Prioritisation of actions in the existing clean air action plan for Pune and Nashik

Acknowledgment

We would like to thank the Swiss Agency for Development and Co-operation (SDC), Switzerland for funding the Clean Air Project in India (CAP India). We express our sincere gratitude to Ministry of Environment, forest and climate change (MoEFCC), Maharashtra Pollution Control Board (MPCB) – Head and Regional offices for their support during the stakeholder's workshop. We would also like to thank the participants from academia, city administration, pollution control board, research institutes, and non-government organizations for their whole hearted participation in the stakeholder's workshop.

1.0 Introduction

In the last decade, improvement in the economic standard of people and migration from rural areas to urban areas has led to degradation of air quality in the cities. Air pollution has emerged as one of the biggest global challenges posing serious threats to human health, economy and the overall ecological balance. In 2017, air pollution was responsible for 8% of the total disease burden and 11% of premature deaths in people younger than 70 years in India. To tackle the problem of air pollution at both national and urban scales, MoEF&CC, GoI, has launched a flagship program named national clean air program (NCAP), which stresses upon national and city-level efforts for air quality management, capacity building, and increased know-how about technologies as key elements for overcoming and tackling air pollution across the country.

Under NCAP, the respective SPCBs have formulated clean air action plans (CAAPs). These plans list various strategies which can reduce sectorial emissions and can contribute towards air quality improvements. In the CAP India project, one of the tasks is to evaluate these plans and prioritise some of the actions based on existing knowledge and stakeholder consultations. The prioritised action list will not only help the MPCB in focusing their energies on more optimal actions but will also help the partners of CAP India project to identify some of the no regret measures for possible pilot demonstrations. The clean air action plans (CAAPs) has been evaluated for Pune and Nashik. These action plans have been designed targeting various sources of air pollution which includes vehicular, industrial, biomass burning, DG sets emissions etc. and keeping in view favorable air quality improvements, technical and economical feasibility and time required for implementation. Further, the interventions listed in clean air action plan has been classified as short term, medium term and long term on the basis its period of implementation. The interventions listed in action plan have to be implemented by different concerned Departments/ Agencies. The major highlights of the Pune and Nashik city action plan are shown in table 1.

Table 1: Major highlights of the Pune and Nashik city action plan

Sector	Pune	Nashik
Transport	Metro rail transport, procurement of CNG and electric buses for public transportation, incentivizing use of CNG autos, promoting the use of bicycles, and better traffic signal management.	Provision for fine for not carrying Pollution Under Control certificate, wrong parking′; Construction of expressways; Promoting Battery operated vehicles in buses and auto rickshaws.
Industry	Industrial units located within city limits are not permitted to use coal by MPCB.	Shifting of kilns outside corporation limits; installing FGD at Thermal Power Plant.

Road	Reduce the road dust re-suspension by implementing the interventions such as wall to wall paving of roads and improved road designs, decongestion and pothole free roads and re-surfacing of the roads. In addition, certain interventions on creating and maintaining the green spaces are also planned.	Reduce the road dust re-suspension by implementing the interventions such as creation of green buffers at Traffic corridor; maintaining pothole free roads for free flow traffic; Introducing water fountains at major traffic intersection etc.
Waste	Ban on open burning of waste, door to door collection of solid wastes, proper transportation of collected solid waste to reduce the air emissions from waste management sector.	Extensive drive against open burning of biomass, crop residue, garbage, leaves etc.; Separate collection mechanism for entire horticulture waste and windrow composting implementation.
Construction	Minimize the particulate emissions from construction and demolition activities and has advised the project proponents to follow better construction practices and covered transportation of construction materials.	Selecting the operator for processing construction and demolition Waste; Control fugitive emissions from material handling, conveying and screening operations through water sprinkling, curtains, barriers and suppression units.
Crematoria	Discourage the use of conventional wood based crematoriums with introduction of electric and gas based crematoriums.	Public awareness generation to make use of electrically operated crematoriums.
Public awareness	Importance of public awareness on air quality with dissemination of information through LED displays, websites and mobile applications.	Systematic collection of air pollution data; Tracking of pollution reduction.

This report presents the methodology adopted in order to prioritize the actions listed in clean air action plans and optimal actions identified for Pune and Nashik cities air quality improvement.

2.0 Methodology

The existing CAAPs for Pune and Nashik are proposed to be strengthened on the basis of multi-criteria analysis and the broad methodology adopted for this is shown in Figure 1.

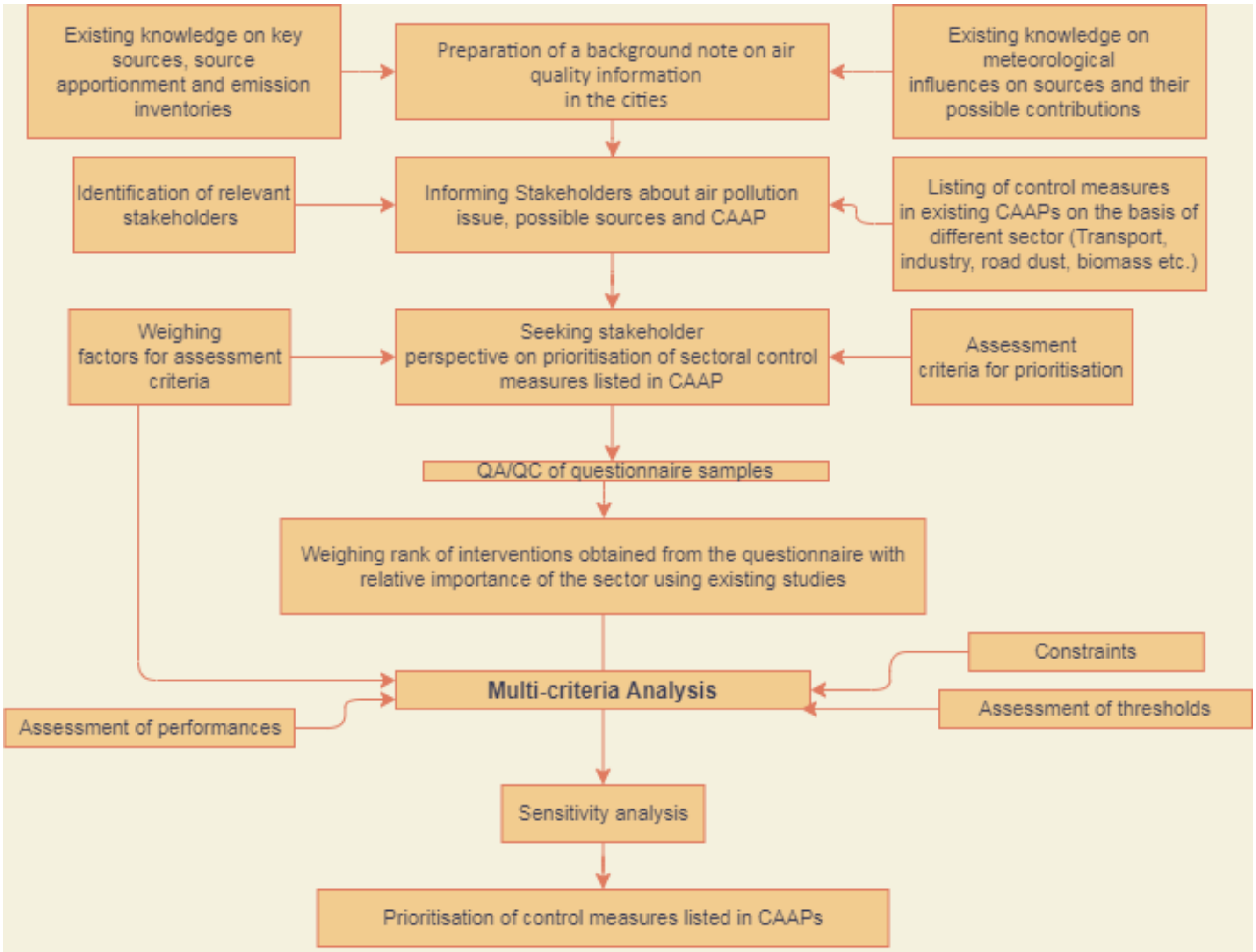


Figure1: Broad methodology to evaluate existing CAAPs (Adopted from: Vlachokostas et al., 2011)

A background note describing key air quality issues, possible sources of pollution, summary of existing studies on source apportionment, emission inventories and meteorological influences was prepared for the Pune and Nashik City. Key local stakeholder groups were identified and the note was used as a tool to inform these stakeholders about relevant issues. List of measures listed in CAAP were also be shared with the stakeholders. Thereafter, through a questionnaire, stakeholders were asked to prioritise different interventions listed in the CAAP based on set assessment criteria. They were also asked to weigh the assessment criteria based on local conditions in the city. After adequate QA/QC of the filled questionnaire samples, retrieved data was used for carrying out multi-criteria analysis (MCA). Sensitivity analysis was also performed to ensure reliability of the results. Results of MCA will lead to identification of most impactful and applicable strategies in the cities. Activities are further detailed out in subsequent sections. Results of MCA will lead to identification of most impactful and applicable strategies in the cities. Activities are further detailed out in subsequent sections.

2.1. Development of a background note

A brief background note summarizing the existing information on Pune and Nashik city characteristics, air quality levels and trends, a list of possible sources, existing knowledge on emission inventory/ source apportionment studies, and meteorological influences, was prepared. The background note was presented and elucidated to the targeted stakeholder groups. The background note is also provided in the Annexure- A of this report.

2.2. Stakeholder groups

Representatives of local academic institutes, industrial experts, NGOs/CSOs were identified and invited to participate in the activity. Other than MPCB, other government departments including Municipal Corporation of Pune and Nashik were also consulted for their perspective.

Figure 2: Target Stakeholders

2.3. Development of questionnaire and criteria for prioritisation

A comprehensive questionaries' was prepared for Pune and Nashik city under which intervention/actions were listed for different sector as per the clean air action plan (CAAP). The questionnaire survey for clean air action plan of Pune and Nashik is provided in Annexure B. The questionnaire survey was designed in order to understand stakeholders' perspectives on prioritisation of interventions within different sectors. Also, seven assessment criteria have been shortlisted to evaluation of different control measures as shown in table 2. The weightages of different options were determined through stakeholder's questionnaire. In addition, the stakeholder groups were asked to provide their relative scores for control measures on different criteria mentioned above. The weightages of different options will vary from among different stakeholder group. Efforts were made to build consensus between different stakeholders groups for prioritising actions under existing CAAP.

Table 2: Assessment criteria used in MCA

Assessment criteria	Codes	Examples	Stakeholder group
Sectorial acceptance	C1	Readiness of the relevant sector for the intervention	(Only for experts in the particular industry for the specific intervention)
Economic benefits	C2	Increased efficiency and energy savings	All other stakeholders
Economic Costing	C3	Capital and Operational costs	All other stakeholders
Social acceptance	C4	Acceptance of social and cultural values, reduced stress	All other stakeholders
Social benefits	C5	Time savings, heritage protections, gender empowerment	All other stakeholders
Environmental benefits	C6	Air pollution reduction and reduced health impacts	All other stakeholders
Employment generated	C7	Number of job created	All other stakeholders

2.4. Questionnaire survey workshop

A half day online workshop was conducted for Pune and Nashik in collaboration with MPCB on 22nd June and 25th June respectively. The regional offices of the PCB were requested to invite various stakeholders to participate. The half day workshops conducted in Pune and Nashik witnessed the participation of around 50-60 stakeholders in each city. During the workshop, the background note was shared and presented to the participants. Then, stakeholder perspective on control measures listed in existing CAAP was then collected based on the questionnaire survey. The data collected through questionnaire surveys was used for further processing. Table 3 provides the category-wise participation details and survey form received.

Table 3: Summary of stakeholder's participation and number of sample

S. No.	Targeted Stakeholder groups	Participation in workshop		Survey Forms Received	
		Pune	Nashik	Pune	Nashik
1.	Local academia	12	10	6	19
2.	Specific industry experts	10	8	6	4
3.	NGOs/ CSOs	6	2	4	3
4	**Government – MPCB, Relevant departments**	18	31	14	9

2.5. Weighing the intra-sectorial stakeholder rankings with relative contribution of sector

In order to obtain the overall ranking of all the interventions listed in CAAP in a scientific and methodical way, the intra- sectorial scores given by the stakeholders were weighed by the relative contribution factor of different sectors such as transport, industry, thermal power plant, DG sets, road dust etc. The relative contributions were assessed based on the existing knowledge on key sources, source apportionment and emission inventories of the two focused cities – Pune and Nashik. For Pune, various studies on inventorization of emission sources have been conducted in the past by different institutions and two studies are currently in progress as per our knowledge. For Nashik, no significant study on inventorization of emission sources was available in the past but recently a study has been conducted by NEERI –Mumbai in collaboration with MPCB at city level. Also, NEERI-Nagpur is in process of conducting a study on inventorization of emission sources in collaboration with TERI at district level. Fig. 3, depicts the sectorial contributions to $PM_{2.5}$ emissions for Pune and Nashik city.

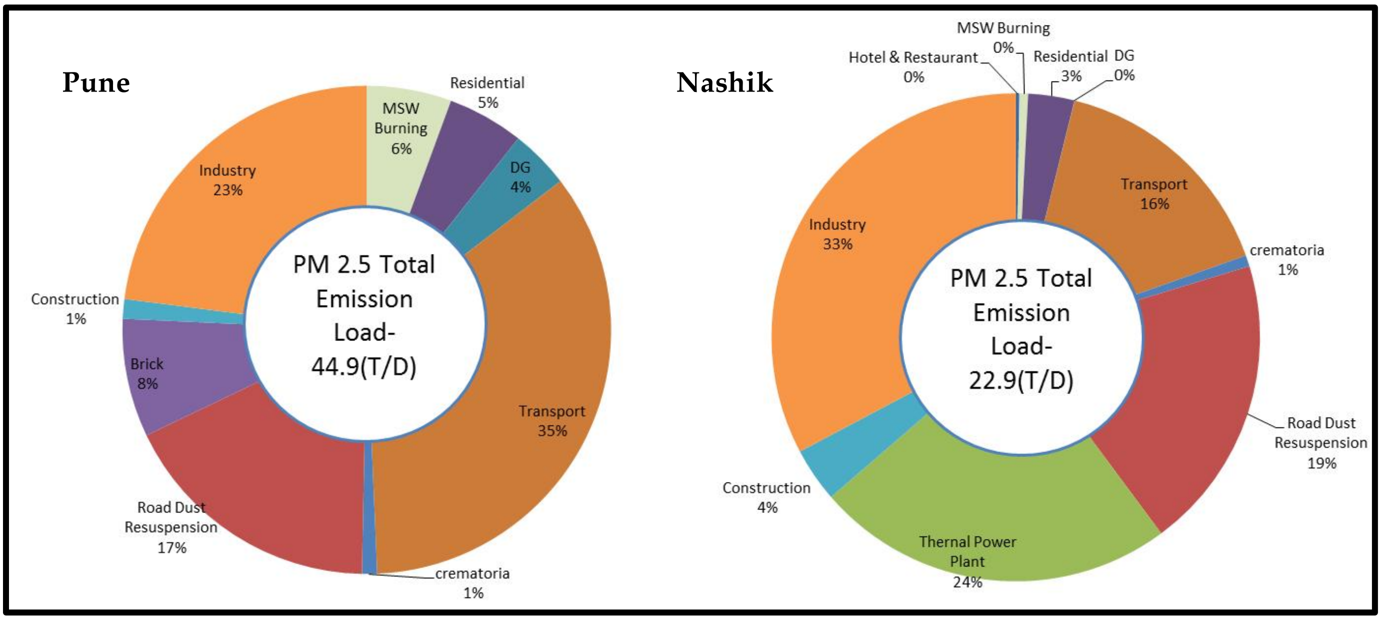


Fig 3: Sectorial contributions to $PM_{2.5}$ emissions for Pune and Nashik city

For Pune, the transport and industries are the two major sectors contributing to about 35% and 23% of total $PM_{2.5}$ emissions respectively. Further, it is important to note the contribution to $PM_{2.5}$ from dust (19%), which includes dust emissions from road dust re-suspension and construction activities.

For Nashik, industry, thermal power plant and road dust are major contributing sectors emitting around 33%, 24% and 19% of total $PM_{2.5}$ emissions respectively. Also, transport sector contribute significantly to the total $PM_{2.5}$ emissions as shown in fig 3.

The weight factor used for the study in presented in table 4. The sectorial weight factor was multiplied with scores received from stakeholder perspective on sector specific interventions to obtain the overall score of the interventions listed in CAAP.

Table 4: Weight factor for Pune and Nashik

Sr. No.	Source Sector	Weighting Factor	
		Pune	Nashik
1.	Transport	0.350	0.2664
2.	Road dust	0.177	0.1956
3.	Construction and demolition waste	0.013	0.0360
4.	Hotel/Other sector		0.0024
5.	Industries	0.230	0.3275
6.	Municipal Solid waste	0.060	0.0057
7.	Diesel generator set	0.040	0.0001

8.	Thermal Power plant		0.2380
9.	Crematorium	0.010	0.0073
10.	Residential	0.050	0.0306
11.	Brick kilns	0.080	

2.6. Multi criteria analysis

The QA/QC ensured dataset was subjected to MCA. For this purpose, ELECTRE-III technique (Roy, 1978; Vlachokostas et al., 2011) was followed. Multi criteria evaluation of available improvement strategies consists of a problem which is formulated by using a set of interventions listed in CAAP (A1, A2, A3.) and a set of criteria (C1, C2, C3) on which data has been collected through questionnaire. The evaluation of criterion k for intervention A is described as Vk(A). The approach adopted in the framework of this analysis uses a ranking scheme, following ELECTRE III principles, based on binary outranking relations in two major concepts; "Concordance" (ck) when intervention A1 outranks intervention A2 if a sufficient majority of criteria are in favor of intervention A1 and "Non-Discordance" (dk) when the concordance condition holds, none of the criteria in the minority should be opposed too strongly to the outranking of A2 by A1. The assertion that A1 outranks A2 is characterised by a credibility index which permits knowing the true degree of this assertion (Roussat et al., 2009). To compare a pair of interventions (A1, A2) for each criterion, the assertion "A1 outranks A2" is evaluated with the help of pseudo-criteria. The pseudo-criterion is built with two thresholds, namely preference (pk) and indifference (qk). WhenVk (A1) − VK (A2) ≤ qk, then no difference between interventions A1 and A2 for the specific criterion k under study is identified. In this case ck (A1, A2) = 0. On the contrary, when Vk (A1) − VK(A2) > pk, then A1 is strictly preferred to A2 for criterion k. In this case ck(A1, A2) = 1. A global concordance index CA1A2 for each pair of alternatives (A1, A2), is computed with the concordance index ck(A1, A2) of each criterion k:

$$C_{A1A2} = \frac{\sum_{k=1}^{K} w_k \times c_k(A_1, A_2)}{\sum_{k=1}^{K} w_k} \quad (1)$$

Where W_k is the weight of criterion k and K the total number of selected criteria. Thereafter, a descending distillation will be constructed to rank from the best available intervention to the worst.

In order to efficiently discriminate among interventions, preference thresholds are connected with the total number of interventions. This provides the decision-maker with a smoothed "relative distance" between available interventions. To that end, preference and indifference thresholds for each criterion will be calculated with the use of referenced equations (2) (Haralambopoulos and Polatidis, 2003; Rogers and Bruen, 1998; Vlachokostas et al., 2011) and (3) (Kourmpanis et al., 2008; Vlachokostas et al., 2011), respectively:

$$p_k = \frac{1}{n}(R_{akMAX} - R_{akMIN}) \quad (2)$$

Where, a: control measure and k: evaluation criteria

$$q_k = 0.3 \times p_k \quad (3)$$

R_{akMAX} = Maximum performance of intervention a for criteria k,

R_{akMIN} = Minimum performance of intervention a for criteria k

n = Number of intervention

After carrying out the multi-criteria analysis, sensitivity analysis was also conducted to assess the robustness of results.

2.7. Sensitivity analysis

Applying sensitivity analysis to multi-criteria decision making processes is essential to ensure the consistency of final results. Through sensitivity analysis, different “what-if” scenarios can be visualized which are helpful to observe the impact of changing on criteria to final alternative rank. It helps in measuring how much changes made by certain extent of deviations in weights of criteria. Based on sensitivity analysis, it can be concluded that the final decision is consistent and reliable.

Results of multi-criteria methods mostly depend on the values of weight criteria coefficients (p, q, and v) that are on the relative importance attributed to particular criteria. Sometimes final choices change with minor changes of weight criteria coefficients, due to that fact, multi- criteria methods results are followed by an analysis of their sensitivity to these changes. The goal of sensitivity analysis of multi-criteria methods was to determine the way in which changes of criteria weight lead to changes in alternative rakings. This kind of analysis can be used to confirm rankings which were obtained through mathematical models and selection of the optimal alternative to robust the results.

2.8. Finalisation of results and report preparation

Finalised results of MCA were then used to identify most appropriate short/medium and long interventions listed in CAAPs. The detailed data analysis and results of MCA modelling are presented in next sections of this report.

3.0 Results and Discussions

3.1. Survey data statistics

As presented in Table 3, for Pune and Nashik we received a total of 30 and 38 survey responses respectively which were first subjected to QA/QC checks. Following the QA/QC process, a total of 27 and 34 surveys were selected for input to ELECTRE-III model while 3 surveys forms in Pune and 4 surveys forms in Nashik were rejected as they were not duly completed. The QA/QC checked survey forms were then subjected to preliminary statistical analysis. Fig. 4 presents the criteria-wise weightages assigned by different groups of stakeholders in Pune and Nashik. It can be seen that for both the cities criteria of Environmental benefits (C6) has received higher scores compared to other criteria and criteria of Employment generated (C7) was given least score by all the groups.

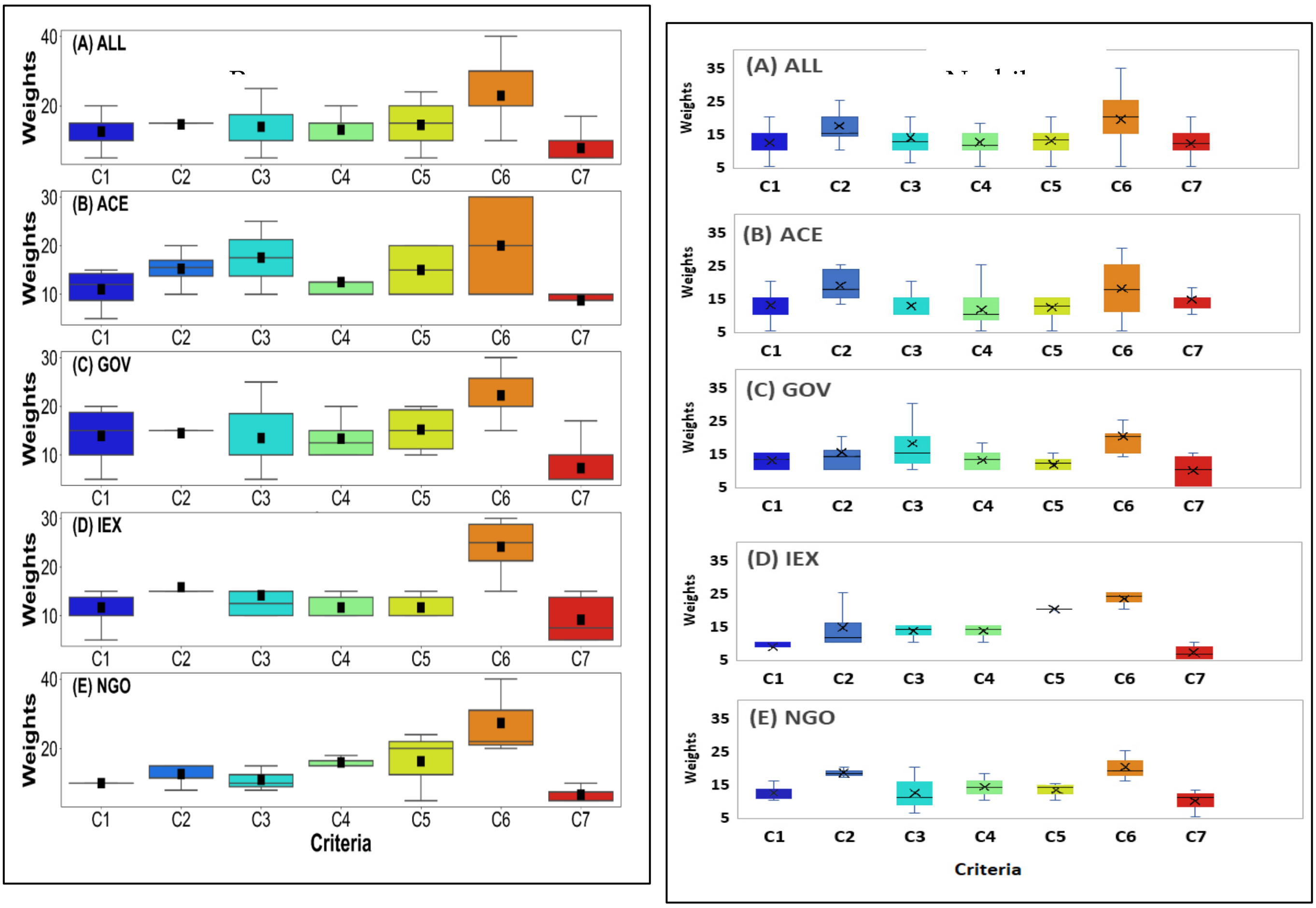


Fig 4. Box plot showing weightage of different criteria's based on target group in Pune and Nashik

3.2. Results of Multi-Criteria Analysis

As discussed in the section 2.6, the ELECTRE-III modelling was performed to obtain the ranking of interventions listed in CAAP. The ELECTRE- III analysis was performed in three different scenarios as mentioned below.

1. ELECTRE-III analysis without source contributions (SCE)
2. ELECTRE-III analysis with source contributions (SCE)

3. ELECTRE-III analysis for public awareness interventions

3.2.1 ELECTRE-III analysis without source contributions

The ELECTRE-III modelling was performed initially without weighing the input scores by source contribution estimates (weight factor). The scores assigned by stakeholders were used directly as input to the ELCTRE-III model to get ranks for each intervention. Fig. 5 and 6 depicts the boxplot distribution of ranks obtained for different interventions in Pune and Nashik city clean air action plan respectively.

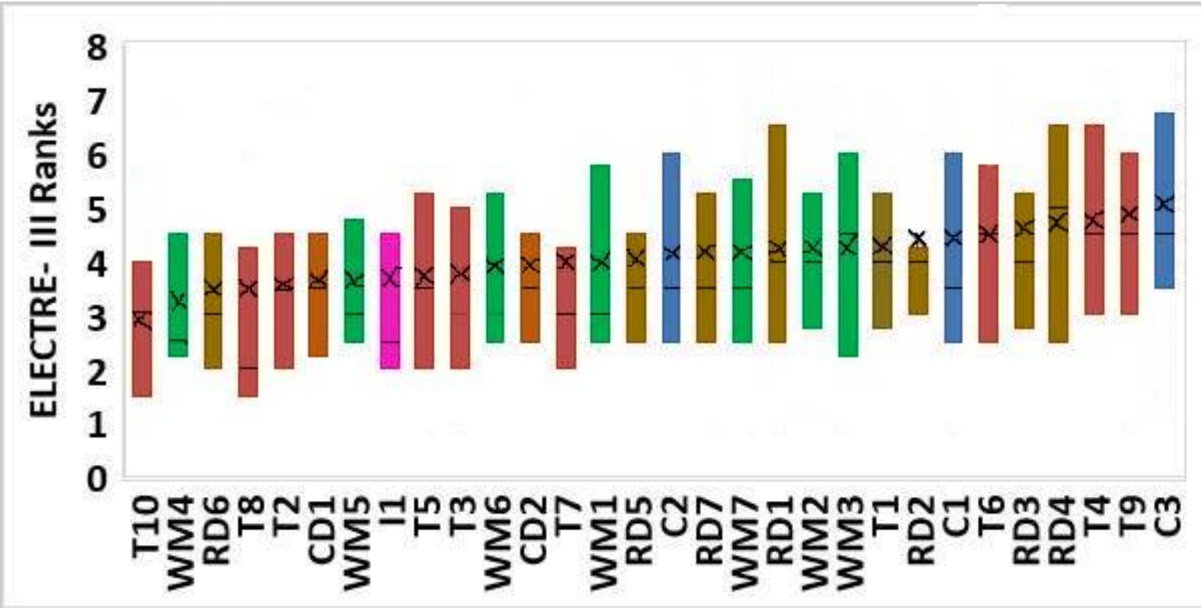


Fig 5: Boxplot distribution of ranks (Y-axis) obtained by 30 interventions (X-axis) in Pune city clean air action plan without source contribution estimates. Each boxrepresents: mean (Cross), median (central horizontal line), 25th and 75th percentiles (lower and upper edges of the box). Ranking is represented on Y-axis, lower the rank higher the importance and vice-versa.

Table 5: Ranking of interventions in Pune clean air action plan

Code	Intervention	Mean	Rank
T10	Metro Rail transport	2.91	1
WM4	Door to Door Collection of Waste	3.24	2
RD6	Greening of open areas, garden, community places, schools and housing societies	3.48	3
T8	Promoting Bicycles in Pune	3.50	4
T2	Promotion of CNG fuel: Subsidy to three wheeler Auto-rickshaws running on CNG	3.59	5

CD1	Better construction practices with PM reduction of 50%	3.65	6
WM5	Incentivising use of Solar Water Heating, Vermicompost and Rain Water Harvesting for existing properties	3.67	7
I1	Industries located within the city jurisdiction	3.69	8
T5	Purchasing of new CNG buses for public transport	3.74	9
T3	Encouraging more CNG stations within city	3.78	10
WM6	Banning use of plastic and thermacol	3.93	11
CD2	Ensure carriage of construction material in closed /covered Vessels	3.94	12
T7	Promoting Electric buses	3.96	13
WM1	Ban on open burning	4.00	14
RD5	Prepare plan for creation of green buffers along the Traffic corridors	4.07	15
C2	Encouraging use of Electric crematoriums	4.15	16
RD7	GIS based Tree Census	4.17	17
WM7	Public Awareness of Waste management	4.17	17
RD1	Wall to wall paving & Road design improvement	4.26	18
WM2	Ensure carriage of municipal solid waste in closed / covered vehicles	4.26	18
WM3	Hotel waste management through decentralised Bio methanization plants	4.26	18
T1	Sulphur reduction in diesel	4.30	19
RD2	Prepare action plan for widening of road and improvement of Infrastructure for de-congestion of Roads.	4.41	20
C1	Gas based Crematoriums	4.43	21
T6	Phasing out old bus fleet of more than 12 years	4.50	22
RD3	Maintain Pothole Free Roads for Free Flow Traffic	4.63	23
RD4	Black topping of metaled Roads including pavement of Road shoulders	4.69	24

T4	Encouraging registration of CNG based vehicles	4.76	25
T9	Synchronize Traffic movements/Introduce Intelligent Traffic systems for Lane Driving	4.87	26
C3	Installation of pollution control equipment at existing wood based crematoriums	5.06	27

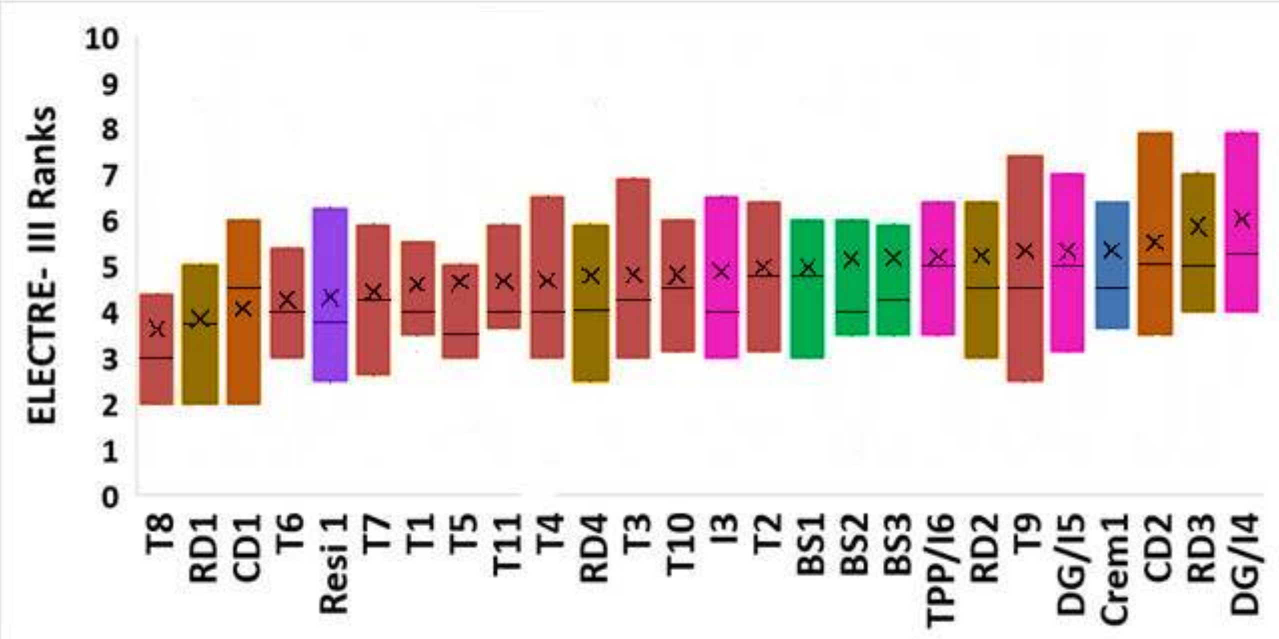


Fig 6: Boxplot distribution of ranks (Y-axis) obtained by 26 interventions (X-axis) in Nashik city clean air action plan without source contribution estimates. Each box represents: mean (cross), median (central horizontal line), 25th and 75th percentiles (lower and upper edges of the box) ranks. Ranking is represented on Y-axis, lower the rank higher the importance and vice-versa.

Table 6: Ranking of intervention listed in Nashik clean air action plan.

Sector	Code	Intervention	Mean	Ranking
Transport	T8	Promoting Battery operated vehicles	3.62	1
Road dust	RD1	Creation of green buffers	3.85	2
Construction & Demolition	CD1	Enforcement of construction & demolition rules	4.06	3
Transport	T6	Widening of road	4.26	4
Residential	Resi 1	Use of LPG in Hotels an "dhabas"	4.32	5

Transport	T7	Construction of expressways	4.44	6
Transport	T1	Extensive drives against polluting vehicles & fine for not carrying PUC	4.59	7
Transport	T5	Checking of fuel adulteration	4.65	8
Transport	T11	Installation of Remote Sensor based PUC systems		9
Transport	T4	Retrofitting of particulate filters in Diesel vehicles	4.68	10
Road dust	RD4	Black topping of metaled Roads	4.78	11
Transport	T3	Prevent parking of vehicles at non- designated areas	4.79	12
Transport	T10	Synchronizing traffic movements	4.82	13
Industry	I3	Action against non- complying industrial units	4.88	14
Transport	T2	Public awareness campaigns	4.99	15
Municipal Solid waste	BS1	Extensive drive against open burning of biomass	5.00	16
Municipal Solid waste	BS2	Regular check and control, of burning of Municipal solid waste	5.13	17
Municipal Solid waste	BS3	Proper collection of waste and its disposal	5.16	18
Thermal Power plant	TPP/I6	Installing FGD (Flue-gas desulfurization) at thermal plant	5.21	19
Road dust	RD2	Maintaining pothole free roads	5.24	20
Transport	T9	Install weigh in motion bridges	5.32	21
Diesel generator	DG SETS/I5	Reduction in DG set operation	5.32	22
Crematorium	Crem1	installation of LPG and electric operated crematoria at Nashik Amardham.	5.32	23
Construction & Demolition	CD2	Control measures for fugitive emissions	5.54	24
Road dust	RD3	Introducing water fountains at major traffic intersection	5.88	25

Diesel generator	DG SET/I4	Monitoring of DG sets and action against violations	6.03	26

An examination of Fig. 6 and Fig 7 reveals that the intervention from transport sector has been given maximum importance in both the cities. It indicates that as per the perception of different stakeholders, interventions from transport sector will play the major role in reducing the emission of $PM_{2.5}$.

The top interventions obtained from ELECTRE-III modelling for Pune and Nashik city is presented in table 5 and table 6 respectively. Also, it is analyzed a mix set of ranking were obtained from different sectors in both the cities as depicted in fig 5 and 6. For an example in case of Nashik the top 5 intervention are from transport, road dust, construction and residential sector. Similarly in Pune, the top 5 intervention are from transport, road dust and municipal solid waste management sector.

It was observed that many of the local scale interventions have outranked interventions which are from the major contributing sector to $PM_{2.5}$ emissions. For instance, interventions such as door to door collection of waste (WM4) and better construction practices with PM reduction of 5% (CD1) have outranked many of the transport sector interventions, which is the major contributor to $PM_{2.5}$ emissions (~35%) in the Pune city. Similarly in Nashik, interventions such as black topping of metaled roads including pavement of road shoulders (RD4) and proper collection of waste and its disposal (BS3) have ranks above the industry sector intervention's which is the major contributor to $PM_{2.5}$ emissions (~16%). It is important to note that although the local scale interventions are aimed at reducing the $PM_{2.5}$ levels, their implementation will not result in significant reduction in city level $PM_{2.5}$ emissions due to their lower contributions (1-5%). Hence, it is important to weigh the scores assigned by the stakeholders, w.r.t. source contribution estimates before using ELECTRE-III technique.

3.2.2. ELECTRE-III analysis with source contributions

The modelling exercise was repeated for each of the survey forms received after weighing the user raw scores by the score contribution estimate (SCE) factor as mentioned in table 4. Fig. 7 and 8 shows ranking obtained from ELECTRE-III model considering the $PM_{2.5}$ source contributions. This indicates the interventions with major contributing sources are given high importance. A significant variation in the ranks of intervention is observed when SCE is included. Also, it is important to note that the interventions are ranked in distinct groups as per their source contributions, which will help the regulatory agencies to assign the implementation responsibility to the concerned departments in a proper way.

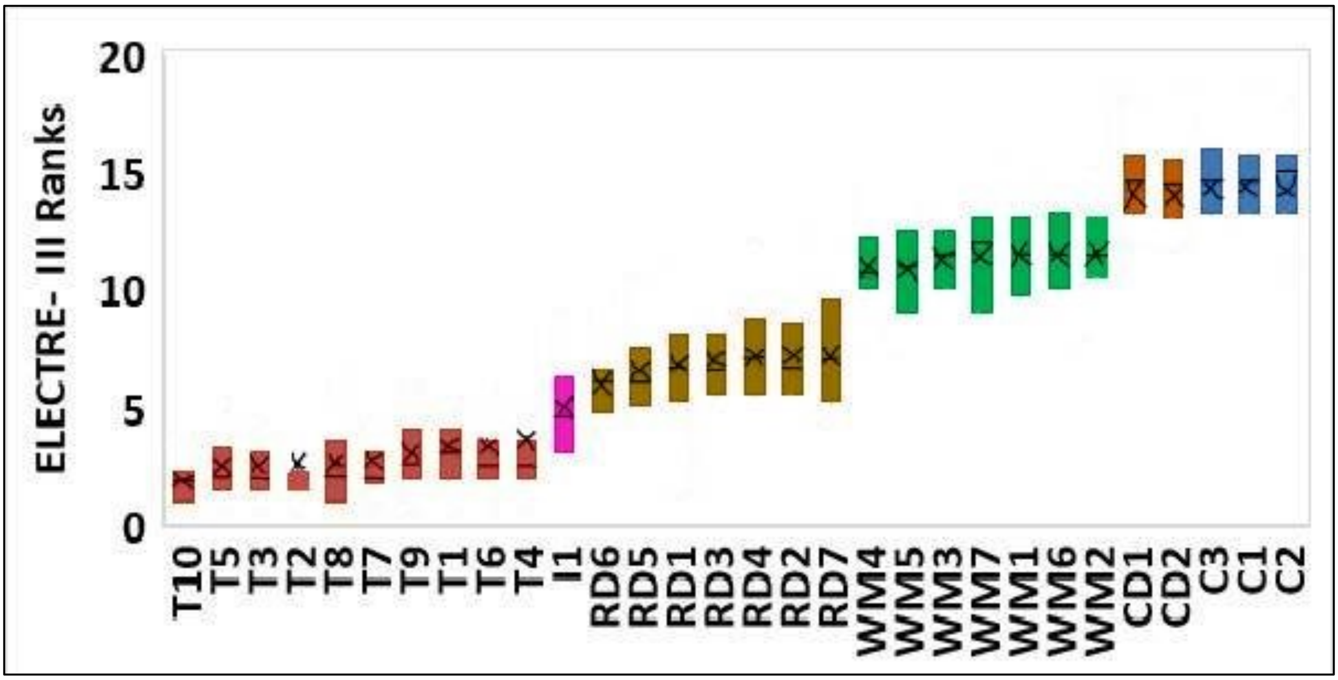


Fig 7: Boxplot distribution of ranks (Y-axis) obtained by 30 interventions (X-axis) in Pune city clean air action plan with source contribution estimates. Each box represents: mean (Cross), median (central horizontal line), 25th and 75th percentiles (lower and upper edges of the box).

In Pune, when SCE is included, the Metro rail transport (T10) is found to be the optimal intervention with a mean rank value of 1.9 whereas encouraging use of Electric crematoriums (C2) was found to be the least important intervention with a mean rank value of 14.3. Table 7 represents the ranking of interventions when source contribution factor was considered.

Table 7: Ranking of interventions with source contribution factor in Pune

Sector	Code	Clean air Action Plan Intervention	Mean	Ranking
Transport	T10	Metro Rail transport	1.9	1
Transport	T5	Purchasing of new CNG buses for public transport	2.4	2
Transport	T3	Encouraging more CNG stations within city	2.4	2
Transport	T2	Promotion of CNG fuel: Subsidy to three wheeler Auto-rickshaws running on CNG	2.5	3
Transport	T8	Promoting Bicycles in Pune	2.6	4
Transport	T7	Promoting Electric buses	2.6	4
Transport **Transport**	T9	Synchronize Traffic movements/Introduce Intelligent Traffic systems for Lane Driving	3	5

Transport	T1	Sulphur reduction in diesel	3.2	6
Transport	T6	Phasing out old bus fleet of more than 12 years	3.2	6
Transport	T4	Encouraging registration of CNG based vehicles	3.6	7
Industry	I1	Industries located within the city jurisdiction	4.8	8
Roads and Garden	RD6	Greening of open areas, garden, community places, schools and housing societies	6	9
Roads and Garden	RD5	Prepare plan for creation of green buffers along the Traffic corridors	6.5	10
Roads and Garden	RD1	Wall to wall paving & Road design improvement	6.8	11
Roads and Garden	RD3	Maintain Pothole Free Roads for Free Flow Traffic	7	12
Roads and Garden	RD4	Black topping of metaled Roads including pavement of Road shoulders	7.1	13
Roads and Garden	RD2	Prepare action plan for widening of road and improvement of Infrastructure for de-congestion of Roads.	7.1	13
Roads and Garden	RD7	GIS based Tree Census	7.3	14
Waste Management	WM4	Door to Door Collection of Waste	10.9	15
Waste Management	WM5	Incentivizing use of Solar Water Heating, Vermicompost and Rain Water Harvesting for existing properties.	10.9	16
Waste Management	WM3	Hotel waste management through decentralized bio methanization plants	11.3	17
Waste Management	WM7	Public Awareness of Waste management	11.4	18
Waste Management	WM1	Ban on open burning	11.4	18
Waste Management	WM6	Banning use of plastic and thermacol	11.5	19
Waste Management	WM2	Ensure carriage of municipal solid waste in closed /covered vehicles	11.6	20
Construction and Demolition	CD1	Better construction practices with PM reduction of 50%	14	21
Construction and	CD2	Ensure carriage of construction material in	14	21

Demolition		closed /covered Vessels		
Crematoria	C1	Gas based Crematoriums	14.3	22
Crematoria	C2	Encouraging use of Electric crematoriums	14.3	22
Crematoria	C3	Installation of pollution control equipment at existing wood based crematoriums	14.3	22

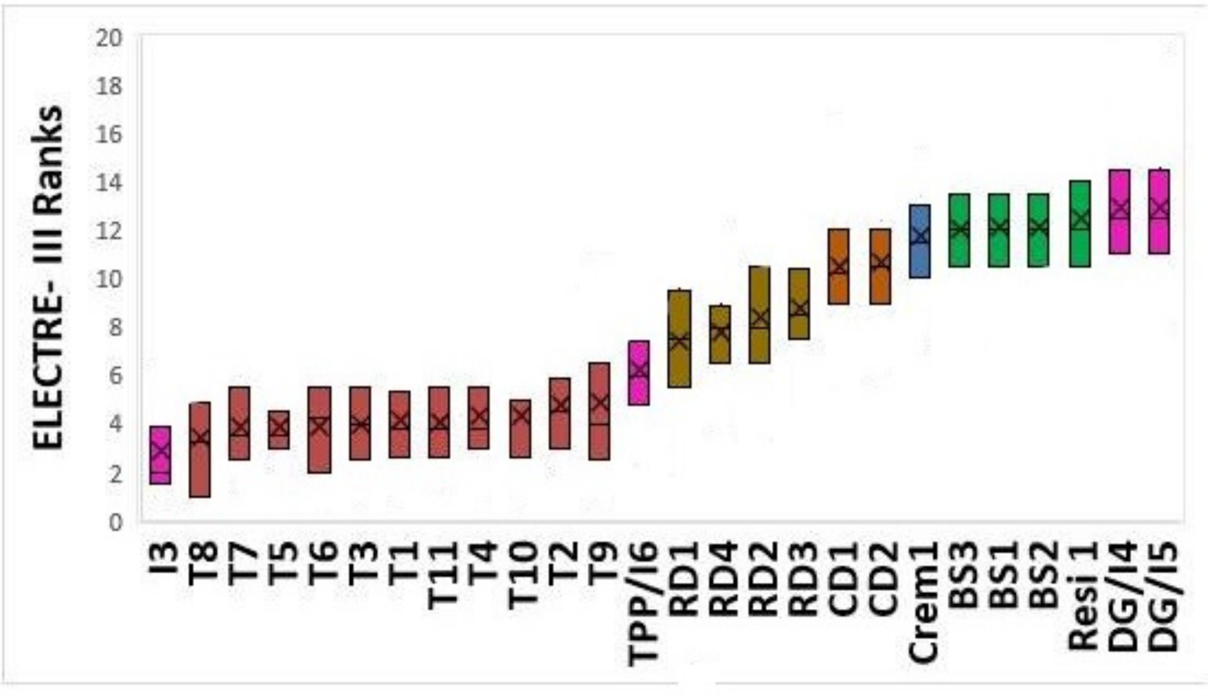


Fig 8: Boxplot distribution of ranks (Y-axis) obtained by 26 interventions (X-axis) in Nashik city clean air action plan with source contribution estimates. Each box represents: mean (cross), median (central horizontal line), 25th and 75th percentiles (lower and upper edges of the box) ranks. Ranking is represented on Y-axis, lower the rank higher the importance and vice-versa.

In case of Nashik, when SCE is included, intervention action against non- complying industrial units by Regular Vigilances and timely actions by MPCB time to time depending upon non-compliance (I3) was found to be the optimal intervention with a mean rank value of 1.9 whereas interventions from monitoring of DG sets and action against violations (I4) was found to be the least important intervention from diesel generator sector with a mean rank value of 13.9. Real world factor is applied to the emissions from transport sector and among all the sources in Nashik, industry, transport sector and thermal power plant emerged as significant source contributors with 33%, 27% and 24% to $PM_{2.5}$ emissions respectively. Table 8 represents the ranking of interventions when source contribution factor was considered.

Table 8: Ranking of interventions with source contribution factor in Nashik

Sector	Code	Intervention	Mean	Ranking
Industry	I3	Action against non- complying industrial units	2.84	1
Transport	T8	Promoting Battery operated vehicles	3.44	2
Transport	T7	Construction of expressways	3.88	3
Transport	T5	Checking of fuel adulteration	3.93	4
Transport	T6	Widening of road	3.93	5
Transport	T3	Prevent parking of Vehicles at Non-designated areas	4.04	6
Transport	T1	Extensive drives against polluting vehicles & fine for not carrying PUC	4.15	7
Transport	T11	Installation of Remote Sensor based PUC systems	4.15	8
Transport	T4	Retrofitting of particulate filters in Diesel vehicles	4.22	9
Transport	T10	Synchronizing traffic movements	4.38	10
Transport	T2	Public awareness campaigns	4.74	11
Transport	T9	Install weigh in Motion bridges	4.74	12
Thermal Power Plant	THERMAL/I6	Installing FGD (Flue-gas desulfurization) at thermal plant	6.34	13
Road dust	RD1	Creation of green buffers	7.41	14
Road dust	RD4	Black topping of metaled roads	7.90	15
Road dust	RD2	Maintaining pothole free roads	8.32	16
Road dust	RD3	Introducing water fountains at major traffic intersection	8.65	17
Construction & Demolition	CD1	Enforcement of construction & demolition rules	10.43	18
Construction & Demolition	CD2	Control measures for fugitive emissions	10.63	19

Crematorium	Crem1	Installation of LPG and Electric operated crematoria at Nashik Amardham.	11.68	20
Municipal Solid Waste	BS3	Proper collection of Horticulture waste and its disposal	11.97	21
Municipal Solid Waste	BS1	Extensive drive against open burning of biomass	12.00	22
Municipal Solid Waste	BS2	Regular check and control, of burning of Municipal Solid waste	12.01	23
Residential	Resi 1	Use of LPG in Hotels and dhabas"	12.37	24
Diesel generator	DG SET/I4	Monitoring of DG sets and action against violations	12.84	25
Diesel generator	DG SETS/I5	Reduction in DG set operation	12.84	26

3.2.3.1 Sector-wise optimal interventions for Pune city

Considering the source contribution estimates, we also sorted the top interventions in each $PM_{2.5}$ source sector. In the transport sector, which the major contributor to $PM_{2.5}$ emission (~35%) in Pune city, Metro Rail transport (T10, Mean Rank: 1.9) is found to be the optimal intervention, followed by Purchasing of new CNG buses for public transport (T5, Mean Rank: 2.4) and Encouraging more CNG stations within city (T3, Mean Rank: 2.4) as shown in Figure 9. The transport sector interventions are proceeded by the industrial sector ($PM_{2.5}$ emissions share: 23%) with intervention I1 i.e. Industries located within the city jurisdiction, obtained a mean rank value of 4.8. This is only intervention planned for industrial sector in Pune city clean air action Plan.

The next important sector in PM2.5 emissions in Pune city is re-suspended road dust. The most optimal intervention for this sector as presented in figure 10, are Greening of open areas, garden, community places, schools and housing societies (RD6, Mean Rank: 6.0), followed by Prepare plan for creation of green buffers along the Traffic corridors (RD5, Mean Rank: 6.5) and Wall to wall paving & Road design improvement (RD1, Mean Rank: 6.8).

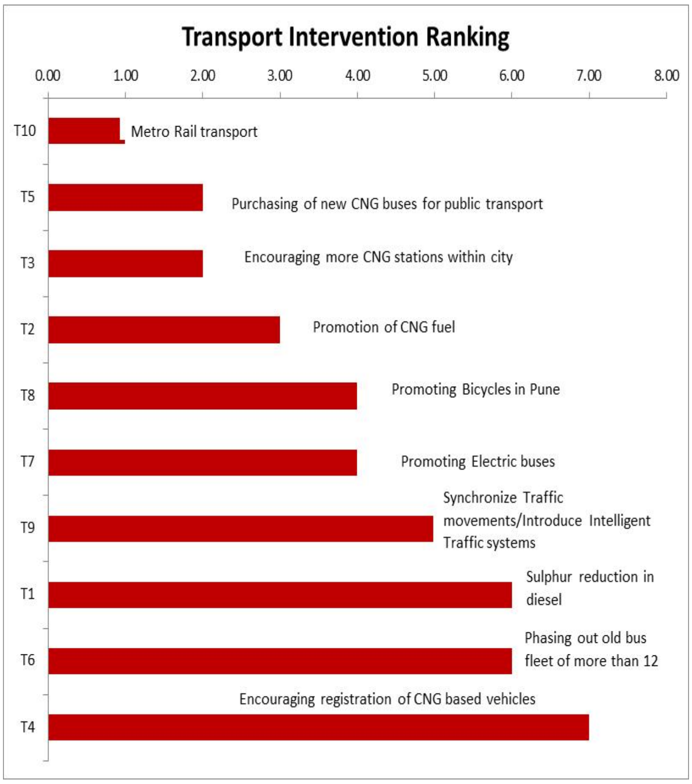


Fig 9: Ranking of intervention under transport sector

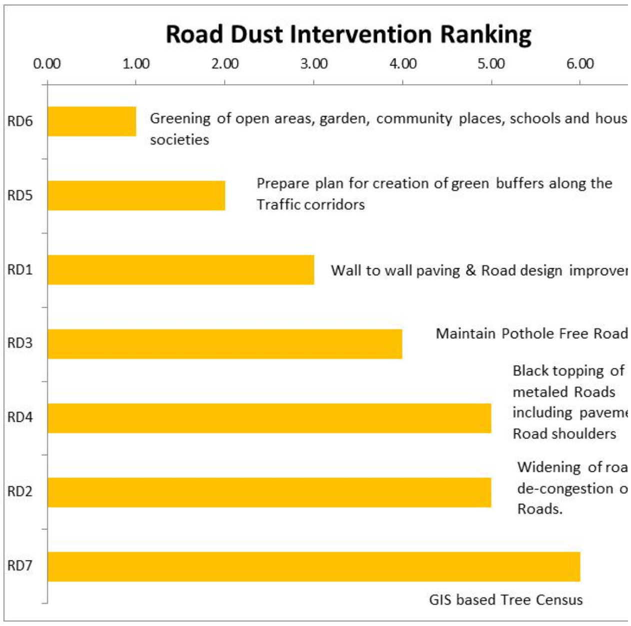


Fig 10: Ranking of intervention under road dust secto

Similarly, three most optimal interventions for waste management sector as presented in figure 11, are Door to Door Collection of Waste (WM4: Mean Rank: 10.9), followed by Incentivizing use of Solar Water Heating, Vermi compost and Rain Water Harvesting for existing properties (WM5, Mean Rank: 10.9) and Hotel waste management through decentralized Bio methanization plants (WM3, Mean Rank: 11.3).

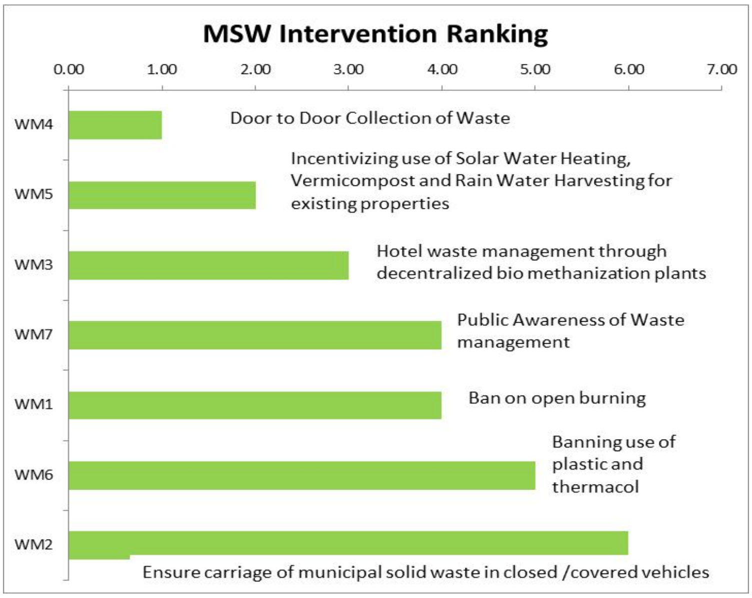


Fig 11: Ranking of intervention under municipal solid waste management sector

The two interventions proposed in Construction and demolition waste sector i.e. Better construction practices with PM reduction of 5% (CD1) and Ensure carriage of construction material in closed /covered Vessels (CD2) obtained a mean rank of 14.0. Similarly, all three interventions in crematoria sector i.e. Gas based Crematoriums (C1), Encouraging use of Electric crematoriums (C2) and Installation of pollution control equipment at existing wood based crematoriums (C3) obtained same mean rank value of 14.3.

3.2.3.2 Sector-wise optimal interventions for Nashik city

Considering the source contribution estimates, sector-wise top interventions were also sorted as shown in figures 12-15.

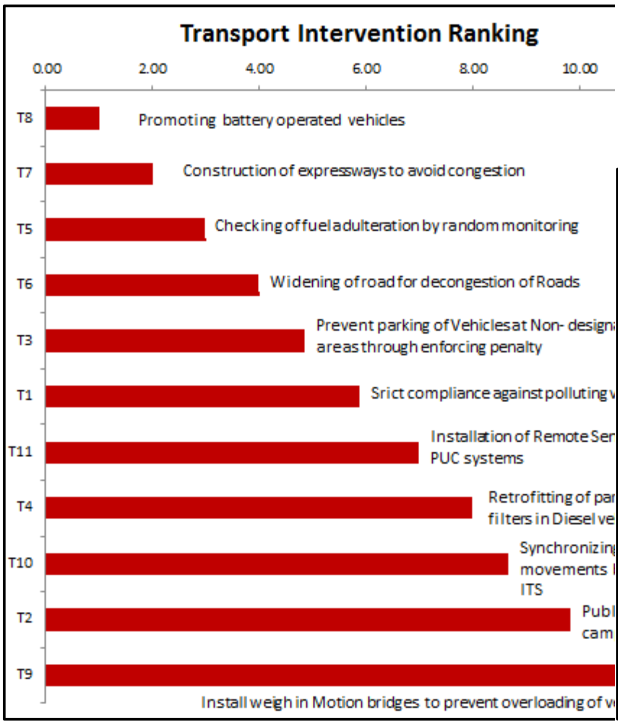


Fig 12: Ranking of intervention under transport sector

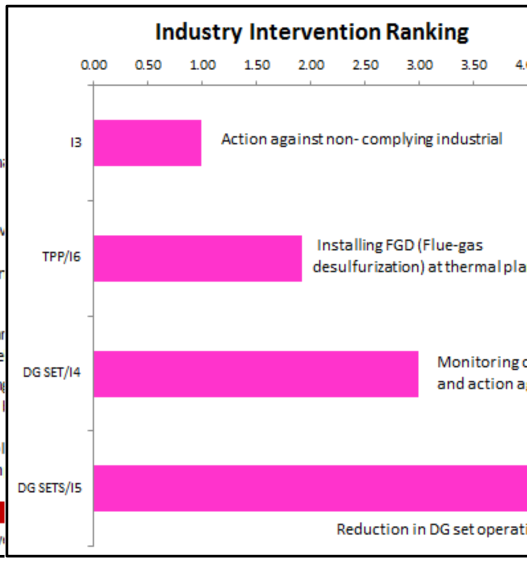


Fig13 : Ranking of intervention under industry and diesel set sector

In industrial sector, action against non- complying industrial units by regular vigilances and timely actions by MPCB is found to be the optimal intervention (I3 mean rank: 2.8) followed by installing FGD (Flue-gas desulfurization) plant to address emissions from thermal power plant (I6 mean rank:6.3) whereas promoting battery operated vehicles in buses and auto rickshaws (T8 mean rank: 3.4) and construction of expressways to avoid congestion (T 7 mean rank: 3.8) given high importance from transport sector.

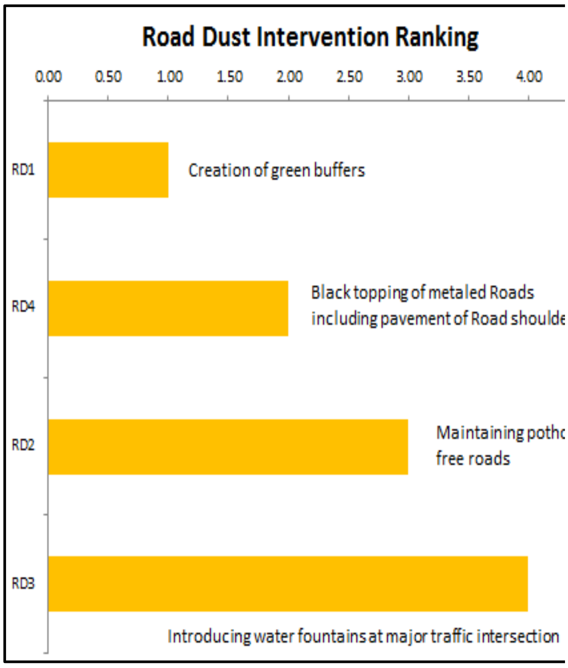


Fig 14: Ranking of intervention under road dust sector

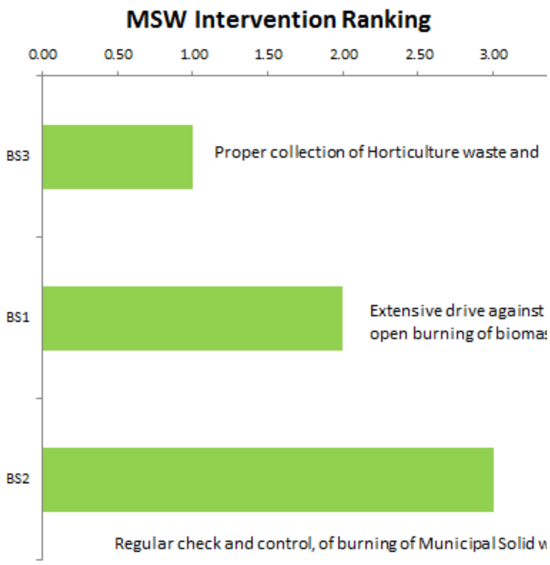
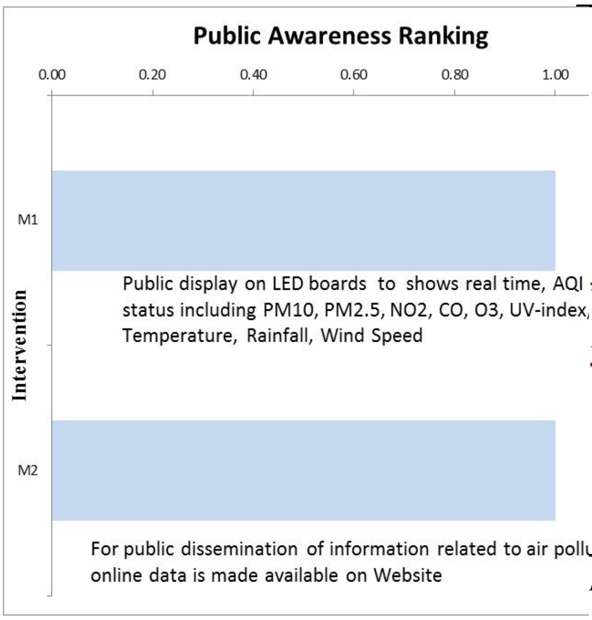


Fig 15: Ranking of intervention under municipal solid waste management sector

As seen in fig 14 the most optimal intervention from road sector is creation of green buffers along the selected Traffic corridor (RD1 mean rank: 7.4) followed by black topping of metaled roads including pavement of road shoulders (RD 4 mean rank: 7.9). In a corresponding manner the most optimal interventions for waste management sector is proper collection of Horticulture waste and its disposal (BS3 mean rank : 11.9) and in construction sector is enforcement of construction & demolition rules 2016 strictly by selecting the operator for processing construction and demolition waste (CD1 mean rank:10.4).

3.2.3. ELECTRE-III analysis for public awareness interventions

The ELECTRE-III modelling was performed separately for the interventions listed under public awareness section. The scores assigned by stakeholders were used directly as input to the ELCTRE-III model to get ranks for each intervention. Fig. XX and XX depicts the ranking obtained for public awareness interventions in Pune and Nashik city clean air action plan.



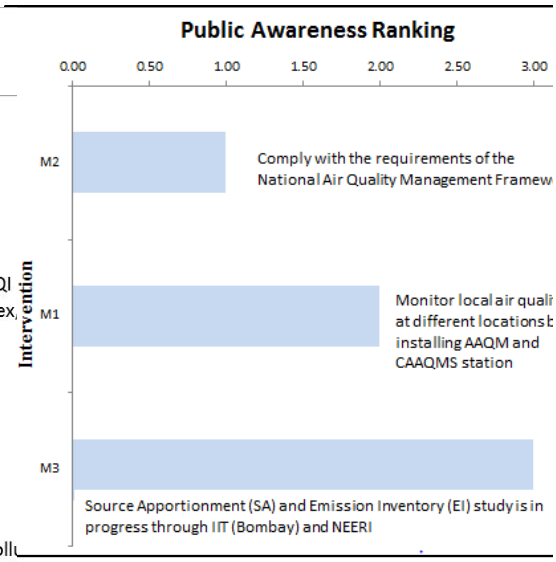


Fig 17: Ranking obtained for public awareness interventions in Nashik

Fig 16: Ranking obtained for public awareness interventions in Pune

3.3 Sensitivity Analysis

Sensitivity analysis was performed to examine variations in the modelling output as a function of three selected thresholds i.e. preference (p), indifference (q), and veto (v). A user survey form was selected for the sensitivity analysis and 8 scenarios with differentiating preference, indifference and veto thresholds by 40% (increasing and decreasing) were analysed w.r.t. the "BASE" scenario in both the cities. Fig. 18-19 shows the changes in ranks obtained in 8 different scenarios compared to "BASE" scenario.

The magnitude of change in rankings in Pune and Nashik stretched in the range of minimum -3.0 (SC8, -40%) and -2.0 (SC3, 20%) to a maximum of +1.5 (SC6, -10%) and +1 (SC8, -40%) respectively. It indicates that the ranking of interventions remain practically unaltered and the model results are robust. This will give an additional confidence to the regulatory agencies in implementing the optimized interventions.

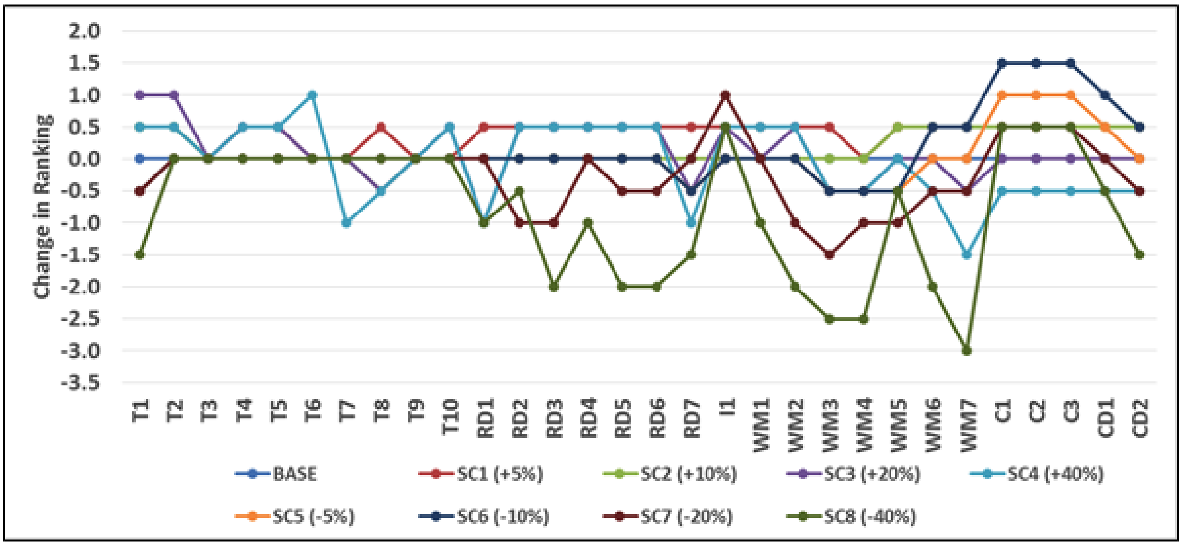


Fig. 18: The observed change in rankings (Y-axis) of the 30 interventions (X-axis) for 8 different threshold scenarios (SC1-SC8) w.r.t. BASE scenario, obtained using ELCTRE-III technique.

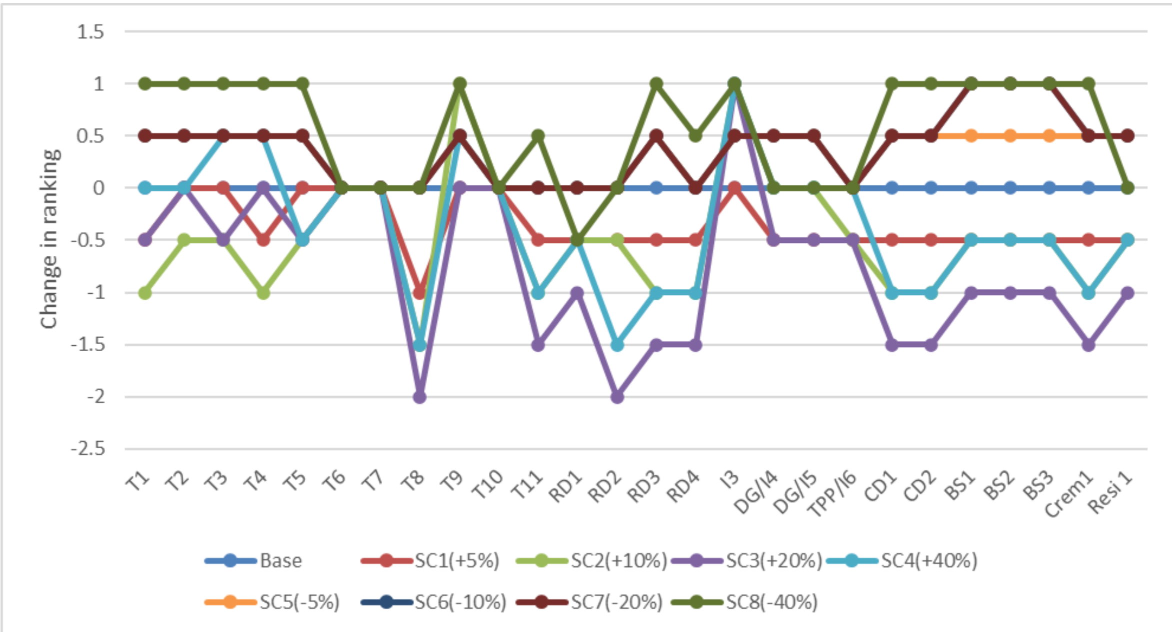


Figure 19: The observed change in rankings (Y-axis) of the 26 interventions (X-axis) for 8 different threshold scenarios (SC1-SC8) w.r.t. BASE scenario, obtained using ELCTRE-III technique.

4.0 Conclusion

Air pollution is a serious environmental concern in this rapidly urbanizing world and Indian cities are no exception. Pune and Nashik city is also currently facing air pollution challenges associated with the rapid growth. The city administration and state regulatory authorities have already devised an action plan under NCAP. These plans list various strategies which can reduce sectorial emissions and can contribute towards air quality improvements. As the resources required in implementation of such action plans are limited in nature, it is very important to concentrate the efforts on specific actions to maximize the effect. Thus, the prioritisation of interventions to control air pollution in the cities is crucial for regulatory agencies and requires the development of the systematic methodological approach. Optimization of interventions is a mammoth task and involves assessment on different criteria such as technology, social, sustainability and environmental benefits, and the costs. It is also important that city level stakeholders are also involved in this process, as they have a better knowledge of the city characteristics and can provide useful insights.

The methodology adopted in prioritization of air pollution control interventions primarily focused on getting the inputs from local stakeholders from industry, academia, government departments, and non-government organizations. The inputs received from this exercise were used to assess the effectiveness of each air pollution intervention listed in CAAP of Pune and Nashik city w.r.t. seven identified criteria including: Sectorial acceptance(C1), Economic benefits(C2), Economic Costing(C3), Social acceptance (C4), Social benefits (C5), Environmental benefits (C6), and Employment generated (C7) using ELECTRE-III multi-criteria analysis technique. This methodology provided the output in the form of ranks for each intervention, which were then used to identify the optimal interventions.

The top five interventions of the two cities are listed in table 9.

Table9: Top five interventions of the two cities

Pune		**Nashik**	
Sector	**Intervention**	**Sector**	**Intervention**
Transport	Metro Rail transport	**Industry**	Action against non- complying industrial units
Transport	Purchasing of new CNG buses for public /Encouraging more	**Transport**	Promoting Battery operated

	CNG stations within city		vehicles
Transport	Promotion of CNG fuel: Subsidy to three wheeler	**Transport**	Construction of expressways
Transport	Promoting Bicycles / Electric buses	**Transport**	Checking of fuel adulteration
Transport	Synchronize traffic movements and Introduce Intelligent Traffic systems for Lane Driving	**Transport**	Widening of road

Also, a sector wise analysis was also conducted to identify the optimal interventions in each sector of the two cities and following interventions topped the list:

For Pune:

A. Transport sector:

- Metro Rail transport
- Purchasing of new CNG buses for public transport
- Encouraging more CNG stations within city

B. Industry sector:

- Industries located within the city jurisdiction

C. Road sector:

- Greening of open areas, garden, community places, schools and housing societies
- Prepare plan for creation of green buffers along the Traffic corridors
- Wall to wall paving & Road design improvement

D. Waste Management sector:

- Door to Door Collection of Waste
- Incentivizing use of Solar Water Heating, Vermi compost and Rain Water Harvesting for existing properties
- Hotel waste management through decentralized Bio methanization plants

E. Construction and Demolition sector:

- Better construction practices with PM reduction of 5%
- Ensure carriage of construction material in closed /covered Vessels

F. Crematorium sector:

- Gas based Crematoriums
- Encouraging use of Electric crematoriums
- Installation of pollution control equipment at existing wood based crematoriums

For Nashik:

A. Industry/ Thermal Power Plant sector:

- Action against non- complying industrial units
- Installing FGD (Flue-gas desulfurization) at thermal plant

B. Transport sector:

- Promoting battery operated vehicles
- Checking of fuel adulteration
- Widening of road

C. Road sector:

- Creation of green buffers
- Black topping of metaled roads
- Maintaining pothole free roads

D. Construction and Demolition sector:

- Enforcement of construction & demolition rules
- Control measures for fugitive emissions

E. Crematorium sector:

- Installation of LPG and electric operated crematorium

F. Waste Management sector:

- Extensive drive against open burning of biomass
- Regular check and control, of burning of municipal solid waste
- Proper collection of horticulture waste and its disposal

It is important that clean air action plans are updated periodically based on scientific inputs from the research community, state regulatory agencies, and local stakeholders. Further, the current action plan shall also try and incorporate the impact caused by activities as mentioned below.

For Pune:

- Diesel generators used in residential and commercial establishments
- Use of biomass as a fuel for heating and cooking purposes
- Parking spaces and traffic congestion
- Strict implementation of phasing out of old vehicle fleet
- Monitoring of pollution control measures implemented at construction sites
- Brick kilns around the city area

For Nashik:

- Setting up of charging stations for electric buses
- Introduction of metro rail
- Strict implementation of phasing out of old vehicle fleet
- Solid waste separation at source and E-waste management
- Monitoring thermal power plant on regular basis
- Installation of CNG / LNG and supply natural gas to industrial & household.

During the stakeholder's workshops, people have also provided their views, observations, remarks and suggestions to improve the air quality. A compiled list of these suggestions for Pune and Nashik is provided in Annexure C of this report.

In addition to focusing the energies on above listed control interventions, it is very important that a continual coordination is maintained among the air quality scientists, policymakers and other local stakeholders to track the effectiveness of implemented actions.

REFERENCES

Bockstaller, C., Guichard, L., Makowski, D., Aveline, A., Girardin, P., Plantureux, S., 2008. Agri-environmental indicators to assess cropping and farming systems. A review Agron. Sustain. Dev., 28, pp. 139-149.

CPCB, 2020. Website: https://cpcb.nic.in/list-of-non-attainment-cities/. Last accessed: September, 2020.

Dragan, P., Darko, B., Aca., R., 2012. Multi-criteria decision making: An example of sensitivity analysis. Serbian Journal of Management 12(1):1-27.

Haralambopoulos, D., Polatidis, H., 2003. Renewable energy projects: structuring a multi- criteria group decision-making framework. Renewable Energy 28, Page: 961-973.

Irfan, S., 2013. Multi-criteria Evaluation and Sensitivity Analysis on Information Security. International Journal of Computer Applications (0975 – 8887) Volume 69– No.24.

Kourmpanis, B., Papadopoulos, A., Moustakas, K., Kourmoussis, F., Stylianou, M., Loizidou, M., 2008. An integrated approach for the management of demolition waste in Cyprus. Waste Management and Research 26, Page: 573-581.

PMC, 2012. Revising/Updating the City Development Plan (CDP) of Pune city – 2041. Final Draft CDP – Vol. I, Pune Municipal Corporation, Pune.

PMC, 2020. Environmental Status Report (ESR) 2019-20. Pune Municipal Corporation, Pune.

Rogers, M., Bruen, M., 1998. Choosing realistic values of indifference, preference and veto thresholds for use with environmental criteria within ELECTRE. European Journal of Operational Research 107, Page: 542-551.

Roussat, N., Dujet, C., Mehu, J., 2009. Choosing a sustainable demolition waste management strategy using multicriteria decision analysis. Waste Management, 29, Page: 2-20.

Roy, B., 1978. Electre III; Algorithme de classement base sur une representation floue des preferences en presence de criteres multiples. Cahiers de CERO 20 (Issue 1), 3-24

Vlachokostas, C., Achillas, C., Moussiopoulos, N., Banias, G., 2011. Multicriteria methodological approach to manage urban air pollution. Atmospheric Environment, 45, Page: 4160-4169.