SUPPLEMENTARY MATERIAL

for "**Identification of critical locations for improvement of air quality developing a Prioritized Clean air Assessment Tool (PCAT)**"

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Table S1 : Details of CPCB monitoring stations considered in the present study
14 cities spread across the geographical expanse of Indian region constituting urban, sub-urban and rural locations were chosen to effectively represent the pollution scenario of the country.

Table S2 : Break Points of criteria pollutants (PM_{10}, $PM_{2.5}$, CO, SO_2, NO_2, O_3) as given by CPCB, India

Table S3 : Seasonal Mean, interquartile range (IQR) and 95th percentile values for all the species during winter and summer season.

Table S4 : Fuzzy Membership Functions
The membership functions characterise the fuzziness in the fuzzy set in a graphical form. Table S3 represents the triangular fuzzy membership function equation of six pollutants (SO_2, CO, NO_2, PM_{10}, $PM_{2.5}$ and O_3) for each of the six linguistic variables.

Table S5 : Estimated National Air Quality Index
Table S5 represents the estimated national air quality index calculated using breakpoint concentrations of six criteria pollutants given by the Central Pollution Control Board (CPCB), India. The concentration of criteria pollutants for 14 Indian cities were obtained from CPCB website.

Table S6 : Estimated Mitigation Priority Index
The developed Prioritised Clean air Assessment Tool (PCAT) was utilised to obtain Mitigation Priority Index (MPI) for 14 Indian cities presented in Table S5.

Table S7 : Comparative study of NAQI and MPI
Table S7 represents the locations considered in the present study, the site type, descriptor pollutant while calculating the NAQI and respective category they fall in as obtained from the estimates.

1 Check for consistency

In a consistent judgement matrix, $\lambda_{max} = $ n, n is the dimension of the judgement matrix and λ_{max} corresponds to the maximum eigenvalue of the matrix (Saaty, 1980; Saaty and Takizawa, 1986). Consistency index (CI) indicates the consistency of values (judgements) in the pairwise judgement matrix. The CI is defined as,

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{6.186 - 6}{6 - 1} = 0.0372 \tag{1}$$

The final consistency check is performed using a parameter called consistency ratio (CR), defined as (Equation:2):

$$Consistency\ Ratio\ (CR) = \frac{Consistency\ Index\ (CI)}{Ratio\ Index\ (RI)} \tag{2}$$

$$= \frac{0.0372}{1.24} = 0.03 \tag{3}$$

Ratio Index (RI) is obtained through averaging the CI of a random reciprocal matrix (Saaty, 1980). The judgement matrix is consistent if the value of CR is found to be less than or equal to 0.1 (Saaty, 2005). A value of CR greater than 0.1 requires reconsideration of the judgements. In the present study CR of the matrix is found to be 0.03 which is well bellow the threshold value of 0.1. Final pairwise judgement matrix with sufficient consistency level is considered for calculation of the weights. Eigenvalue and eigenvector analysis method for calculating the weights are adopted for the purpose. Normalized eigen vectors corresponding to the λ_{max} are considered as weights in this method. In our case, eigen vector corresponding to λ_{max} is denoted as $\vec{\lambda}_{max}$.

Table S1 : Details of CPCB monitoring stations considered in the present study

S.NO.	City	Station Considered	Latitude	Longitude
1	Patna	IGSC Planetarium Complex, Patna	85.137°E	25.594°N
2	Delhi	Mandir Marg, Delhi	28.637°E	77.200°N
3	Navi Mumbai	Airoli, Navi Mumbai	19.158°E	72.994°N
4	Pune	Karve Road, Pune	73.816°E	18.501°N
5	Chandrapur	Chandrapur, Chandrapur	19.971°E	79.303°N
6	Solapur	Solapur, Solapur	75.906°E	17.659°N
7	Jaipur	Police Commissionerate, Jaipur	75.799°E	26.916°N
8	Jodhpur	Collectorate, Jodhpur	73.037°E	26.292°N
9	Hyderabad	Zoo Park, Hyderabad	78.451°E	17.349°N
10	Muzaffarpur	Muzaffarpur Collectorate, Muzaffarpur	85.364°E	26.120°N
11	Kolkata	Victoria, Kolkata	88.34 °E	22.544°N
12	Varanasi	Ardhali Bazar, Varanasi	82.908°E	25.350°N
13	Bengaluru	BWSSB Kadabesanahalli, Bengaluru	77.698°E	12.947°N
14	Chennai	Alandur Bus Depot, Chennai	80.209°E	13.007°N

Table S2 : Break Points of criteria pollutants (PM_{10}, $PM_{2.5}$, CO, SO_2, NO_2, O_3) as given by CPCB, India

NAQI Category (Range)	PM_{10} $(\mu g/m^3)$	$PM_{2.5}$ $(\mu g/m^3)$	SO_2 $(\mu g/m^3)$	NO_2 $(\mu g/m^3)$	CO (mg/m^3)	O_3 $(\mu g/m^3)$
Good (0-50)	0-50	0-30	0-40	0-40	0-1	0-50
Satisfactory (51-100)	51-100	31-60	41-80	41-80	1.1-2.0	51-100
Moderately Polluted (101-200)	101-205	61-90	81-380	81-180	2.1-10	101-168
Poor (201-300)	251-350	91-150	381-800	181-280	10.1-17	169-208
Very Poor (301-400)	351-430	151-250	801-1600	281-400	17.1-34	209-748
Severe (401-500)	>430	>250	>1600	>400	>34	>748

Table S3 : Seasonal Mean, interquartile range (IQR) and 95th percentile values for all the species during winter and summer season. The values of seasonal mean, IQR and 95th percentile for the summer season is given inside brackets. VNS: Varanasi, KOL: Kolkata, MFP: Muzaffarpur, CDR: Chandrapur, SUR: Solapur, JPR: Jaipur, JDR: Jodhpur, HYB: Hyderabad, DEL: Delhi, MUM: Mumbai, PAT: Patna

SITE	SO₂ Mean	SO₂ IQR	SO₂ 95th%	NO₂ Mean	NO₂ IQR	NO₂ 95th%	CO Mean	CO IQR	CO 95th%	O₃ Mean	O₃ IQR	O₃ 95th%	PM₁₀ Mean	PM₁₀ IQR	PM₁₀ 95th%	PM₂.₅ Mean	PM₂.₅ IQR	PM₂.₅ 95th%
Pune	32.1 (23.7)	24.7 (2.6)	45.0 (46.0)	50.4 (40.2)	38.6 (4.4)	75.1 (27.0)	2.3 (2.2)	1.4 (0.5)	6.2 (2.8)	12.0 (17.4)	8.6 (5.9)	13.3 (27.8)	171.1 (90.3)	70.1 (26.5)	261.7 (154.3)	108.3 (62.0)	40.9 (31.4)	186.1 (114.5)
VNS	32.1 (5.5)	38.1 (5.2)	69.6 (38.0)	31.9 (24.7)	9.7 (14.1)	44.0 (11.4)	1.6 (1.1)	1.0 (0.9)	3.3 (2.7)	16.2 (22.5)	10.0 (10.7)	41.3 (25.4)	395.7 (306.6)	152.9 (156.1)	460.7 (437.7)	288.6 (116.8)	119.5 (63.1)	418.6 (234.3)
KOL	5.0	0.9	6.1	75.5	27.3	119.0	1.2		6.1	35.3		41.7	140.1					
MFP	11.2 (8.4)	6.0 (5.1)	18.6 (22.1)	10.8 (10.0)	13.0 (13.0)	22.7 (23.9)	1.8 (1.4)	1.2 (0.4)	3.2 (3.6)	21.8 (14.2)	7.4 (8.4)	33.6 (30.5)				258.5 (85.8)	142.5 (55.5)	319.7 (181.2)
CDR	5.1 (6.8)	2.1 (3.6)	11.8 (10.0)	14.4 (5.0)	18.7 (3.4)	29.9 (18.1)	0.9 (0.6)	0.4 (0.3)	1.6 (1.1)	22.9 (11.2)	7.8 (9.1)	41.0 (23.0)	154.0 (127.4)	60.1 (66.2)	233.1 (214.6)	71.0 (56.1)	25.8 (32.0)	126.0 (109.1)
SUR	16.9 (12.0)	1.4 (1.3)	18.6 (46.9)	39.5 (41.2)	3.3 (6.9)	49.8 (14.1)	2.1 (2.2)	1.2 (0.8)	3.4 (3.2)	47.8 (67.4)	19.9 (27.8)	87.8 (101.5)	109.1 (101.4)	48.9 (40.5)	193.2 (155.8)	55.2 (38.3)	18.5 (17.2)	77.1 (59.7)
JPR	11.4 (13.0)	5.3 (6.3)	22.0 (31.4)	37.4 (21.9)	9.9 (6.3)	49.3 (25.9)	0.8 (0.7)	0.1 (0.3)	1.2 (1.7)	18.2 (53.3)	30.9 (13.8)	47.0 (108.0)	261.4 (215.6)	58.8 (77.0)	284.4 (315.3)	171.9 (90.1)	54.3 (49.6)	228.7 (169.1)
JDR	9.6 (8.2)	6.5 (3.0)	18.7 (37.1)	35.5 (21.8)	14.9 (4.2)	65.8 (18.2)	1.0 (0.7)	0.6 (0.4)	3.6 (1.9)	27.8 (28.4)	15.4 (16.2)	54.5 (49.0)	293.0 (234.8)	117.1 (70.8)	358.7 (438.1)	121.4 (97.5)	54.4 (29.0)	204.8 (239.5)
HYB	11.5 (5.8)	3.0 (2.2)	16.8 (64.8)	2.3 (19.4)	0.8 (40.9)	3.9 (11.6)	1.0 (1.0)	0.6 (0.5)	2.0 (1.6)	41.3 (33.1)	22.3 (26.7)	95.5 (79.6)	100.7 (88.3)	10.3 (23.6)	115.8 (110.2)	56.8 (43.8)	22.2 (23.5)	74.5 (65.1)
DEL	19.8 (23.1)	8.4 (11.5)	31.3 (84.7)	80.3 (50.7)	36.3 (22.5)	126.8 (44.4)	1.8 (1.0)	1.2 (0.5)	3.1 (1.6)	44.7 (36.5)	25.0 (26.9)	129.6 (75.5)	344.8 (201.2)	93.2 (98.5)	538.3 (349.3)	215.6 (63.1)	79.2 (30.8)	325.2 (125.2)
MUM	24.9 (36.8)	17.6 (6.3)	38.0	19.3		(48.1)	3.3 (1.9)	1.3 (0.5)	5.7 (2.6)	31.5			89.8 (71.7)	13.6 (25.4)	116.2 (115.9)	36.7 (42.2)	8.6 (18.3)	43.6 (70.9)
PAT	7.9 (6.8)	2.2 (2.9)	24.0 (30.2)	35.4 (15.9)	10.8 (10.9)	44.7 (16.4)	2.5 (1.4)	1.5 (1.2)	6.1 (3.0)	15.7 (24.0)	12.8 (17.2)	41.7 (50.7)	135.3			324.2 (99.4)	133.6 (47.4)	359.2 (226.9)

Table S4 : Fuzzy Membership Functions

Pollutant	Range of variation	Good	Monitoring for Mitigation	Mitigation	Desired Mitigation	Urgent Mitigation	Very Urgent Mitigation
SO$_2$ ($\mu g m^{-3}$)	< 20	1	0	0	0	0	0
	$20 \leq x < 40$	$\frac{40-x}{40-20}$	$1 - \frac{40-x}{40-20}$	0	0	0	0
	$40 \leq x < 80$	0	$\frac{80-x}{80-40}$	$1 - \frac{80-x}{80-40}$	0	0	0
	$80 \leq x < 380$	0	0	$\frac{380-x}{380-80}$	$1 - \frac{380-x}{380-80}$	0	0
	$380 \leq x < 800$	0	0	0	$\frac{800-x}{800-380}$	$1 - \frac{800-x}{800-380}$	0
	$800 \leq x < 1600$	0	0	0	0	$\frac{1600-x}{1600-800}$	$1 - \frac{1600-x}{1600-800}$
	≥ 1600	0	0	0	0	0	1
CO ($mg m^{-3}$)	< 0.5	1	0	0	0	0	0
	$0.5 \leq x < 1.0$	$\frac{1.0-x}{1.0-0.5}$	$1 - \frac{1.0-x}{1.0-0.5}$	0	0	0	0
	$1.0 \leq x < 2.0$	0	$\frac{2.0-x}{2.0-1.0}$	$1 - \frac{2.0-x}{2.0-1.0}$	0	0	0
	$2.0 \leq x < 10$	0	0	$\frac{10-x}{10-2.0}$	$1 - \frac{10-x}{10-2.0}$	0	0
	$10 \leq x < 17$	0	0	0	$\frac{17-x}{17-10}$	$1 - \frac{17-x}{17-10}$	0
	$17 \leq x < 34$	0	0	0	0	$\frac{34-x}{34-17}$	$1 - \frac{34-x}{34-17}$
	≥ 34	0	0	0	0	0	1
PM$_{10}$ ($\mu g m^{-3}$)	< 25	1	0	0	0	0	0
	$25 \leq x < 50$	$\frac{50-x}{50-25}$	$1 - \frac{50-x}{50-25}$	0	0	0	0
	$50 \leq x < 100$	0	$\frac{100-x}{100-50}$	$1 - \frac{100-x}{100-50}$	0	0	0
	$100 \leq x < 250$	0	0	$\frac{250-x}{250-100}$	$1 - \frac{250-x}{250-100}$	0	0
	$250 \leq x < 350$	0	0	0	$\frac{350-x}{350-250}$	$1 - \frac{350-x}{350-250}$	0
	$350 \leq x < 430$	0	0	0	0	$\frac{430-x}{430-350}$	$1 - \frac{430-x}{430-350}$
	≥ 430	0	0	0	0	0	1

Membership function distribution

Pollutant	Range of variation	Membership function distribution					
		Good	Monitoring for Mitigation	Mitigation	Desired Mitigation	Urgent Mitigation	Very Urgent Mitigation
PM$_{2.5}$ ($\mu g m^{-3}$)	< 15	1	0	0	0	0	0
	$15 \leq x < 30$	$\frac{30-x}{30-15}$	$1 - \frac{30-x}{30-15}$	0	0	0	0
	$30 \leq x < 60$	0	$\frac{60-x}{60-30}$	$1 - \frac{60-x}{60-30}$	0	0	0
	$60 \leq x < 90$	0	0	$\frac{90-x}{90-60}$	$1 - \frac{90-x}{90-60}$	0	0
	$90 \leq x < 120$	0	0	0	$\frac{120-x}{120-90}$	$1 - \frac{120-x}{120-90}$	0
	$120 \leq x < 250$	0	0	0	0	$\frac{250-x}{250-120}$	$1 - \frac{250-x}{250-120}$
	≥ 250	0	0	0	0	0	1
NO$_2$ ($\mu g m^{-3}$)	< 20	1	0	0	0	0	0
	$20 \leq x < 40$	$\frac{40-x}{40-20}$	$1 - \frac{40-x}{40-20}$	0	0	0	0
	$40 \leq x < 80$	0	$\frac{80-x}{80-40}$	$1 - \frac{80-x}{80-40}$	0	0	0
	$80 \leq x < 180$	0	0	$\frac{180-x}{180-80}$	$1 - \frac{180-x}{180-80}$	0	0
	$180 \leq x < 280$	0	0	0	$\frac{280-x}{280-180}$	$1 - \frac{280-x}{280-180}$	0
	$280 \leq x < 400$	0	0	0	0	$\frac{400-x}{400-280}$	$1 - \frac{400-x}{400-280}$
	≥ 400	0	0	0	0	0	1
O$_3$ ($\mu g m^{-3}$)	< 25	1	0	0	0	0	0
	$25 \leq x < 50$	$\frac{50-x}{50-25}$	$1 - \frac{50-x}{50-25}$	0	0	0	0
	$50 \leq x < 100$	0	$\frac{100-x}{100-50}$	$1 - \frac{100-x}{100-50}$	0	0	0
	$100 \leq x < 168$	0	0	$\frac{168-x}{168-100}$	$1 - \frac{168-x}{168-100}$	0	0
	$168 \leq x < 208$	0	0	0	$\frac{208-x}{208-168}$	$1 - \frac{208-x}{208-168}$	0
	$208 \leq x < 748$	0	0	0	0	$\frac{748-x}{748-208}$	$1 - \frac{748-x}{748-208}$
	≥ 748	0	0	0	0	0	1

Table S5 : Estimated National Air Quality Index

Station	Nov 2015	Category	Dec 2015	Category	Jan 2016	Category	March 2016	Category	April 2016	Category	May 2016	Category
Patna	279	Poor	328	Very Poor	346	Very Poor	308	Very Poor	161	Moderately Polluted	192	Moderately Polluted
Delhi	376	Very Poor	360	Very Poor	383	Very Poor	146	Moderately Polluted	194	Moderately Polluted	162	Moderately Polluted
Mumbai	110	Moderately Polluted	122	Moderately Polluted	115	Moderately Polluted	99	Satisfactory	100	Satisfactory	75	Satisfactory
Pune	282	Poor	262	Poor	229	Poor	165	Moderately Polluted	105	Moderately Polluted	78	Satisfactory
Chandrapur	148	Moderately Polluted	149	Moderately Polluted	127	Moderately Polluted	126	Moderately Polluted	127	Moderately Polluted	102	Moderately Polluted
Solapur	110	Moderately Polluted	117	Moderately Polluted	139	Moderately Polluted	114	Moderately Polluted	105	Moderately Polluted	105	Moderately Polluted
Jaipur	347	Very Poor	345	Very Poor	328	Very Poor	181	Moderately Polluted	218	Poor	209	Poor
Jodhpur	212	Poor	320	Very Poor	311	Very Poor	142	Moderately Polluted	166	Moderately Polluted	314	Very Poor
Hyderabad	103	Moderately Polluted	94	Satisfactory	115	Moderately Polluted	96	Satisfactory	94	Satisfactory	72	Satisfactory
Muzaffarpur	375	Very Poor	259	Poor	288	Poor	282	Poor	234	Poor	82	Satisfactory
Kolkata	140	Moderately Polluted	117	Moderately Polluted	123	Moderately Polluted	-	-	-	-	-	-
Varanasi	351	Very Poor	394	Very Poor	447	Severe	345	Very Poor	275	Poor	211	Poor
Bengaluru	46	Good	63	Satisfactory	100	Satisfactory	103	Satisfactory	90	Satisfactory	92	Satisfactory
Chennai	99	Satisfactory	123	Moderately Polluted	182	Moderately Polluted	52	Satisfactory	71	Satisfactory	58	Satisfactory

Table S6 : Estimated Mitigation Priority Index

Station	Nov 2015	Category	Dec 2015	Category	Jan 2016	Category	March 2016	Category	April 2016	Category	May 2016	Category
Patna	2.75	M	2.77	M	2.72	M	1.9	MM	1.63	MM	1.69	MM
Delhi	3.42	M	3.2	M	3.33	M	2.69	M	2.91	M	2.6	M
Mumbai	1.82	MM	1.88	MM	1.89	MM	2.13	MM	1.91	MM	1.9	MM
Pune	2.72	M	2.67	M	2.33	MM	2.5	MM	2.41	MM	2.17	MM
Chandrapur	1.98	MM	1.98	MM	1.96	MM	2.3	MM	2.3	MM	2.06	MM
Solapur	1.68	MM	2.33	MM	2.42	MM	2.68	M	2.14	MM	2.47	MM
Jaipur	2.73	M	2.64	M	2.47	MM	2.68	M	2.14	MM	2.47	MM
Jodhpur	2.4	MM	2.79	M	2.57	M	2.57	M	2.57	M	2.92	M
Hyderabad	1.97	MM	1.88	MM	2.22	MM	2.23	MM	2.13	MM	1.68	MM
Muzaffarpur	2.18	MM	2.29	MM	2.27	MM	1.77	MM	1.77	MM	1.44	MM
Kolkata	1.87	MM	1.79	MM	1.81	MM	-	-	-	-	-	-
Varanasi	2.81	M	3.08	M	3.26	M	3.72	DM	2.81	M	2.67	M
Bengaluru	1.43	G	1.34	G	1.54	MM	1.6	MM	1.52	MM	1.67	MM
Chennai	1.56	MM	1.63	MM	2.06	MM	1.67	MM	1.67	MM	1.59	MM

VUM: Very urgent mitigation
UM: Urgent mitigation
DM: Desired mitigation
M: Mitigation
MM: Monitoring for mitigation
G: Good

Table S7 : Comparitive study of NAQI and MPI

Location	Area	Descriptive Pollutant	NAQI Category	MPI Category
Pune	Metropolitan	PM_{10}, $PM_{2.5}$, CO	Moderately Polluted	Monitoring for mitigation
Patna	Metropolitan	$PM_{2.5}$	Poor	Monitoring for mitigation
Chandrapur	Urban	PM_{10}, $PM_{2.5}$	Moderately Polluted	Monitoring for mitigation
Solapur	Urban	PM_{10}, CO	Moderately Polluted	Monitoring for mitigation
Mumbai	Megacity	CO	Moderately Polluted	Monitoring for mitigation
Jaipur	Metropolitan	PM_{10},$PM_{2.5}$	Poor	Mitigation
Jodhpur	Metropolitan	PM_{10},$PM_{2.5}$	Poor	Mitigation
Muzaffarpur	Urban	PM_{10},$PM_{2.5}$	Poor	Monitoring for mitigation
Kolkata	Megacity	PM_{10}	Moderately Polluted	Monitoring for mitigation
Hyderbad	Metropolitan	PM_{10}, $PM_{2.5}$	Satisfactory	Monitoring for mitigation
Varanasi	Metropolitan	PM_{10}, $PM_{2.5}$	Very Poor	Mitigation
Delhi	Megacity	PM_{10}, $PM_{2.5}$	Poor	Mitigation
Bengaluru	Metropolitan	$PM_{2.5}$	Satisfactory	Good
Chennai	Metropolitan	$PM_{2.5}$	Satisfactory	Monitoring for mitigation

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