ISSN 0304-9892 (Print) ISSN 2455-7463 (Online)
www.vijnanaparishadofindia.org/jnanabha
***Jñānābha* Vol. 55 (I) Special Issue 2025, 16-22**
Proceedings: 5th International Conference and Golden Jubilee Celebrations of VPI (IC-RA-MSA-ET 2022) JNU, New Delhi, India

ANALYSIS OF POLLUTION CAUSING ATTRIBUTES DURING TRAFFIC ON ROADS

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(Received: October 09*,* 2023*, In format: October* 27*,* 2023*; Revised: March* 03*,* 2024*; Accepted March* 10*,* 2025*)*

DOI: https://doi.org/10.58250/jnanabha_SI.2025.55102

Abstract

Due to urbanization and the increase in the population, means of transportation have increased drastically because it makes traveling easy for people and also because of ease of availability. Either 2 wheeler or 3 or 4 wheeler or self-owned car or rented taxi, all are in huge demand based upon the preference of the people. But besides all these advantages, these vehicles come with a big disadvantage which will surely not only impact people's time but only have a great effect on their health and Pollution is one among them. The tremendous use of these services will definitely increase the congestion on the road, especially at the intersection points which are busy all the time and this will be dangerous as it will not only impact the pocket of the people in terms of fuel consumption but also increases the pollutions in terms of air and noise. This paper mainly deals with the critical analysis of the attributes that cause air pollution and the contribution of each type of vehicle during traffic by the number of vehicles using mutated critic and AHP method so that the traffic department can take necessary steps to reduce the traffic at these intersection points so that the consumption of fuel as well the pollutant level that increases these problems decreases.

2020 Mathematical Sciences Classification: 90B50, 90C27, 90C29.
Keywords and Phrases: Traffic, Optimization, Pollution, Air, AHP, Mutated Critic Method

1 Introduction

Continuous increase in the economy along with the enhancement in the pattern of livelihood of the people poses a threat to the environment as well as the ecology. It even creates a recession in the ecological balance. Cities are more inclined towards the development of humans and in the ecological and civilization advancement [1,13]. Over the past many years, migration of people to the cities has increased from 5% to more than 50%, and by 2050, it is expected to increase by 66% mainly in developing countries/cities. In today's era due to the increase in urbanization people need more facilities to do their daily activities and Travelling and Motorization are some of the most frequent activities that are included in their day-to-day activities [19]. Ease in the availability of transportation facilities makes it even easier for people mainly in urban areas to travel for their work/ for whatever reason they want to travel [14,15]. There is a huge linkage between these transportation facilities provided by different vehicles, overcrowded cities, and the effect on the environment as well as on the people [11]. The increase in the population somewhere gives the advantage in terms of human resources but also increases the pressure on the resources that are vulnerable to extinction like water, air, and land and somehow affects the transportation facilities too [1,12]. Due to the increase in these motorization facilities, there is a tremendous increase in the traffic on the roads which in turn increases the accidents on the roads as well as the pollution released from these vehicles also affects our health [3,7,8]. Not only air pollution but also the noise pollution caused by these vehicles mainly at the intersection points as most of the time there is a fair chance of being stuck at traffic at these points and then simultaneously increases these pollutions as well increases the mortality rate of the people at these sites [20,21]. From the recent studies, we can conclude that people living near major roadways have a high chance of being affected by the diseases caused due to this pollution [22]. Among all the pollution-causing attributes, particulate mainly PM 2.5 is the most dangerous one due to which 480000 people die in Europe. According to the

reports of the Institute for Health Effects, 95% of people all over the world breathe polluted air and die due to several diseases caused by this [5,17]. Not only air pollution but it also enhances noise pollution [4,18]. According to the report of *WHO*, Noise pollution is the second stressor after air which is caused by the traffic on roads. Besides the harmful diseases caused by air pollution, Noise pollution also affects the body in a very ways which include early death, constant stress, tension, depression, hearing problems, etc. So, there is an urgent need to overcome this issue and a need to make a balance between the environment and the ecology as both are important for survival and growth. Presently there are very few studies that consider the effect of congestion of vehicles on the environment and on the health of the people [9]. There is not a single method through which we can estimate the impact of this. It depends on the choice of the users which method they want to choose and more on the accuracy of that method. There is an urgent need to identify these factors not only theoretically but also quantitatively. There are many areas through which we can deal with this problem but in this study, we are using Multi Criteria Decision Making Techniques more specifically *AHP* (Analytical Hierarchical Process) which is basically a technique used to solve complex decision-making processes which is proposed by Satty. Here we are taking different criteria as well as the alternatives based on the objectives [17,18]. It is basically based on the subjective weights where we need a different decision maker for the data [10]. Mutated Critic Method is also a good method of *MCDM* which helps in analyzing the attributes clearly and in making the decisions. This paper mainly deals with the analysis of the attributes which cause pollution mainly air during the traffic or congestion on roads and the number or the type of vehicles which are involved in causing this. In this study, we are using both the methods which are discussed above i.e. Analytical Hierarchy Process (*AHP*) as well as the mutated critic analysis method so that the government can take immediate and proper steps based on this.

2 Methodology Used

2.1 AHP (Analytical Hierarchical Process)

Step 1. We first define the objectives hierarchy as the decision criteria. The first level consists of the objective of the overall problem then the criteria /subcriteria in the subsequent level and at the last the alternatives if we have any.

Step 2. Decision makers analyze the objectives, criteria as well and subcriteria and assign importance according to that.

Step 3. Create a pairwise matrix based on the Satty's scale rule.

Step 4. After creating a decision matrix, we calculate the local priorities with the normalized matrix and then the global weights are calculated.

Step 5. Then the consistency of the matrix is checked and result is obtained. From this we can easily rank the criteria as well as the alternatives.

2.2 Mutated CRITIC Method

Step 1. Collect the data of the given objective problem.

Step 2. Represent the data in the matrix format.

Step 3. Normalized the data using the logarithmic method as compared to the best-worst method that we used in the original critic method.

For normalization, we are using the following formulas:

$$\text{Useful Criteria } = \frac{\ln(Z_{ij})}{\ln(\prod_{i=1}^{m} Z_{ij})}. \tag{2.1}$$

where Z_{ij} represents the entry of the criteria/ subcriteria in the matrix formed.

$$\text{Lost Criteria} = (1 - \frac{\ln(Z_{ij})}{\ln\left(\prod_{i=1}^{b} Z_{ij}\right)})/(b-1). \tag{2.2}$$

where b represents the number of stations.

Step 4. Calculate the standard deviation to analyze the variability among the criteria/subcriteria.

$$\textbf{S.D.} = \sqrt{\frac{\left(Z'_{\beth j} - \overline{Z}_j\right)^2}{b-1}}. \tag{2.3}$$

where Z'_{ij} represents the normalized value of each entry in the matrix.

Z'_j bar represents the mean value of each entry in the matrix.

b represents the number of stations.

Step 5. Modified Distance correlation is used here to calculate the correlation matrix.

$$Dcor\left(_j\ ,j^{'}\right) = \frac{Dcov\left(_j\ ,j^{'}\right)}{sqrt\left(dvar(\ \ _j\ )\ dvar(j^{'})\right)}. \tag{2.4}$$

Where dj, dj$^{'}$ represents the criteria.

Step 6. Calculate the information content to analyze the information that each criterion has. It is given by: -

$$\mathrm{I.F_j} = \mathrm{S.D_j}(\sum_{j=1}^{b}(1 - Dcor(_j\ ,j^{'})). \tag{2.5}$$

Step 7. The weight of each criterion is calculated by using the information content: -

$$W_j = I.F_j / \sum_{j=1}^{m} I.F_j. \tag{2.6}$$

3 Case Study and Results

The case study area which is taken for study is Sibiu, Romania, and data is taken from the research [21]. Here in this paper, we are taking 6 pollutants emitted from the intersection of roads which are CarbonMonoxide, Hydrocarbons, NO_x, Noise, Ozone, and PM10, and 5 intersections are taken which are described in Table 3.1 below:

***Table* 3.1:** *Pollutants data*

Intersections/Pollutants	CO	HC	Nox	Noise	Ozone	PM10
Intersection 1	187	7	16	91.36	39.14	67.87
Intersection 2	170	5	23	80.56	38.22	40.33
Intersection 3	165	6	19	85.3	37.97	41.27
Intersection 4	187	10	37	78.1	40.08	43.48
Intersection 5	245	19	49	76.3	40.33	25.06
	954	**47**	**144**	**411.62**	**195.74**	**218.01**

Here Intersection i represents the Aral Miles, Semaforului Paltinului, Semaforului-U.Militara, IBIS, Turismului-Morilor resp. Here $\boldsymbol{i}$ *= 1 to 5.*

In this study, we first analyze the pollutants using the mutated critic method and then rank each intersection using the AHP method. By applying the modified critic method, we get the following results as shown in Table 3.2 below:

***Table* 3.2:** *Result Matrix with weights*

Pollutants	CO	HC	Nox	Noise	Ozone	PM10
CO	1	0.9487711	0.8009438	0.6408855	0.8481255	0.8377564
HC	0.9487711	1	0.9269491	0.7643755	0.9195976	0.8115062
Nox	0.8009438	0.9269491	1	0.9304878	0.8839028	0.8022815
Noise	0.6408855	0.7643755	0.9304878	1	0.7335265	0.8451089
Ozone	0.8481255	0.9195976	0.8839028	0.7335265	1	0.6475484
PM10	0.8377564	0.8115062	0.8022815	0.8451089	0.6475484	1
S.D.	0.0016499	0.0040613	0.0142801	0.074726	0.0454397	0.0099764
Information Content(I.F)	0.0031735	0.0066151	0.0236398	0.1558498	0.0893935	0.0205095
Weight	0.0106074	0.0221105	0.0790151	0.5209212	0.2987938	0.0685521
Weight(%)	1.0607386	2.2110542	7.901506	52.092116	29.879376	6.8552097

Here we can see the Information provided by each pollutant and the weight/ contribution of each pollution in analysing pollution.

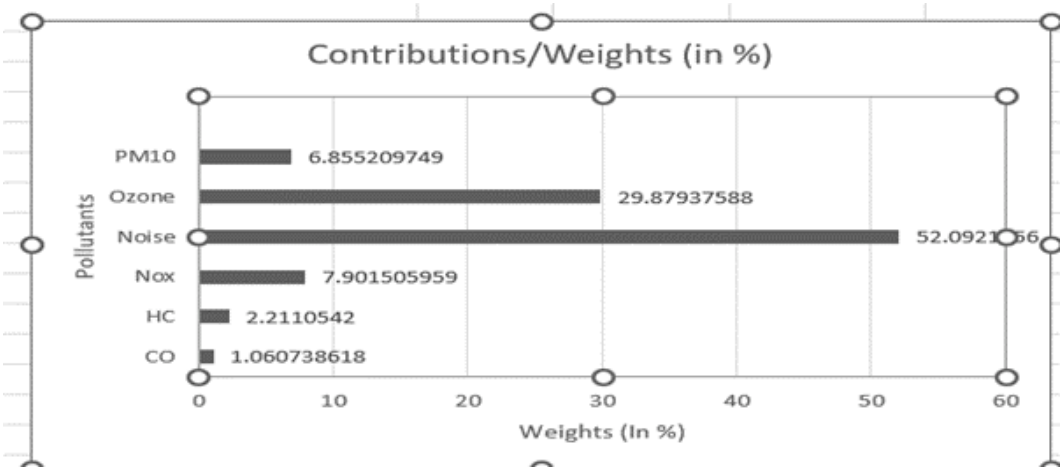

***Figure* 3.1:** *Weights of Different Criteria*

From Fig 3.1 and Fig 3.2, we can see that Noise is a major contributor in analyzing the pollution caused by traffic followed by the ozone concentration.

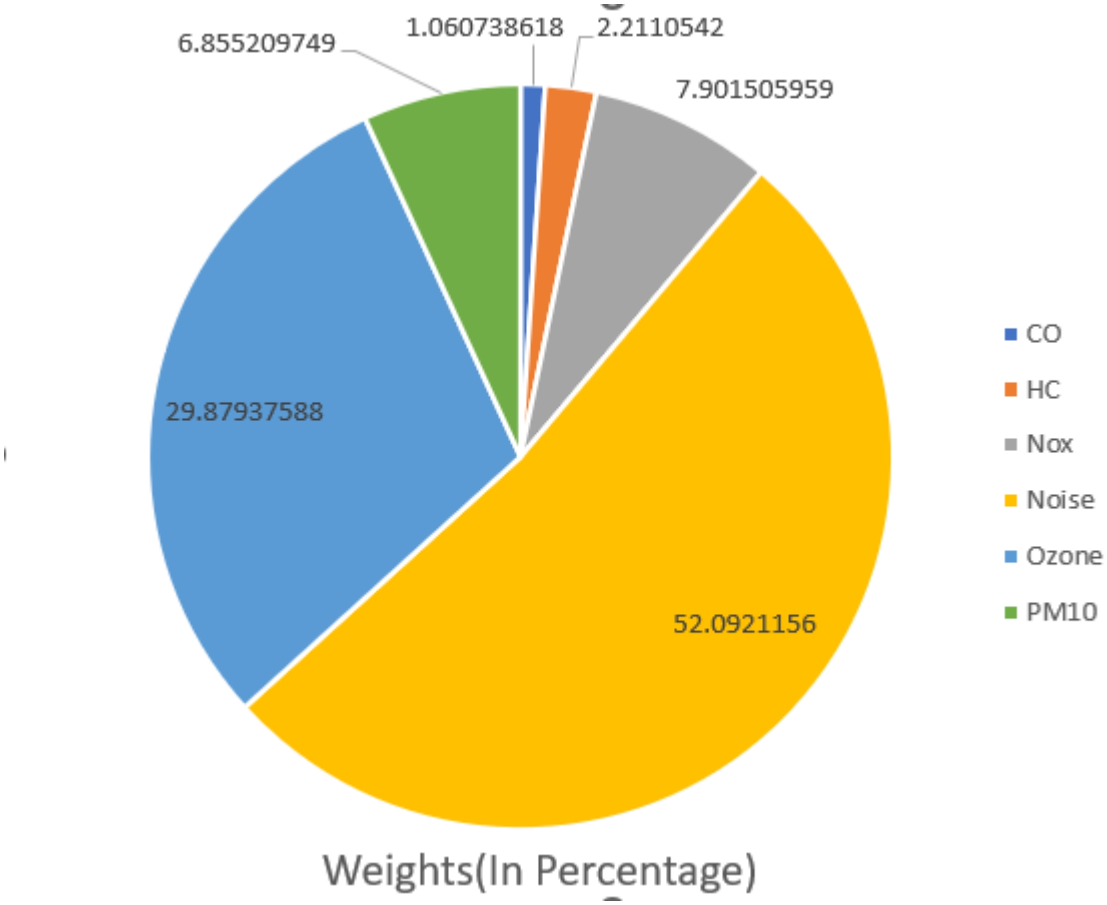

***Figure* 3.2:** *Contribution of pollutants*

After analyzing the weight of each pollutant, now we are in the position to rank the intersections roads based on the data given below:

***Table* 3.3:** *Intersection Data*

Intersection 1	Intersection 2	Intersection 3	Intersection 4	Intersection 5
1	3	2	4	5
0.333333	1	2	3	4
0.5	0.5	1	4	5
0.25	0.333333	0.25	1	2
0.2	0.25	0.2	0.5	1

After applying the AHP method, we get the following result as follows:

***Table* 3.4:** *Result Matrix (with AHP)*

	Weights
Intersection 1	41.00%
Intersection 2	24.10%
Intersection 3	21.50%
Intersection 4	8.10%
Intersection 5	5.30%
Consistency ratio	5.50%
No of comparisons	10

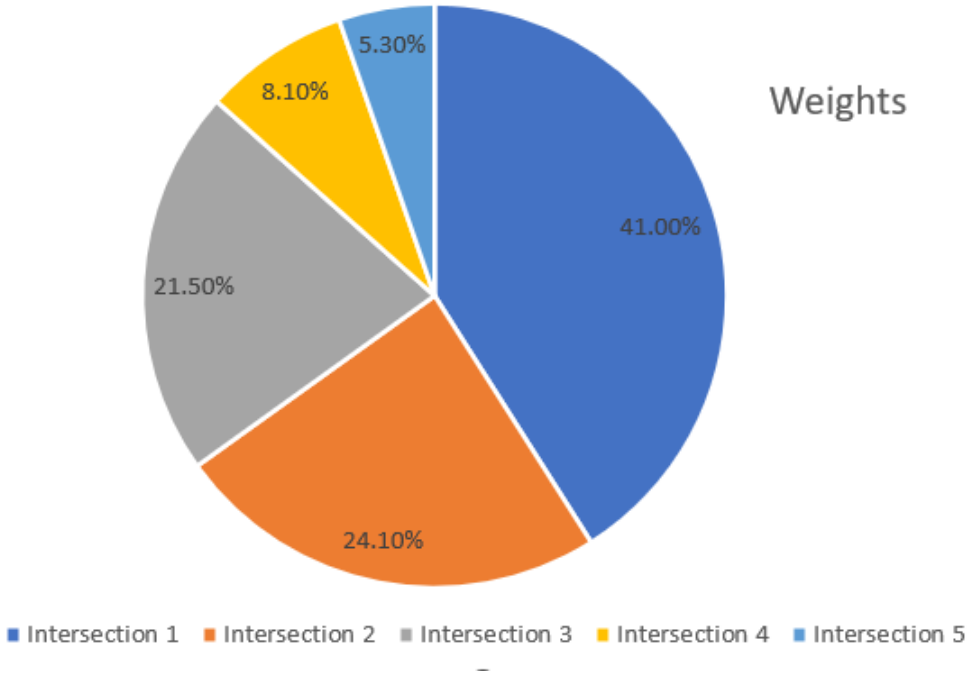

***Figure* 3.3:** *Contribution of Intersections*

4 Conclusion

As the quality of the environment continuously degrades over time due to these pollution-causing attributes/pollutants there is always a need to devise a proper methodology to reduce these pollutants. MCDM methods make a clear understanding of the results. Combining both methods, we get the overall result which can be analysed easily. From the above-calculated results, we can conclude that Intersection 1 contributes more to the pollution which means there is more congestion on these roads which does not affect the pocket of the people during the wastage of fuel, not only the time of the people because of the long waiting hours but also affect the health. Within the intersection 1 Noise attribute plays an important role in this with the maximum contribution in this. So, to reduce these negative effects we need to take steps like lowering the content of lead in fuel should be used, and Eco-friendly vehicles should be used as much as possible.

Acknowledgement. We are thankful to Guru Gobind Singh Indraprastha University for understanding this research.

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