	113.52		164.088	1.2104839
Compact Lowrise	0.220	7.00	PSP FACILITIES	0.863	27.5		June	95.83		229.146	1.7435
Compact Midrise	0.493	15.70	GOVERNMENT	0	0.0		July	72.83		267.084	1.4308065
Compact Highrise	0.000	0.00	UTILITY	0	0.0		August	52.11		373.127	1.9283051
Large lowrise	0.041	1.30	SPECIAL AREA		0.0		September	37.40		172.028	1.3311667
Sparsely built	0.000	0.00	WATERBODY		0.0		October	112.78		131.082	0.9959677
Green belt	0.400	12.74	GREEN BELT		0.0		November	163.62		163.289	1.2773333
Open area	0.850	27.07					December	171.28		126.308	1.3624194
Waterbody	0.000	0.00									
Road	0.000	0.00									
Heavy Industry		0.00									

Table 43: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

Table 44: Emission sources around NSIT Monitoring station

NSIT Dwarka	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	5.20	0.16	3.70		
		Eat Out			0.25	1.60	
		DG Set				1.83	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	8.90	0.28	Not accounted		
		Road Dust			9.08	71.94	
	Recreational	Biogenic	3.70	0.12	Not accounted		
	Residential	Cooking	61.30	1.93	2.28	14.49	
		Refuse burning			1.99	2.91	
	PSP		20.70	0.65	Not accounted		
	Government		0.00	0.00			
	Utility		0.20	0.01			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					17.30	92.78	

Note: Vehicle emission have not been accounted due to non-availability of latest traffic volume data. However, as per observations and study of source apportionment reports, the emission from vehicular sources will contribute significantly and thus should be considered as a major source in any case.

Table 45: Emission sources around DTU Monitoring station

DTU, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	7.30	0.23	Not accounted		
		Road Dust			7.46	59.09	
	Recreational	Biogenic	11.00	0.35	Not accounted		
	Residential	Cooking	54.00	1.69	1.99	12.69	
		Refuse burning			1.74	2.55	
	PSP		24.60	0.77	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		3.20	0.10			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					11.19	74.34	

Note: Vehicle emission have not been accounted due to non-availability of latest traffic volume data. However, as per observations and study of source apportionment reports, the emission from vehicular sources will contribute significantly and thus should be considered as a major source in any case.

5.4. OTHER STATIONS

Similarly, emission sources from all other stations can also be concluded as follows:

Table 46: Emission sources around ITO Monitoring station

ITO, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	1.60	0.05	1.16		
		Eat Out			0.08	0.50	
		DG Set				0.57	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.60	0.30	Not accounted		
		Road Dust			9.73	77.08	
	Recreational	Biogenic	19.00	0.59	Not accounted		
	Residential	Cooking	19.00	0.59	0.70	4.43	
		Refuse burning			0.61	0.89	
	PSP		34.70	1.09	Not accounted		
	Government		11.00	0.35			
	Utility		5.00	0.16			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.10			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					12.27	83.47	

Table 47: Emission sources around Sirifort Monitoring station

Sirifort, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	5.70	0.18	Not accounted		
		Road Dust			5.84	46.25	
	Recreational	Biogenic	27.50	0.87	Not accounted		
	Residential	Cooking	51.80	1.63	1.92	12.24	
		Refuse burning			1.68	2.46	
	PSP		15.90	0.50	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					9.44	60.95	

Table 48: Emission sources around Mandir marg Monitoring station

Mandir Marg, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	2.50	0.08	1.85		
		Eat Out			0.13	0.80	
		DG Set				0.91	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.70	0.31	Not accounted		
		Road Dust			10.05	79.65	
	Recreational	Biogenic	41.00	1.29	Not accounted		
	Residential	Cooking	28.50	0.89	1.05	6.68	
		Refuse burning			0.92	1.34	
	PSP		9.30	0.29	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		8.90	0.28			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					14.00	89.39	

Table 49: Emission sources around Anand Vihar Monitoring station

Anand Vihar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	30.30	0.95		612.30	
	Transportation	Vehicles	25.10	0.79	Not accounted		
		Road Dust			25.62	202.97	
	Recreational	Biogenic	1.60	0.05	Not accounted		
	Residential	Cooking	42.20	1.33	1.57	9.99	
		Refuse burning			1.37	2.01	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					28.56	827.27	

Table 50: Emission sources around R.K.Puram Monitoring station

RK Puram, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	4.50	0.14	3.24		
		Eat Out			0.22	1.40	
		DG Set				1.60	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.20	0.29	Not accounted		
		Road Dust			9.40	74.51	
	Recreational	Biogenic	19.70	0.62	Not accounted		
	Residential	Cooking	57.00	1.79	2.11	13.44	
		Refuse burning			1.84	2.70	
	PSP		0.30	0.01	Not accounted		
	Government		9.50	0.29			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					16.82	93.65	

Table 51: Emission sources around Punjabi Bagh Monitoring station

Punjabi Bagh, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	29.80	0.94	Not accounted		
		Road Dust			30.48	241.51	
	Recreational	Biogenic	19.80	0.62	Not accounted		
	Residential	Cooking	44.20	1.39	1.64	10.44	
		Refuse burning			1.43	2.10	
	PSP		6.20	0.19	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					33.56	254.05	

Table 52: Emission sources around ITO Monitoring station

ITO, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	1.60	0.05	1.16		
		Eat Out			0.08	0.50	
		DG Set				0.57	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.60	0.30	Not accounted		
		Road Dust			9.73	77.08	
	Recreational	Biogenic	19.00	0.59	Not accounted		
	Residential	Cooking	19.00	0.59	0.70	4.43	
		Refuse burning			0.61	0.89	
	PSP		34.70	1.09	Not accounted		
	Government		11.00	0.35			
	Utility		5.00	0.16			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.10			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					12.27	83.47	

Table 53: Emission sources around Sirifort Monitoring station

Sirifort, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	5.70	0.18	Not accounted		
		Road Dust			5.84	46.25	
	Recreational	Biogenic	27.50	0.87	Not accounted		
	Residential	Cooking	51.80	1.63	1.92	12.24	
		Refuse burning			1.68	2.46	
	PSP		15.90	0.50	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					9.44	60.95	

Table 54: Emission sources around Mandir marg Monitoring station

Mandir Marg, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	2.50	0.08	1.85		
		Eat Out			0.13	0.80	
		DG Set				0.91	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.70	0.31	Not accounted		
		Road Dust			10.05	79.65	
	Recreational	Biogenic	41.00	1.29	Not accounted		
	Residential	Cooking	28.50	0.89	1.05	6.68	
		Refuse burning			0.92	1.34	
	PSP		9.30	0.29	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		8.90	0.28			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
Biogenic		Not accounted					
Total					14.00	89.39	

Table 55: Emission sources around Aya Nagar Monitoring station

Aya Nagar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	7.60	0.24	Not accounted		
		Road Dust			7.78	61.66	
	Recreational	Biogenic	0.00	0.00	Not accounted		
	Residential	Cooking	38.20	1.20	1.42	9.01	
		Refuse burning			1.24	1.81	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	54.10	1.70	3.01	3.76	
		Biogenic			Not accounted		
Total					13.44	76.24	

Table 56: Emission sources around Anand Vihar Monitoring station

Anand Vihar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	30.30	0.95		612.30	
	Transportation	Vehicles	25.10	0.79	Not accounted		
		Road Dust			25.62	202.97	
	Recreational	Biogenic	1.60	0.05	Not accounted		
	Residential	Cooking	42.20	1.33	1.57	9.99	
		Refuse burning			1.37	2.01	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					28.56	827.27	

Table 57: Emission sources around RK Puram Monitoring station

RK Puram, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	4.50	0.14	3.24		
		Eat Out			0.22	1.40	
		DG Set				1.60	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.20	0.29	Not accounted		
		Road Dust			9.40	74.51	
	Recreational	Biogenic	19.70	0.62	Not accounted		
	Residential	Cooking	57.00	1.79	2.11	13.44	
		Refuse burning			1.84	2.70	
	PSP		0.30	0.01	Not accounted		
	Government		9.50	0.29			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					16.82	93.65	

Table 58: Emission sources around Punjabi Bagh Monitoring station

Punjabi Bagh, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
Land Use	Commercial	Hotel	0.00	0.00	PM2.5	PM10	
		Eat Out			0.00		
		DG Set			0.00	0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	29.80	0.94	Not accounted		
		Road Dust			30.48	241.51	
	Recreational	Biogenic	19.80	0.62	Not accounted		
	Residential	Cooking	44.20	1.39	1.64	10.44	
		Refuse burning			1.43	2.10	
	PSP		6.20	0.19	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					33.56	254.05	

Table 59: Emission sources around Lodhi Road Monitoring station

Lodhi Road, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.90	0.03	0.69		
		Eat Out			0.05	0.30	
		DG Set				0.34	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.20	0.29	Not accounted		
		Road Dust			9.40	74.51	
	Recreational	Biogenic	20.20	0.63	Not accounted		
	Residential	Cooking	47.40	1.49	1.76	11.19	
		Refuse burning			1.53	2.25	
	PSP		16.90	0.53	Not accounted		
	Government		5.80	0.18			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					13.44	88.59	

Table 60: Emission sources around North campus DU Monitoring station

North Campus, DU, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	19.10	0.59		380.27	
	Transportation	Vehicles	9.90	0.31	Not accounted		
		Road Dust			10.05	79.65	
	Recreational	Biogenic	4.10	0.13	Not accounted		
	Residential	Cooking	61.70	1.94	2.29	14.57	
		Refuse burning			2.00	2.93	
	PSP		4.90	0.15	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					14.34	477.42	

Table 61: Emission sources around Burari Crossing Monitoring station

Burari Crossing, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	3.00	0.09	2.08		
		Eat Out			0.14	0.90	
		DG Set				1.03	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	11.10	0.35	Not accounted		
		Road Dust			11.35	89.93	
	Recreational	Biogenic	13.70	0.43	Not accounted		
	Residential	Cooking	14.30	0.45	0.53	3.38	
		Refuse burning			0.46	0.68	
	PSP		7.20	0.23	Not accounted		
	Government		0.00	0.00			
	Utility		5.10	0.16			
	Special Area		0.00	0.00			
	Waterbody		4.80	0.15			
	Agricultural	Agri. Burning	41.40	1.30	2.30	2.87	
		Biogenic			Not accounted		
Total					16.87	98.79	

Table 62: Emission sources around CRRM Mathura Monitoring station

CRRM Mathura Road, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	24.60	0.77		496.29	
	Transportation	Vehicles	10.20	0.32	Not accounted		
		Road Dust			10.38	82.22	
	Recreational	Biogenic	13.80	0.43	Not accounted		
	Residential	Cooking	20.30	0.64	0.76	4.81	
		Refuse burning			0.66	0.97	
	PSP		16.80	0.53	Not accounted		
	Government		0.00	0.00			
	Utility		14.00	0.44			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					11.79	584.28	

Table 63: Emission sources around Pusa Monitoring station

Pusa, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	7.80	0.24	5.55		
		Eat Out			0.38	2.40	
		DG Set				2.74	
	Industrial	Industries	18.30	0.58		373.83	
	Transportation	Vehicles	8.60	0.27	Not accounted		
		Road Dust			8.76	69.37	
	Recreational	Biogenic	2.10	0.07	Not accounted		
	Residential	Cooking	17.90	0.56	0.66	4.21	
		Refuse burning			0.58	0.85	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	46.20	0.00	0.00	0.00	
Biogenic		Not accounted					
Total					15.92	453.39	

Table 64: Emission sources around IGI Airport Monitoring station

IGI Airport, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0	
	Transportation	Vehicles	91.40	2.87	Not accounted		
		Road Dust			93.07	737.39	
	Recreational	Biogenic	0.00	0.00	Not accounted		
	Residential	Cooking	0.00	0.00	0.00	0.00	
		Refuse burning			0.00	0.00	
	PSP		0.00	0.00	Not accounted		
	Government		9.40	0.29			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					93.07	737.39	

Table 65: Emission sources around East Arjun Nagar Monitoring station

East Arjun Nagar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	12.90	0.41	9.48		
		Eat Out			0.64	4.10	
		DG Set				4.68	
	Industrial	Industries	0.00	0.00		0	
	Transportation	Vehicles	7.60	0.24	Not accounted		
		Road Dust			7.78	61.66	
	Recreational	Biogenic	0.20	0.01	Not accounted		
	Residential	Cooking	62.30	1.96	2.31	14.72	
		Refuse burning			2.02	2.96	
	PSP		12.40	0.39	Not accounted		
	Government		2.00	0.06			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		3.20	0.10			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					22.24	88.12	

Table 66: Emission sources around Ashok Vihar Monitoring station

Ashok Vihar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	2.70	0.09	2.08		
		Eat Out			0.14	0.90	
		DG Set				1.03	
	Industrial	Industries	9.10	0.29		186.91	
	Transportation	Vehicles	9.20	0.29	Not accounted		
		Road Dust			9.40	74.51	
	Recreational	Biogenic	21.70	0.68	Not accounted		
	Residential	Cooking	52.70	1.66	1.96	12.47	
		Refuse burning			1.71	2.51	
	PSP		4.80	0.15	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					15.30	278.32	

Table 67: Emission sources around Jawaharlal Nehru Stadium Monitoring station

Jawaharlal Nehru Stadium,	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
Land Use	Commercial	Hotel	1.10	0.03	PM2.5	PM10	
		Eat Out			0.69		
		DG Set			0.05	0.30	
	Industrial	Industries	0.00	0.00		0	
	Transportation	Vehicles	7.00	0.22	Not accounted		
		Road Dust			7.13	56.52	
	Recreational	Biogenic	22.60	0.71	Not accounted		
	Residential	Cooking	62.40	1.96	2.31	14.72	
		Refuse burning			2.02	2.96	
	PSP		0.90	0.03	Not accounted		
	Government		6.10	0.19			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					12.21	74.85	

Table 68: Emission sources around Nehru Nagar Monitoring station

Nehru Nagar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.60	0.02	0.46		
		Eat Out			0.03	0.20	
		DG Set				0.23	
	Industrial	Industries	2.50	0.08		51.56	
	Transportation	Vehicles	9.60	0.30	Not accounted		
		Road Dust			9.73	77.08	
	Recreational	Biogenic	5.00	0.16	Not accounted		
	Residential	Cooking	70.00	2.19	2.58	16.45	
		Refuse burning			2.26	3.31	
	PSP		5.50	0.17	Not accounted		
	Government		0.00	0.00			
	Utility		6.80	0.21			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					15.06	148.82	

Table 69: Emission sources around Dr. Karni Singh Shooting Range Monitoring station

Dr. Karni Singh Shooting Range, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	0.00	0.00	Not accounted		
		Road Dust			0	0	
	Recreational	Biogenic	96.00	3.01	Not accounted		
	Residential	Cooking	0.00	0.00	0.00	0.00	
		Refuse burning			0.00	0.00	
	PSP		3.30	0.11	Not accounted		
	Government		0.80	0.03			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		

Table 70: Emission sources around Patparganj Monitoring station

Patparganj, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	6.20	0.19		122.46	
	Transportation	Vehides	11.50	0.36	Not accounted		
		Road Dust			11.67	92.49	
	Recreational	Biogenic	5.50	0.17	Not accounted		
	Residential	Cooking	71.30	2.23	2.63	16.75	
		Refuse burning			2.30	3.37	
	PSP		1.70	0.05	Not accounted		
	Government		0.00	0.00			
	Utility		1.40	0.05			
	Special Area		0.00	0.00			
	Waterbody		2.20	0.07			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					16.60	235.07	

Table 71: Emission sources around Sonia Vihar Monitoring station

Sonia Vihar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	6.40	0.20	Not accounted		
		Road Dust			6.49	51.39	
	Recreational	Biogenic	0.60	0.02	Not accounted		
	Residential	Cooking	28.00	0.88	1.04	6.61	
		Refuse burning			0.91	1.33	
	PSP		9.50	0.29	Not accounted		
	Government		0.00	0.00			
	Utility		19.10	0.59			
	Special Area		0.00	0.00			
	Waterbody		9.60	0.30			
	Agricultural	Agri. Burning	27.70	0.87	1.54	1.92	
		Biogenic			Not accounted		
Total					9.97	61.25	

Table 72: Emission sources around Jahangirpuri Monitoring station

Jahangirpuri, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	2.30	0.07	1.62		
		Eat Out			0.11	0.70	
		DG Set				0.80	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	4.80	0.15	Not accounted		
		Road Dust			4.86	38.54	
	Recreational	Biogenic	13.30	0.42	Not accounted		
	Residential	Cooking	59.80	1.88	2.22	14.12	
		Refuse burning			1.94	2.84	
	PSP		4.00	0.13	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		15.90	0.50			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					10.75	57.00	

Table 73: Emission sources around Rohini Monitoring station

Rohini, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.10	0.01	0.23		
		Eat Out			0.02	0.10	
		DG Set				0.11	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	9.30	0.29	Not accounted		
		Road Dust			9.40	74.51	
	Recreational	Biogenic	20.10	0.63	Not accounted		
	Residential	Cooking	51.60	1.62	1.91	12.17	
		Refuse burning			1.67	2.45	
	PSP		7.90	0.25	Not accounted		
	Government		0.00	0.00			
	Utility		1.10	0.03			
	Special Area		6.40	0.20			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					13.23	89.34	

Table 74: Emission sources around Najafgarh Monitoring station

Najafgarh, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	4.80	0.15	Not accounted		
		Road Dust			4.86	38.54	
	Recreational	Biogenic	0.00	0.00	Not accounted		
	Residential	Cooking	6.40	0.20	0.24	1.50	
		Refuse burning			0.21	0.30	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	88.50	2.78	4.92	6.14	
		Biogenic			Not accounted		
Total					10.23	46.49	

Table 75: Emission sources around Vivek Vihar Monitoring station

Vivek Vihar, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
Land Use	Commercial	Hotel	2.60	0.08	PM2.5	PM10	
		Eat Out			1.85		
		DG Set			0.13	0.80	
	Industrial	Industries	16.60	0.52		335.16	
	Transportation	Vehicles	8.20	0.26	Not accounted		
		Road Dust			8.43	66.80	
	Recreational	Biogenic	9.60	0.30	Not accounted		
	Residential	Cooking	57.10	1.79	2.11	13.44	
		Refuse burning			1.84	2.70	
	PSP		6.00	0.19	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					14.36	419.82	

Table 76: Emission sources around Major DCN Monitoring station

Major DCN Stadium, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	0.80	0.03	Not accounted		
		Road Dust			0.97	7.71	
	Recreational	Biogenic	45.50	1.43	Not accounted		
	Residential	Cooking	26.30	0.83	0.98	6.23	
		Refuse burning			0.85	1.25	
	PSP		24.80	0.78	Not accounted		
	Government		2.40	0.07			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					2.81	15.19	

Table 77: Emission sources around Narela Monitoring station

Narela, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	7.80	0.25	5.78		
		Eat Out			0.39	2.50	
		DG Set				2.85	
	Industrial	Industries	54.50	1.71		1102.15	
	Transportation	Vehicles	32.10	1.01	Not accounted		
		Road Dust			32.75	259.50	
	Recreational	Biogenic	2.40	0.08	Not accounted		
	Residential	Cooking	3.20	0.10	0.12	0.75	
		Refuse burning			0.10	0.15	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					39.15	1367.90	

Table 78: Emission sources around Okhla Phase-2 Monitoring station

Okhla Phase 2, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
Land Use	Commercial	Hotel	1.80	0.06	PM2.5	PM10	
		Eat Out			1.39		
		DG Set			0.09	0.60	
	Industrial	Industries	48.40	1.52		979.69	
	Transportation	Vehicles	6.10	0.19	Not accounted		
		Road Dust			6.16	48.82	
	Recreational	Biogenic	20.40	0.64	Not accounted		
	Residential	Cooking	23.20	0.73	0.86	5.48	
		Refuse burning			0.75	1.10	
	PSP		0.00	0.00	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					9.26	1036.37	

Table 79: Emission sources around Wazirpur Monitoring station

Wazirpur, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	3.00	0.09	2.08		
		Eat Out			0.14	0.90	
		DG Set				1.03	
	Industrial	Industries	29.00	0.91		586.52	
	Transportation	Vehicles	8.00	0.25	Not accounted		
		Road Dust			8.11	64.23	
	Recreational	Biogenic	11.70	0.37	Not accounted		
	Residential	Cooking	47.60	1.49	1.76	11.19	
		Refuse burning			1.53	2.25	
	PSP		0.70	0.02	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					13.62	666.12	

Table 80: Emission sources around Bawana Monitoring station

Bawana, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	40.70	1.28		825.00	
	Transportation	Vehicles	7.50	0.24	Not accounted		
		Road Dust			7.78	61.66	
	Recreational	Biogenic	0.10	0.01	Not accounted		
	Residential	Cooking	30.90	0.97	1.14	7.28	
		Refuse burning			1.00	1.46	
	PSP		3.70	0.11	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		3.80	0.12			
	Agricultural	Agri. Burning	13.40	0.42	0.74	0.93	
		Biogenic			Not accounted		
Total					10.67	896.34	

Table 81: Emission sources around Shri Aurobindo Marg Monitoring station

Sri Aurobindo Marg, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.70	0.02	0.46		
		Eat Out			0.03	0.20	
		DG Set				0.23	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	6.40	0.20	Not accounted		
		Road Dust			6.49	51.39	
	Recreational	Biogenic	63.40	1.99	Not accounted		
	Residential	Cooking	4.20	0.13	0.15	0.98	
		Refuse burning			0.13	0.20	
	PSP		25.50	0.80	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
Biogenic		Not accounted					
Total					7.27	52.99	

Table 82: Emission sources around Mundka Monitoring station

Mundka, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	1.10	0.04	0.92		
		Eat Out			0.06	0.40	
		DG Set				0.46	
	Industrial	Industries	19.80	0.62		399.61	
	Transportation	Vehicles	6.40	0.20	Not accounted		
		Road Dust			6.49	51.39	
	Recreational	Biogenic	8.80	0.28	Not accounted		
	Residential	Cooking	60.70	1.91	2.25	14.34	
		Refuse burning			1.97	2.88	
	PSP		4.00	0.13	Not accounted		
	Government		0.00	0.00			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	0.00	0.00	0.00	0.00	
		Biogenic			Not accounted		
Total					11.69	469.08	

Table 83: Emission sources around Dwarka Sec-8 Monitoring station

Dwarka Sector 8, Delhi	Land Use	Activity/ Source	L.U. Percentage	Areas (in Sq.Km)	Emission in tonnes/year		Source
					PM2.5	PM10	
Land Use	Commercial	Hotel	0.00	0.00	0.00		
		Eat Out			0.00	0.00	
		DG Set				0.00	
	Industrial	Industries	0.00	0.00		0.00	
	Transportation	Vehicles	25.70	0.81	Not accounted		
		Road Dust			26.27	208.11	
	Recreational	Biogenic	13.30	0.42	Not accounted		
	Residential	Cooking	22.50	0.71	0.84	5.33	
		Refuse burning			0.73	1.07	
	PSP		5.70	0.18	Not accounted		
	Government		19.80	0.62			
	Utility		0.00	0.00			
	Special Area		0.00	0.00			
	Waterbody		0.00	0.00			
	Agricultural	Agri. Burning	13.10	0.41	0.73	0.91	
		Biogenic			Not accounted		
Total					28.56	215.42	

6. FURTHER STUDIES

The chapter suggests all the further studies that needs to be carried out related to landuse, built form, vegetation for control of air pollution in NCT Delhi.

NCT Delhi spread over an area of 1483 sq. kms. with a population of 16.75 million (Census 2011) and a density of 11,297 persons per sq.km is proposed to grow to 230 lakhs by 2021 and as per best fit curve model of population projection could reach upto 250 lakhs by 2030. The major environmental issue in the city is the high levels of pollution especially $PM_{2.5}$ and PM_{10} .

The urban sprawl, builtform density need to be studied to control local level increase in pollution levels. The Source Apportionment Studies and Carrying Capacity Analysis has identified zones reporting high pollution levels or hotspots. Detailed scientific studies need to be undertaken both in the hotspot areas and the other areas to arrive at patterns of landuse, built form and vegetation types that would help to contain the rise an air pollution levels .

6.1. SCIENTIFIC STUDY TO CORRELATE LAND USE ACTIVITIES AND AIR POLLUTION

The study would include identification of planning zones, sub zones or wards which fall into hotspot and non-hotspot areas w.r.t $PM_{2.5}$ and PM_{10} and record the air pollution trends as available from the monitoring stations in the area and study the following in the area followed by:

- **Overview of the selected area** to arrive at population, density predominant landuse, green,recreation and waterbodies, traffic characteristics, infrastructural status etc.
- **Landuse typology-** Residential, Commercial, Industrial, Public-Semipublic, Mixed use (types of mix), recreation, waterbodies etc and trends as per the MPD,1962, PDP 1980 and MPD 2021 and proposed interventions as per MPD 2041.
- **Flooruse** – Building use and flooruse in select landuses alongwith and heights to understand the existing patterns in the selected area.
- **Study of Byelaws and Development controls-** as applicable to the landuse size of building to understand violations if any
- **Identification of activities w.r.t to Landuse** – Activity listing to arrive at air polluting activities such as traffic composition, volume, street vending, cooking, manufacturing, waste disposal etc.and identification of air polluting activoties
- **Location and spread of activities w.r.t landuse and seasons** - appropriate mapping to understand the spread and intensity of the activities
- **Preparation of emission inventory based on the air polluting activities through primary surveys**

- **Estimation of air pollution load due to the polluting activities based on appropriate emission factors**
- **Identification of aspects of landuse and built form that impact air pollution and suggestions for their management and control**

6.2. BUILT- FORM CHARACTERISTICS, AIR FLOW AND VENTILATION COEFFICIENT

The study would include identification of planning zones, sub zones or wards which fall into hotspot and non-hotspot areas w.r.t $PM_{2.5}$ and PM_{10} and record the air pollution trends as available from the monitoring stations in the area and study the following in the area followed by:

- **Overview of the selected area** to arrive at population, density predominant landuse, green, recreation and waterbodies, traffic characteristics, infrastructural status etc.
- **Study of Byelaws and Development controls-** as applicable to the landuse, size of building to understand the applicable FloorArea Ratios, Ground Cover, setbacks etc. and violations if any
- **Built form Characteristics** – building heights, building density, open to built ratio, predominant orientation
- **Ground Level Concentration of pollution** – for $PM_{2.5}$ and PM_{10} based on GIS or applicable models
- Estimation of air pollution load due to the polluting activities based on appropriate emission factors
- **Simulation of wind flow movement seasonwise** – by application of appropriate models to arrive at areas which trap pollution
- **Suggestions for building heights, orientation etc to be included in the bye laws to enable dispersal of air pollution**

6.3. AIR POLLUTION AND TOLERANT VEGETATION

The study would include study of existing tree, shrub, climbers and ground cover in identified planning zones, sub zones or wards which fall into hotspot and non-hotspot areas w.r.t $PM_{2.5}$ and PM_{10} and record the air pollution trends as available from the monitoring stations in the area and study the following in the area followed by:

- **Overview of the selected area** to arrive at population, density predominant landuse, green, recreation and waterbodies, traffic characteristics, infrastructural status etc.
- **Literature study on guidelines for greenbelt development for mitigating air pollution** – species suggested for various agroclimatic zones in India and suggestions for propagation, location w.r.t air pollution source, density and width of plantations in the case of NCT Delhi
- **Pattern of existing vegetation** – location, spread and species typology along roads of various hierarchy, parks of various hierarchy, residential, institutional, commercial, industrial areas, along waterbodies and within urban /city forests w.r.t – type of species, height spread, canopy size (large shrubs and trees), evergreen/deciduous, leaf characteristics,

condition etc

- **Air Pollution Tolerance Index** – estimation of the APTI of existing vegetation based on laboratory analysis of samples from the area
- **Suggestion for selection of the right vegetation to enhance air pollution exposure/mitigation for study area**– type of species mix, propagation, location and maintenance for existing area
- **Suggestion for selection of the right vegetation to enhance air pollution exposure/mitigation for NCT Delhi**– type of species mix w.r.t. various transport corridors Industrial, Commercial, Institutional, Residential landuses including propagation, location and maintenance guidelines

6.4. DELINEATION OF AIR SHED OF NCT DELHI

Airshed is roughly analogous to the concept of the watershed and considers air basins as geographical areas that share the same air because of topography, meteorology and climate. To address the problem of air pollution comprehensively, Sagnik Dey, Associate Professor at IIT-Delhi and Coordinator for the Centre for Excellence for Research for Clean Air (CERCA), said, **“We need to delineate airsheds based on wind flows and their pollutant reach. The city action plans should be integrated with the larger airshed management strategy to deal with the problem”.**

An approach of delineating Airshed can be developed with focus on inflows and outflows. The quality of air is influenced by the intensity of activity(ies). Cities are dependent on each other for goods, raw materials, employment opportunities, etc. Therefore, identifying the intensity of flows will help in building a functional relationship between the dominant centre (focus area) and the surrounding cities/towns

- **Gravitation Analysis between cities adjoining NCT Delhi in NCR** – Ghaziabad, Noida, Greater Noida, Faridabad, Gurugram, Jhajjar, Sonapat, Baghpat etc. to understand the intensity of activities and flows between these cities and implication on air pollution load.
- **Sources of Pollution in NCR** – Identification of sources of pollution based on latest Source Apportionment studies conducted for NCR
- **Estimation of Ground Level Concentrations of air pollutants** - based on appropriate models w.r.t identified sources
- **Delineation of Airshed of NCT Delhi**-guidelines for development and recommendations for regulation of landuse and activities in the Delineated region.

7. ANNEXURE

BEST PRACTICES ON WASTE TO WEALTH

1. Vengurla - zero-garbage hamlet on India's coast

Vengurla, a small municipality just half-hour drive from India's tourist hub of Goa is an example of how a community can effectively tackle waste. It recycles every bit of the 7 tonnes of waste generated each day by the community. Converting its waste to wealth, it earns a hefty income, which is ploughed back into municipal activities. The project is led by Ramdas Kokare, the chief officer of Vengurla municipality under the aegis of United Nations Development Programme (UNDP). According to him, Waste is not a problem. It is the mixed waste and its segregation that is the real challenge.

The highlights of this achievement are:

- Waste is segregated at the primary source of generation by households.
- 3,000 households separate waste in up to four different coloured bins. Municipal collectors pick up waste six days a week and transport it to the municipal dumping ground. The waste collection centre has lush green gardens developed using organic fertilizer. Here it is further segregated by 20 workers in to 23 categories.
- Wet waste is used to generate biogas, producing 30 units of electricity per tonne. This powers all the machines in the dumping ground.
- One of the machines powered by the biogas is a plastic shedding machine. It crushes up to 180 kg of light plastic every day.
- Used with bitumen, shredded plastic is effective in helping build sturdier roads that are able to withstand more wear and tear. These roads offer greater resistance to inclement weather and reduce costs. A one kilo metre stretch of road can use up to 1 tonne of plastic or 1 million carry bags and save INR 10,000 per stretch.
- Vengurla has 12 km of 'plastic' roads and earns Rs.15 per kg of plastic sold to contractors for road building in nearby areas.
- A briquette machine helps process dry waste such as cloth, paper, cardboard into briquettes, which are sold to nearby industries as alternate fuels for boilers.
- Heavy plastic is sold to cement factories where it is melted at 3000 degrees Celsius.
- Each month, the municipality earns Rs. 150,000 which is used to improve solid waste management systems in the village.
- The facility has drawn 7000 visitors so far.

2. Conversion of Waste Plastic into Liquid Hydrocarbons/Energy

Prof. Alka Zadgaonkar and Dr. Umesh Zadgaonkar invented the process to convert waste plastic into useful products like furnace oil and LPG. The process is based on the principle of random depolymerisation and involves selective breaking of C-C bonds. Both plastics and petroleum derived fuels are hydrocarbons. However, the plastic molecules have longer carbon chains than those in LPG, petrol and diesel fuels. Therefore, it is possible to convert waste

plastic into fuels. The process is a thermal selective splitting reaction of the large molecular weight polymer carbon chains under an oxygen free environment and produces small molecular weight molecules.

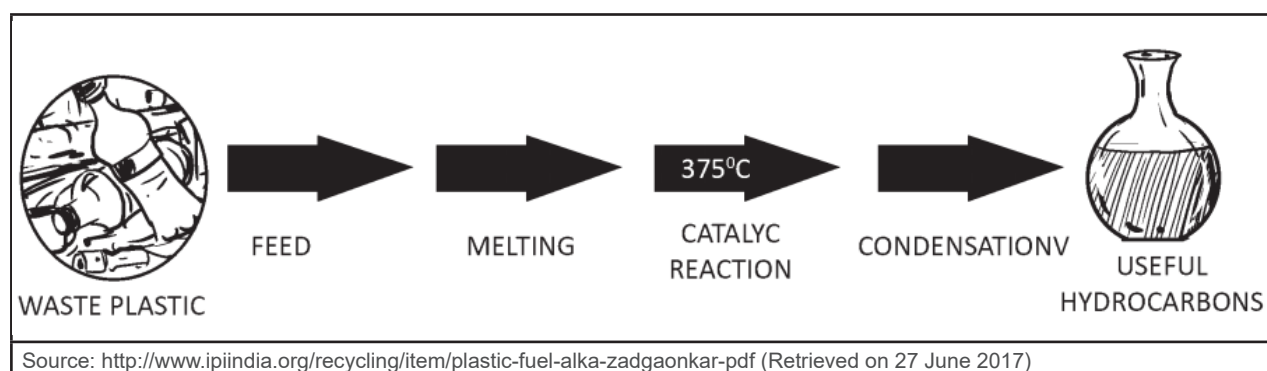
The output from 1 Kg of plastic is shown in table:

Name of End Product	Quantity	End Users
Liquid Hydrocarbons	600 - 800 gm	Agricultural pumps, D.G. Sets, Boiler Fuel, Marine Fuel (bunker), input feed for petroleum refineries, Fuel oil
Coke	70 – 100 gm	Nearby industries using LPG, in-house consumption
Gas	Equivalent to produce net 2.25 units of electricity	Thermal power plants, metallurgical industries

Input: Carry bags, broken buckets and chairs, PVC pipes, CDS, computer keyboards and other e-waste

Advantages:

- 100% waste is converted into value added products.
- Solution to the waste plastic problem, can change global economic scenario by saving millions of dollars in import of crude oil
- No preparatory cleaning or segregation
- Easy transportation of bulky waste
- Sulphur content in the fuel generated is less than 0.002 ppm
- There is no emission in the atmosphere or liquid effluents
- High quality of Liquid Distillate, matches de-sulphurised crude oil



3. Bio-Methanation Plant at Koyambedu Wholesale Market

The Bio-Methanation plant was established in Koyambedu Wholesale Market Complex (Chennai, Tamil Nadu) as a unique national level demonstration project in order to utilize the organic waste generated from the perishables market for power generation. This project is a joint venture between Chennai Metropolitan Development Authority and the Ministry of Non-conventional Energy Sources (MNES) of Government of India. The plant is designed to handle about 30 Metric Tonnes of perishable wastes per day and will generate on an average of 2375 cubic metric of gas through 'Bio-gas Induced Mixing Arrangement' (BIMA digester) to produce 5000 units of electricity per day. The energy production is being fed into the TNEB grid. The

plant is functioning since 4 September 2005.²⁷

4. Polythene Recycling Unit by CEE

Plastic recycling is an alternative method to prevent plastic from entering our environment and thus, reducing the menace. Centre for Environment Education (CEE) has developed the 'Polyloom' which is a plastic weaving handloom that helps reuse and recycling of discarded plastic bags (polybags). The Polyloom is used to produce plastic woven fabric with different designs, which is then used to tailor and create finished products like bags, pouches, bottle holders, etc.²⁸

²⁷ <http://www.cmdachennai.gov.in/mmc.html> (Retrieved on 28 June 2017)

²⁸ Zero Waste System booklet published by Centre for Environment Education (CEE)

Disclaimer Notice:

All the maps and figures are intellectual property of DPCC and SPA Delhi. None of the information in this report may be reproduced, republished or redisseminated in any manner or form without the prior written permission of competent authority.