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INVIGORATING MEASURES TO MELIORATE AIR QUALITY INDEX: A CASE STUDY

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Abstract: Increasing air pollution is gravely jeopardizing our planet; as evidenced by global warming and rapid climate changes. Based on recent studies of World Health Organization (WHO) on air quality index, Consumer News and Business Channel (CNBC) has reported that India has 9 out of the 10 highly polluted cities in the world, including the capital city, New Delhi.

This work administers an extensive study on the pollution indicators in New Delhi during the year 2019, and proposes practical measures to regulate the prevailing exigency. Real time data for five different places in New Delhi have been drawn from the Central Pollution Control Board (CPCB) website. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) has been employed to designate the relative priorities to suggested corrective measures.

***Index Terms* - Pollution Control Measures, Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)**

I. INTRODUCTION

National Capital Territory of Delhi (NCT) attracts a large segment of population from all over the country, seeking improved facilities and employment opportunities. Currently, with an estimated population of around 20 million, Delhi is experiencing toilsome issues due to alarmingly deteriorating air quality levels in recent decades.

To overhaul the current menace, we need to look into the triggering factors of the predicament. Primary reason of air-pollution in Delhi is over-crowdedness. To accommodate the congested communities, vacant areas are being captured by construction sites, causing unmanageable surge in the amount of dust and various polluting agents. Another important outcome of over-population is increased number of vehicles on the roads. CPCB has declared vehicular emissions as the major contributors of air and noise borne pollution. Additional havoc is being caused by setting up of industrial projects in and around Nation Capital Region. Industrial emissions and garbage dumps are further deteriorating the air quality extensively. Agricultural waste burning in surrounding states is making the situation outrageous. During the onset of winter season, stagnant winds and lack of moisture in air induces these pollutants to get trapped in air, resulting in hazardous smog.

Massive population growth and variegated localized attributes have sparked inordinate levels of PM2.5 (particulate matter having less than 2.5 micrometers of diameter) and PM10 (tiny particulate matter with a diameter of 10 micrometers), along with high levels of toxic gases like NOx (collective taxonomy for Nitrogen Monoxide (NO) and Nitrogen Dioxide (NO2)), Sulphur Dioxide (SO_2), Carbon Monoxide (CO) etc. As per National Ambient Air Quality Standards (NAAQS), the noxious levels of air pollution in recent years have been dangerously alarming. Adulterated air and water are causing distressing allergies, breathlessness, asthma attacks, pneumonia, tuberculosis, and many other serious health implications among the residents. The precarious air quality index in this region is a matter of extreme concern and should be recuperated with utmost precedence.

Intrigued by the ongoing contingency in Delhi region, the layout model of this work was incepted. The paper is organized into five sections. Section I introduces the causes and effects of air pollution in Delhi. Section II provides an insight into existing research works on corrective measures to combat air pollution. Section III gives an overview of data sources and methodologies used in this work. Section IV elucidates the application part, using the proposed methodology. Finally, the conclusion part elaborating on the results and recommendations for further scope of research are given in section V.

II. LITERATURE REVIEW

Numerous researches have been employed to study the ill effects of air pollution on human health and environment. Effect of long-term ozone exposure on human mortality rate was analyzed for ninety-six metropolitan areas in America [1], and a significant association was established among increased ozone concentration in air and death risk owing to respiratory causes. Amato et al. [2] studied the efficacy of washing the streets and using anti-dust sprays on air particulate matter levels. Lang et al. [3] surveyed electric and hybrid vehicles for environmental implications and energy generation. Goyal et al. [4] asserted that the air quality in Delhi has highly deteriorated due to toxic emissions in air. Environmental and socioeconomic impacts of air pollution were analyzed by Nduwayezu et al. [5], in the Kigali city of Rwanda. Sharma and Dikshit [6] submitted a comprehensive report to environmental department, Govt. of NCT and also to Pollution Control Committee, Delhi, which studied air pollution indices (PM2.5, PM10) and greenhouse gases emission (particularly NOx, SO_2, CO) during summer and winter seasons. Timmers and Achten [7] studied electric vehicles for reducing particulate matter emissions, although they reported increased levels of SO_2 in this work. Vallero [8] worked on air pollution monitoring setups to review impacts on control systems. Kheirbek et al. [9] investigated the vehicular emissions for fine particulate matter presence, which are causing serious health complications. Millstein et al. [10] asserted for betterment in air-quality indices by using wind and solar power energy as alternative fuel sources. Vidhi and Shrivastava [11] reported that electricity-based vehicles

III. PROJECTED METHODOLOGY

Literature surveys on similar works suggested some felicitous control measures, which could fit into our framework; aspiring to reduce pollution indices in the Delhi region by substantial amounts. These decisive control measures were worked out for the estimated reduction of pollutants; on the basis of previous researches. In order to work on control measures, a correlation table is required to gauge the covariance among the polluting elements under study. The layout plan of this works consists of a structured approach with given procedural steps:

1. Identify the key polluting elements and extract the past data from a reliable source for an elongated time period, for enhanced accuracy.
2. Compile the average levels for each element under consideration on a spreadsheet.
3. Form a correlation matrix on excel sheet;
   this can be easily done on the data analysis tab by selecting the correlation option. Correlation matrix marks one to one relationships among the selected polluting elements.
4. For the symmetrical correlation matrix formed here, we can easily find eigenvectors and subsequent threshold weights for polluting elements, by the process of normalization.
5. Having done with pre-requisites of weight calculations, we can easily estimate the sequential effectiveness of suggested control measures using PROMETHEE method.

Here we have used PROMETHEE II (explained in subsection 'A') for complete ranking; the idea behind this is to recon preferential allotment of resources, for the targeted reduction in pollution indices.

Preference Ranking Organization Method for Enrichment Evaluation II (PROMETHEE II)

PROMETHEE II is a well-known outranking technique used for positioning decision alternatives; simultaneously manipulating propitious (beneficial) and unpropitious (non-beneficial) criteria with predefined weights. PROMETHEE is a well-known Multicriteria Decision Making (MCDM) technique; widely used for performance evaluation requisite. Albadvi, Chaharsooghi and Esfahanipour [12] used this method for decision making in stock trading. Bagla and Gupta [13] used PROMETHEE II for leader selection problem.

Let there be m alternatives $(A_1,\ A_2, \ldots, A_m)$ to be ranked on the bases of n propitious/unpropitious criteria $(C_1,\ C_2, \ldots, C_n)$, with associated weights as $(W_1,\ W_2, \ldots, W_n)$. Let x_{ij} be the performance measure of the alternative A_i corresponding to the criterion C_j, as shown in the given decision matrix.

$$\begin{array}{c|ccc} & C_1 & \ldots C_j \ldots & C_n \\ & W_1 & \ldots W_j \ldots & W_n \\ \hline A_1 & & & \\ \vdots & & & \\ A_i & & x_{ij} & \\ \vdots & & & \\ A_m & & & \end{array}$$

The matrix is normalized using equation (1) for propitious criteria and equation (2) for unpropitious criteria.

$$r_{ij} = \frac{[x_{ij} - min(x_{ij})]}{[max_j(x_{ij}) - min_j(x_{ij})]} \quad (i = 1,\ldots,m), \forall j \quad (1)$$

$$r_{ij} = \frac{[max_j(x_{ij}) - x_{ij}]}{[max_j(x_{ij}) - min_j(x_{ij})]} \quad (i = 1,\ldots,m),\ \forall j \quad (2)$$

Note that equation(2) makes unpropitious criteria compatible with propitious ones, to be evaluated on the same measurement scale.

Now establish preference values $P_j(A_i, A_{i'})$, within the alternatives A_i and $A_{i'}$, comparing the corresponding values r_{ij} and $r_{i'j}$ for each set, using equation (3).

$$P_j(A_i, A_{i'}) = \begin{cases} 0 \quad , & if\ r_{ij} \le\ r_{i'j} \\ r_{ij} -\ r_{i'j}, & if\ r_{ij} >\ r_{i'j} \end{cases} \quad (3)$$

Here each $P_j(A_i, A_{i'}) \in [0,1]$, greater the value, higher the preference.

$P_j(A_i, A_{i'}) = 0$ implies indifference, whereas $P_j(A_i, A_{i'}) = 1$ depicts ultimate preference. This exercise establishes sequential preference among the two alternatives in consideration. Finally, compute multi-criteria global preference index $\pi(A_i, A_{i'})$ showing the weighted preference of A_i over $A_{i'}$, using equation (4).

$$\pi(A_i, A_{i'}) = \sum_{j=1}^{n} W_j . P_j(A_i, A_{i'}) \quad (4)$$

Now determine outranking flows $\varphi^+ A_i$ and $\varphi^- A_i$, denoting positive (or leaving) and negative (or entering) vectors as given by equations (5) and (6).

$$\varphi^{+}(A_i) = \frac{1}{m-1}\sum_{i=1}^{m}\pi(A_i, A_{i'}), \quad (i \neq i') \qquad (5)$$

$$\varphi^{-}(A_i) = \frac{1}{m-1}\sum_{i=1}^{m}\pi(A_{i'}, A_i), \quad (i \neq i') \qquad (6)$$

The positive (or leaving) flow determines the extent of domination of an alternative over remaining ones, while the negative (or entering) flow signifies the domination faced by an alternative exerted by remaining alternatives in the study. The net outranking flow for each alternative is given by Equation (7).

$$\varphi(A_i) = \varphi^{+}A_i - \varphi^{-}A_i \qquad (7)$$

Finally, the alternatives are ranked on the basis of $\varphi(A_i)$ values; maximum value fetches the highest ranking.

IV. PRACTICAL APPLICATION WITH DATA SET

- Based on past research works on pollution control means, control measures for moderating air quality index in Delhi are as suggested:
- M_1 : Replacing conventional vehicles by electric models. Data sources: [3], [7], [11].
- M_2 : Shifting industrial activities farther from residential areas. Data sources: [14]
- M_3 : Controlling dust emissions from construction and other activities. Data sources: [14]
- M_4 : Regulating coal and fossil fuel consumption in power plants for reduced emissions. Data sources: [14]
- M_5: Using wind and solar power energy as fuel sources in the power sectors. Data sources: [10]
- M_6: Discouraging the use of private vehicles by means of the advanced public transportation systems. Data sources: [9], [16]
- M_7: Installing Air-Purification towers. Data sources: [17]
- M_8: Curbing biomass and agricultural waste burning practices. Data sources: [14]

Identifying the key air polluting elements as PM2.5, PM10, NOx, SO_2 and CO, and working on real emission data at five places, viz. Anand Vihar (East Delhi), Rohini (North-West Delhi), Rama Krishna Puram (South Delhi), Dwarka (South-West Delhi) and Punjabi Bagh (West Delhi), for a period of one year (01/01/2019 to 01/01/2020); by extracting actual data from CPCB website [15].

Subsequent average values of these pollutants for the said period were computed on an excel sheet, and a correlation matrix was formed to establish the extent of covariance between these five pollutants. Consequent weights were computed by normalizing the eigenvector obtained using MATLAB; results are shown in Table 1.

Table 1: Correlation Matrix and corresponding normalized weights for polluting elements.

	PM2.5	PM10	NOx	SO_2	CO
PM2.5	1				
PM10	0.8803	1			
NOx	0.7362	0.7690	1		
SO_2	0.1799	0.3852	0.4554	1	
CO	0.7994	0.7832	0.8569	0.3536	1
Weights	0.2153	0.2233	0.2214	0.1173	0.2228

Now we use PROMETHEE II to allocate preferences to above mentioned corrective measures ($M_1, M_2, \ldots, M_8$) taken as alternatives, and polluting elements (PM2.5, PM10, NOx, SO_2 and CO) as criteria with predefined respective weights (0.2153, 0.2233, 0.2214, 0.1173, 0.2228**).**

Table2 summarizes the impact of respective corrective measures on reduction of selected pollutants. For instance, the first row depicts that replacing conventional vehicles by electric models may reduce PM2.5 levels by 0.2%, NOx by 10%, CO by 18%, no evident effect on PM10 levels, whereas SO2 levels may increase by 3.5%, as in [3], [7] and [11].

These values are taken compatible with similar studies of a particular measure conducted on some of the highly polluted cities in the world. This approach may provide the nearby results by application of same measures in the Delhi region.

Table 2: Speculated reduction percentage of pollution indices

Control Measures ↓	PM 2.5	PM 10	NOx	SO_2	CO
M_1	0.20	0.00	10.00	-3.50	18.00
M_2*	12.07	14.17	4.81	31.18	6.25
M_3*	3.64	8.90	0.00	0.00	0.00
M_4	3.89	3.63	7.50	16.66	0.14
M_5	46.00	20.00	50.00	72.00	20.00

M_6	8.75	3.38	25.00	5.00	17.00
M_7	25.00	45.00	0.00	0.00	0.00
M_8*	11.50	9.50	2.50	1.00	9.00

The control measures marked with '*' signify that these results have been obtained by reducing the source pollution by around 50%, since complete ban may not be applicable in practical scenarios.
Normalized value r_{ij} against each x_{ij} is computed using equation (1), as all criteria considered here seek a higher (propitious) reduction in pollution indices. Table 3 shows normalized r_{ij} values against all x_{ij}'s.

Table 3: Normalized reduction values

Control Measures ↓	PM 2.5	PM 10	NOx	SO_2	CO
M_1	0.00	0.00	0.20	0.00	0.90
M_2*	0.26	0.31	0.10	0.46	0.31
M_3*	0.08	0.20	0.00	0.05	0.00
M_4	0.08	0.08	0.15	0.27	0.01
M_5	1.00	0.44	1.00	1.00	1.00
M_6	0.19	0.08	0.50	0.11	0.85
M_7	0.54	1.00	0.00	0.05	0.00
M_8*	0.25	0.21	0.05	0.06	0.45

Now, computations for preference functions $P_j(M_i, M_{i'})$ as per equation (3) and multi-criteria preference index $\pi(M_i, M_{i'})$ showing weighted preference of A_i over $A_{i'}$ using equation (4) are enumerated in Table 4.

Table 4: Pairwise preference functions and multi-criteria preference index

Preference Functions ↓	PM 2.5	PM 10	NOx	SO_2	CO	$\pi(M_i, M_{i'})$
$P_j(M_1, M_2)$	0.00	0.00	0.10	0.00	0.59	0.16
$P_j(M_1, M_3)$	0.00	0.00	0.20	0.00	0.90	0.25
$P_j(M_1, M_4)$	0.00	0.00	0.05	0.00	0.89	0.21
$P_j(M_1, M_5)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_1, M_6)$	0.00	0.00	0.00	0.00	0.05	0.01
$P_j(M_1, M_7)$	0.00	0.00	0.20	0.00	0.90	0.25
$P_j(M_1, M_8)$	0.00	0.00	0.15	0.00	0.45	0.14
$P_j(M_2, M_1)$	0.26	0.31	0.00	0.46	0.00	0.18
$P_j(M_2, M_3)$	0.18	0.12	0.10	0.41	0.31	0.21
$P_j(M_2, M_4)$	0.18	0.23	0.00	0.19	0.31	0.18
$P_j(M_2, M_5)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_2, M_6)$	0.07	0.24	0.00	0.35	0.00	0.11
$P_j(M_2, M_7)$	0.00	0.00	0.10	0.41	0.31	0.14
$P_j(M_2, M_8)$	0.01	0.10	0.05	0.40	0.00	0.08
$P_j(M_3, M_1)$	0.08	0.20	0.00	0.05	0.00	0.07
$P_j(M_3, M_2)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_3, M_4)$	0.00	0.12	0.00	0.00	0.00	0.03
$P_j(M_3, M_5)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_3, M_6)$	0.00	0.12	0.00	0.00	0.00	0.03
$P_j(M_3, M_7)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_3, M_8)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_4, M_1)$	0.08	0.08	0.00	0.27	0.00	0.07
$P_j(M_4, M_2)$	0.00	0.00	0.05	0.00	0.00	0.01
$P_j(M_4, M_3)$	0.01	0.00	0.15	0.22	0.01	0.06
$P_j(M_4, M_5)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_4, M_6)$	0.00	0.01	0.00	0.15	0.00	0.02

$P_j(M_4, M_7)$	0.00	0.00	0.15	0.22	0.01	0.06
$P_j(M_4, M_8)$	0.00	0.00	0.10	0.21	0.00	0.05
$P_j(M_5, M_1)$	1.00	0.44	0.80	1.00	0.10	0.63
$P_j(M_5, M_2)$	0.74	0.13	0.90	0.54	0.69	0.61
$P_j(M_5, M_3)$	0.92	0.25	1.00	0.95	1.00	0.82
$P_j(M_5, M_4)$	0.92	0.36	0.85	0.73	0.99	0.78
$P_j(M_5, M_6)$	0.81	0.37	0.50	0.89	0.15	0.51
$P_j(M_5, M_7)$	0.46	0.00	1.00	0.95	1.00	0.66
$P_j(M_5, M_8)$	0.75	0.23	0.95	0.94	0.55	0.66
$P_j(M_6, M_1)$	0.19	0.08	0.30	0.11	0.00	0.14
$P_j(M_6, M_2)$	0.00	0.00	0.40	0.00	0.54	0.21
$P_j(M_6, M_3)$	0.11	0.00	0.50	0.07	0.85	0.34
$P_j(M_6, M_4)$	0.11	0.00	0.35	0.00	0.84	0.29
$P_j(M_6, M_5)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_6, M_7)$	0.00	0.00	0.50	0.07	0.85	0.31
$P_j(M_6, M_8)$	0.00	0.00	0.45	0.05	0.40	0.20
$P_j(M_7, M_1)$	0.54	1.00	0.00	0.05	0.00	0.35
$P_j(M_7, M_2)$	0.28	0.69	0.00	0.00	0.00	0.21
$P_j(M_7, M_3)$	0.47	0.80	0.00	0.00	0.00	0.28
$P_j(M_7, M_4)$	0.46	0.92	0.00	0.00	0.00	0.30
$P_j(M_7, M_5)$	0.00	0.56	0.00	0.00	0.00	0.12
$P_j(M_7, M_6)$	0.35	0.92	0.00	0.00	0.00	0.28
$P_j(M_7, M_8)$	0.29	0.79	0.00	0.00	0.00	0.14
$P_j(M_8, M_1)$	0.25	0.21	0.00	0.06	0.00	0.11
$P_j(M_8, M_2)$	0.00	0.00	0.00	0.00	0.14	0.03
$P_j(M_8, M_3)$	0.17	0.01	0.05	0.01	0.45	0.16
$P_j(M_8, M_4)$	0.17	0.13	0.00	0.00	0.44	0.17
$P_j(M_8, M_5)$	0.00	0.00	0.00	0.00	0.00	0.0
$P_j(M_8, M_6)$	0.06	0.14	0.00	0.00	0.00	0.04
$P_j(M_8, M_7)$	0.00	0.00	0.05	0.01	0.45	0.12

Table 5 provides the numeric preferences in a comprehensive form; for instance, the preference of M_1 over M_2 is 0.16 (as determined by Row1 in Table 4), while that of M_2 over M_1 is 0.18 (Row8, Table 4). It is to be noted that M_1 cannot have any preference over itself; hence no entry in cell (1,1) of Table5; similarly, all other diagonal entries are void. Also, the outranking flows $\varphi^+ A_i$ and $\varphi^- A_i$, calculated using equations (5) and (6) are given in last column and last row of Table 5. $\varphi^+ A_i$ values are the sum of elements in i[th] row, divided by $(m-1)$, and similarly $\varphi^- A_i$ values are calculated via column sums.

Table 5: Aggregated preference function matrix

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	$\boldsymbol{\varphi^+ A_i}$
M_1	-	0.16	0.25	0.21	0.00	0.01	0.25	0.14	**0.15**
M_2	0.18	-	0.21	0.18	0.00	0.11	0.14	0.08	**0.13**
M_3	0.07	0.00	-	0.03	0.00	0.03	0.00	0.00	**0.02**
M_4	0.07	0.01	0.06	-	0.00	0.02	0.06	0.05	**0.04**
M_5	0.63	0.61	0.82	0.78	-	0.51	0.66	0.66	**0.67**
M_6	0.14	0.21	0.34	0.29	0.00	-	0.31	0.20	**0.21**
M_7	0.35	0.21	0.28	0.30	0.12	0.28	-	0.24	**0.26**
M_8	0.11	0.03	0.16	0.17	0.00	0.04	0.12	-	**0.09**
$\boldsymbol{\varphi^- A_i}$	**0.22**	**0.18**	**0.30**	**0.28**	**0.02**	**0.14**	**0.22**	**0.19**	

Net outranking flow $\varphi(A_i)$ is evaluated using equation (7). Table 6 shows the preferential sequence of control measures, as determined by $\varphi(A_i)$ values, highest value ranked as first. Highest preference is given to M_5, i.e. using wind and solar power energy as fuel sources is highly recommendable for air quality improvement. M_6 , i.e. restricting the vehicles on the roads may be the next prioritized move;

followed by installation of air-purification towers M_7. Like-wise, other prioritized measures can be easily designated as per their efficacies, as shown in Table 6.

Table 6: Evaluating preferential sequence for control measures

	$\varphi(A_i) = \varphi^+ A_i - \varphi^- A_i$	Ranking
M_1	-0.07	5
M_2	-0.05	4
M_3	-0.28	8
M_4	-0.24	7
M_5	0.65	1
M_6	0.07	2
M_7	0.04	3
M_8	-0.10	6

As per ranking results in Table 6, M_3, i.e. controlling dust emissions from construction and other activities is the least effective measure, but results may vary as per localized specifications of area under study.

V. CONCLUSION

This work attempts to formulate potential measures to improve air quality index in the National Capital, Delhi Identification of control measures was performed through extensive researches on similar appreciable works in the field. The aftermath of this profound study strongly supported, urging to promote the use of wind and solar power based industrial models for momentous enhancements of the air quality index. Although the practical implementation of this measure in Delhi ought to be consuming, but would certainly be significantly rewarding.

Other proposed measures can be implemented on a priority basis; like the use of private vehicles should be restricted. Other nations like Singapore have presented an exemplary model by elevating the cost of owning private cars by a substantial amount.

As a result, people do not prefer buying personal cars and most of the people use public transport for commuting. Likewise, policies can be made for maneuvering other control measures. In the wake of this pursuit, the first smog clearing tower has been installed in Lajpat Nagar, which aims to purify 25 to 60 million cubic meters air on a daily basis.

Implementation of suggested control measures is hoped to be effective in a broad sense, although numerical accuracy may be a bit compromised due to varied localized factors. It is anticipated that most of the findings and action measures are applicable for enforcement in Delhi.

Due to lack of financial funding, results from similar works have been included without testing their effectiveness in Delhi itself. Future researches may include conducting air quality testing by the implementation of suggested control measures in specified areas itself. The well-being of mankind, upcoming generations and the planet would assert gratitude to its implementation.

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