



Health Risk Assessment for Transport Corridors in Delhi through Vehicular Air Polluting Mapping

Nitin Kumar*, Amrit Kumar

Department of Environmental Engineering, Delhi Technological University, Delhi, India

*Email: nk9.dtu@gmail.com

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ABSTRACT

Vehicles are recognized as one of the major sources of air pollution. Delhi having a very large number of vehicles produces a lot of air pollution. There is an utter need to ascertain the concentration of the pollutants and their impact on the health of the people of the concerned region. This paper makes an attempt towards such an examination. The method employed here is based on Epidemiology. The assessment of health risks due to increased levels of various pollutants on people represented in this paper is based on the spreadsheet model, Risk of Mortality/Morbidity due to Air Pollution (Ri-MAP). This paper presents the findings of the study that evaluates the Impact of increasing air pollution on human health, especially vehicular pollution, in the monitored region, i.e., National Capital Territory of Delhi (NCT Delhi) during the year 2015 by choosing fifteen study sites from different parts of the capital city. The findings are in terms of excess number of cases of cardiovascular and respiratory mortality, and cardiovascular and respiratory morbidity for all fifteen transport corridors. Among others, Noida link road recorded highest excess number of cases of cardiovascular mortality and morbidity and respiratory Morbidity. In case of respiratory mortality, Wazirabad road recorded maximum excess number of cases. With respect to least excess number of cases, it was Connaught Place (Outer circle). The excess number of cases are directly proportional to the population density of the respective region. Also, the regions showing smaller excess number of cases are the planned, less crowded and posh regions of the national capital territory of Delhi.

1. Introduction

The National Capital Territory of Delhi (NCT) covers an area of approximately 1500 km² including parts of the neighbouring states of Haryana, Uttar Pradesh, and Rajasthan and is counted among the most densely populated cities of the country as well as of the world. The region has grown rapidly over past 20 years. Delhi shows huge growth in its population every year which is estimated to cross approximately 20 million in 2020. The rapid urbanization and industrialization have resulted in the tremendous rise in population of Delhi, the capital city of India and its surrounding areas. Along with the large size population, Delhi is a prime centre for trade and commerce. It is heavily used for various socio-economic, cultural, political and major tourism activities. The national highways and other major road networks of the city carries intra and inter-city traffic traversing to and from the different parts of the country. As a result of these factors, the number of vehicles roaming on the roads of Delhi has rapidly increased over the past two decades and is still rising. In last two decades, the vehicle numbers have increased by more than five folds (i.e., 21 million in 1991 to 114 million in 2009) (MoRTH, 2011). With rising transport demand, India became 7th largest vehicle producing country in the world (OICA, 2010). Around 80% of passenger and 60% of freight movement depend on road transport (MoEF, 2000). It has been reported that steep rise in vehicle number and poor emission control practices results in serious air

pollution problem (Guo et al., 2007a). On-road vehicles were believed to be the single largest source of major atmospheric pollutants till 1998 (USEPA, 2000; Pokharel, 2002) and according to some reports Emission of airborne pollutants from transport sector accounts for more than 50% of gross emission in urban as well as semi-urban areas (Gujar et al., 2004; Fu, 2004; Wang et al., 2005; Zhang et al., 2008; Ramachandran and Shwetamala, 2009; Sahu et al., 2011). According to Nagpure et al., 2013 traffic is one of the major sources of pollution in all big cities and most of the urban regions.

Air pollution has various impacts on public health, causes urban and regional haze, and can contribute significantly to climate change (Molina and Molina, 2004). Proximity to major roadways and exposure to traffic related atmospheric pollutants may be associated with a number of respiratory and cardiovascular issues including asthma, reduced lung function, adverse birth outcomes, cardiac effects, respiratory symptoms, premature mortality, and lung cancer (HEI, 2010). Recently, diesel exhaust was officially classified as carcinogenic by the International Agency for Research on Cancer (IARC) of the World Health Organization (Straif et al., 2013). Gauderman et al., 2007 found that children who lived within 500 m of a freeway had substantial deficits in lung function, when compared to children who lived 1500 m or more from a freeway.

Table 1: Relative risk for mortality/morbidity due to respiratory and cardiovascular disorder in NCT Delhi.

Pollutant	Mortality/Morbidity	Relative Risk ^a (RR)	Baseline Incidence Per 100,000 (I)
NO ₂	Cardiovascular Mortality	1.00100 (1.0002164-1.001783) ^b	325
	Cardiovascular Morbidity	1.06138 (1.061094-1.061658)	2,533
	Respiratory Mortality	1.00016 (0.9997154-1.00061)	147
	Respiratory Morbidity	0.99505 (0.9941494-995956)	20,465
PM _{2.5}	Cardiovascular Mortality	1.01502 (1.0147869-1.015248)	325
	Cardiovascular Morbidity	1.04560 (1.0453666-1.045842)	2,533
	Respiratory Mortality	1.12824 (1.1279848-1.128498)	147
	Respiratory Morbidity	1.00685 (1.0066255-1.007083)	20,465

Source: Aggarwal and Jain (2015)

Note:

^a10 ug/m³ increment in NO₂ and PM_{2.5} concentration.

^bLower and upper limits (range) of the 95% confidence interval of RR values.

Knowing (or often assuming) a certain baseline frequency (at threshold concentration value given by WHO guideline) of selected health outcomes (i.e., I), the rate (or number of cases per unit population) attributed to the exposure in population (i.e., IE) can be calculated according to this formula (WHO, 1999):

$$IE = I \times AP$$

Equation (3)

Then IE can be used to estimate the number of cases attributed to exposure (i.e., NE) in the whole population of given size N, using the following equation:

$$NE = IE \times N$$

Equation (4)

Consequently, the frequency of the outcome in the population that is free from exposure (i.e., INE) can be estimated by the following equation:

$$INE = I - IE = I \times (1 - AP)$$

Equation (5)

The RR value at a certain level of pollution and the estimated incidence in non-exposed population can be further used for obtaining the excess incidence [i.e., $\Delta I(c)$] and excess number of cases [i.e., $\Delta N(c)$], respectively, at a certain category of exposure (c) can be calculated using the following equations:

$$\Delta I(c) = (RR(c) - 1) \times p(c) \times INE$$

Equation (6)

$$\Delta N(c) = \Delta I(c) \times N$$

Equation (7)

All the above mentioned formulas are based on the assumption that the RR estimate is adjusted for any possible confounding variables. When the limits of the confidence interval for the RR estimate are used in the

first equation, we obtain the corresponding range for AP and the respective range for the number of cases in the population that can be attributed to pollutant exposure.

The last equation is used to calculate the excess number of morbidity cases, which denotes the number of mortalities in the exposed population. In practice, however, the uncertainty of the impact (and the range of the estimated effect) is greater due to presence of errors in exposure assessment and non-statistical uncertainty of the exposure-response function (WHO, 1999; WHO, 2003; Nagpure et al., 2014).

3.3 Case Study Description

The study was performed in the national capital territory of Delhi during the year 2015. Fifteen different transport corridors were selected as study sites for monitoring of various pollutants across NCT of Delhi on twenty four hour basis observation. All the assessment and mortality/morbidity calculations presented in this paper are based on the readings from the case study. This paper focuses primarily on the study for respiratory and cardiovascular mortality/morbidity due to vehicular emissions. Pollutants like PM_{2.5} and NO₂ are the main concern in this paper.

3.4 Description of the Method

Data was collected on vehicular emission on twenty four hour basis. Then the population attributable-risk proportion concept was implemented on this data for the calculation of excess cases of mortality/morbidity due to cardiovascular and respiratory diseases (Woodruff et al., 1997; Douwes et al., 2002; Rothman et al., 2008). The calculation of mortality/morbidity was performed over sub-district populations for the respective transport corridors of the NCT Delhi. The population related data was taken from census of India 2011 and population for the year 2015 was projected (Sub-district, S. D. (2012)). The projected population was obtained using growth rate for the period 2011-2015, which itself was calculated through linear regression. The relative risk values used were taken from Aggarwal and Jain, 2015.

4. Results and Discussion

4.1 Study Parameters Data

We used the following data for the purpose of analysis as shown in the Table 2 and Table 3.

4.2 Transport Corridors

The first transport corridor lies in the Karol Bagh sub-district of Central Delhi district in NCT Delhi. The sub-district had a population of 136630 persons at that time. Figure 2 illustrates the trend of the excess number of cases of respiratory mortality and figure 3 illustrates the cases associated with cardiovascular mortality. For the year 2015, excess number of cases of cardiovascular mortality was 16. Similarly, figure 4 and 5 shows the trend of respiratory and cardiovascular morbidity respectively for all the studied transport corridors. In case of cardiovascular morbidity excess number of cases in 2015 was 1042. For respiratory mortality, excess number of cases was 31 and morbidity cases were 366 in number. Results indicate that particulate matter is responsible for the majority of the excess number of cases of both cardiovascular and respiratory mortality/morbidity in the area during the study period (2015). However, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

Mehrauli Road transport corridor passes through the Vasant Vihar sub-district of South-West Delhi district in NCT Delhi. The sub-district hosted a population of 679795 persons. Above figures illustrate the trend of the excess number of cases of cardiovascular and respiratory mortality/morbidity in this region. For the year

2015, excess number of cases of cardiovascular mortality was calculated to be 680 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was obtained as 19979 (Figure 5). For respiratory mortality, excess number of cases was found to be 767 (Figure 2) and for morbidity, number was 21145 (Figure 4). Results indicate that similar to above observations, particulate matter is responsible for most of the excess number of cases of both cardiovascular and respiratory mortality/morbidity in the area. However, few cases of mortality/morbidity were observed due to NOx pollution.

Rajghat stretches through the Shahdara sub-district of North-East Delhi district. A population of 344508 persons was living in the sub-district region at the time of study. Above graph figures 2 to 5 show the trend of the excess number of cases of cardiovascular and respiratory mortality and morbidity in this region. For the year 2015, excess number of cases of cardiovascular mortality was calculated to be 551 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was 13174 (Figure 5). For respiratory mortality, excess number of cases was 551 (Figure 2) and morbidity cases were 17695 in number (Figure 4). Here again, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

Lala Lajpat Rai transport corridor stretches through the Defence colony sub-district of South Delhi district in NCT Delhi and hosted a population of 680396 persons at that time. The excess number of cases of cardiovascular mortality/mortality and respiratory mortality/morbidity is shown in above figures. For the year 2015, excess number of cases of cardiovascular mortality was 684 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was calculated

Table 2: Population and Pollutants concentration values for study sites in NCT Delhi.

No.	Transport Corridor	Sub District	Population	NO ₂ Concentration [ug/m ³]	PM2.5 Concentration [ug/m ³]
1	Bara Khamba Road	Karol Bagh	136,630	213.56	49.33
2	Mehrauli Road	Vasant Vihar	679,795	261.62	261.66
3	Ring Road (Rajghat)	Shahdara	344,508	738.18	489.17
4	Lala Lajpat Rai Road	Defece Colony	680,396	401.39	247.05
5	Ring Road (Ashram F.O)	Gandhi Nagar	421,497	342.85	191.58
6	Africa Avenue	Hauz Khas	1,316,305	286.22	138.92
7	C.P. (Outer Circle)	Connaught Place	29,496	300.90	93.26
8	Rajokri Border (NH 8)	Chanakya Puri	54,758	426.12	379.63
9	Rohtak Road (NH 10)	Punjabi Bagh	840,542	213.11	184.86
10	Karnal Road (NH 1)	Model Town	636,253	439.57	415.13
11	G.T.Road (Old NH 1)	Narela	863,132	316.92	308.22
12	NH 24 Bypass	Vivek Vihar	263,648	214.60	173.22
13	NOIDA Link Road	Preet Vihar	1,137,366	441.64	429.64
14	Mathura Road (NH 2)	Kalkaji	920,802	565.50	538.50
15	Wazirabad Road	Seelam Pur	1,471,599	179.35	156.49

Table 3: Excess mortality and morbidity values for study sites in NCT Delhi.

No.	Transportation Corridor	Respiratory Mortality	Cardiovascular Mortality	Respiratory Morbidity	Cardiovascular Morbidity
1	Bara Khamba Road	31	16	366	1042
2	Mehrauli Road	774	680	21,145	19,979
3	Ring Road (Rajghat)	443	551	17,695	13,174
4	Lala Lajpat Rai Road	767	684	20,154	21,389
5	Ring Road (Ashram F.O)	444	352	10,007	12,216
6	Africa Avenue	1,248	858	23,407	34,178
7	C.P. (Outer Circle)	24	15	362	708
8	Rajokri Border (NH 8)	67	72	2,313	1,883
9	Rohtak Road (NH 10)	873	651	19,334	21,805
10	Karnal Road (NH 1)	794	881	28,829	22,304
11	G.T.Road (Old NH 1)	1,019	974	30,793	27,214
12	NH 24 Bypass	269	195	5,723	6,743
13	NOIDA Link Road	1,427	1,606	52,927	40,120
14	Mathura Road (NH 2)	1,195	1,498	50,780	34,682
15	Wazirabad Road	1,450	995	29,158	35,055
	TOTAL	10,825	10,028	312,993	292,492

to be 21389 (Figure 5). For respiratory mortality, excess number of cases was 767 (Figure 2) and morbidity cases were 20153 in number (Figure 4).

The Gandhi Nagar sub-district of East Delhi district in NCT Delhi have Ashram transport corridor. 421497 persons lived in this sub-district at the time of study. The graphs represented in the above figures show the trend of the excess number of cases of cardiovascular and respiratory mortality/morbidity for this region. For the year 2015, excess number of cases of cardiovascular mortality was calculated to be 352. In case of cardiovascular morbidity excess number of cases in 2015 was 12215 (Figure 5). For respiratory mortality, excess number of cases was 444, as shown in figure 2 and morbidity cases were 10007 in number (Figure 4).

Africa Avenue transport corridor lies in the Hauz Khas sub-district of South Delhi district. The district hosted a population of 1316305 persons at the time. The trend of excess number of cases of cardiovascular mortality as well as morbidity and respiratory mortality as well as morbidity is shown in above graph figures. For the year 2015, excess number of cases of cardiovascular mortality was 858 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was calculated as 34178 (Figure 5). For respiratory mortality, excess number of cases was 1248 (Figure 2) and morbidity cases were 23407 in number as in figure 4. Again, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

The Connaught place sub-district of New Delhi district have this corridor and it hosted a population of 29496 persons. For the year 2015, excess number of cases of cardiovascular mortality was calculated to be 15 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was 708 (Figure 5). For respiratory mortality, excess number of cases was 24 (Figure 2) and morbidity cases were 362 in number (Figure 4).

The Rajokri Border transport corridor lies in the Chanakya Puri sub-district of New Delhi district. The sub-district hosted a population of

54758 persons. For the year 2015, excess number of cases of cardiovascular mortality was 72 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was calculated to be 1883 as shown in figure 5. For respiratory mortality, excess number of cases was 67 (Figure 2) and morbidity cases were 2313 in number as shown in 4th graph figure.

The Rohtak corridor lies in the Punjabi Bagh sub-district of West Delhi district. For the year 2015, it hosted a population of 840542 persons and among these excess number of cases of cardiovascular mortality was 651 (Figure 3). In case of cardiovascular morbidity excess number of cases was calculated to be 21805 as shown in figure 5. For respiratory mortality, excess number of cases was 873 (Figure 2) and morbidity cases were 19334 in number, from figure 4. However, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

The Karnal (NH1) transport corridor stretches through the Model Town sub-district of North West district as displayed in the above map figure. A population of 636253 persons was living in the sub-district region at the time of study. For the year 2015, excess number of cases of cardiovascular mortality was 881 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was calculated at 22304 (Figure 5). For respiratory mortality, excess number of cases was 794 as in figure 2 and morbidity cases were 28829 in number (Figure 3).

The GT road corridor is located in Narela sub-district of North-West district in NCT Delhi. It hosted a population of 863132 persons. in the Narela sub-district district of North West district in NCT Delhi. For the year 2015, excess number of cases of cardiovascular mortality was 974 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was 27214 (Figure 5). For respiratory mortality, excess number of cases was calculated to be 1019 (Figure 2) and morbidity cases were 30793 in number (Figure 4). Yet again, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

This NH24 Bypass transport corridor passes through the Vivek Vihar sub-district of East Delhi district and is displayed in the above map figure. It

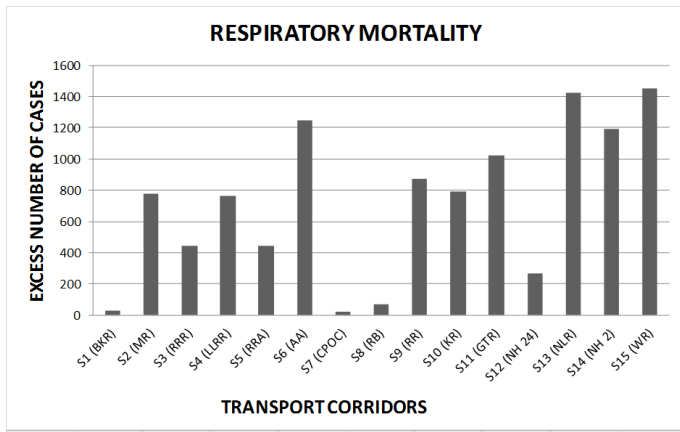


Figure 2: Respiratory Mortality across observed transport corridors in Delhi.

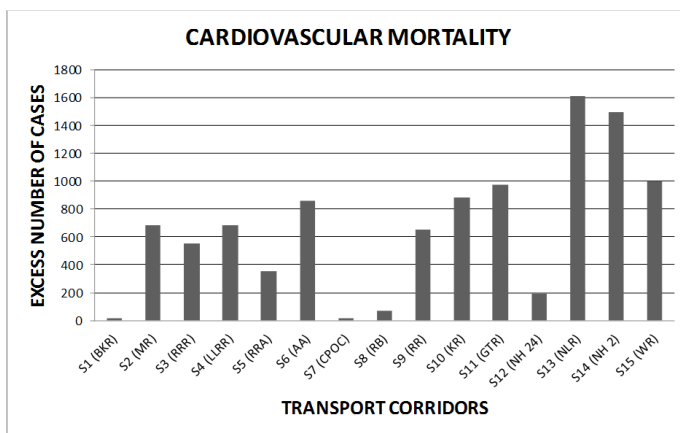


Figure 3: Cardiovascular Mortality across observed transport corridors in Delhi.

hosted a population of 263648 persons. For the year 2015, excess number of cases of cardiovascular mortality was 195 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was calculated as 6743 persons (Figure 5). For respiratory mortality, excess number of cases was 269 as shown in figure 2 and morbidity cases were 5723 in number as in figure 4.

The trend of excess number of cases of cardiovascular and respiratory mortality and morbidity in the Preet Vihar sub-district of East Delhi district are displayed in the above figure graphs. This sub-district have the Noida link road. It hosted a population of 1137366 persons. For the year 2015, excess number of cases of cardiovascular mortality was 1606 persons as displayed in figure 3. In case of cardiovascular morbidity excess number of cases in 2015 was 40120 (Figure 5). For respiratory mortality, excess number of cases was 1427 (Figure 2) and morbidity cases were calculated to be 52927 in number as shown in figure 4.

The Mathura transport corridor passes through the Kalkaji sub-district of South Delhi district. A population of 920802 persons was living in the sub-district region at that time. For the year 2015, excess number of cases of cardiovascular mortality was 1498 (Figure 3). In case of cardiovascular morbidity excess number of cases in

2015 was calculated to be 34682 (Figure 5). For respiratory mortality, excess number of cases was 1195 (Figure 2) and morbidity cases were 50780 in number (Figure 4).

The trend of excess number of cases of cardiovascular and respiratory mortality and morbidity in the Seelam pur sub-district of North-East district in NCT Delhi are displayed in the above graph figures. The Wazirabad road passes through this sub-district. It hosted a population of 1471599 persons exposed to the ambient air pollution. For the year 2015, excess number of cases of cardiovascular mortality was calculated to be 994 (Figure 3). In case of cardiovascular morbidity excess number of cases in 2015 was 35055 persons (Figure 5). For respiratory mortality, excess number of cases was 1450 (Figure 2) and morbidity cases were 29158 in number (Figure 4). Again, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

4.3 Interpretation

Among the fifteen observed corridors, ten have higher respiratory mortality than cardiovascular mortality and five have vice versa. When it comes to morbidity, eight corridors show higher cardiovascular morbidity than respiratory morbidity where seven corridors show the

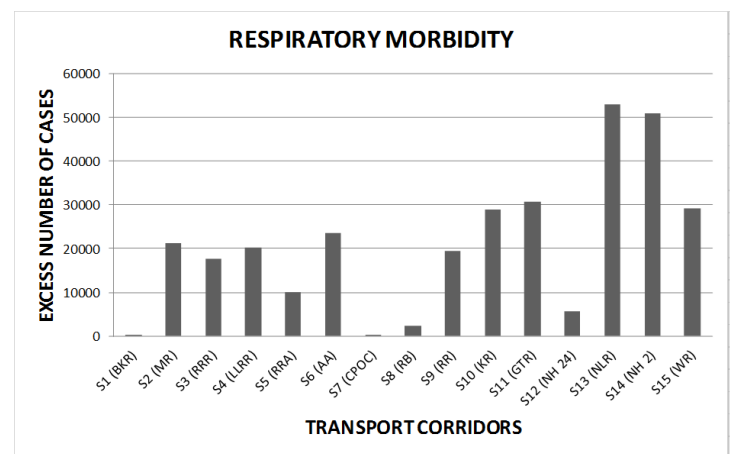


Figure 4: Respiratory Morbidity across observed transport corridors in Delhi.

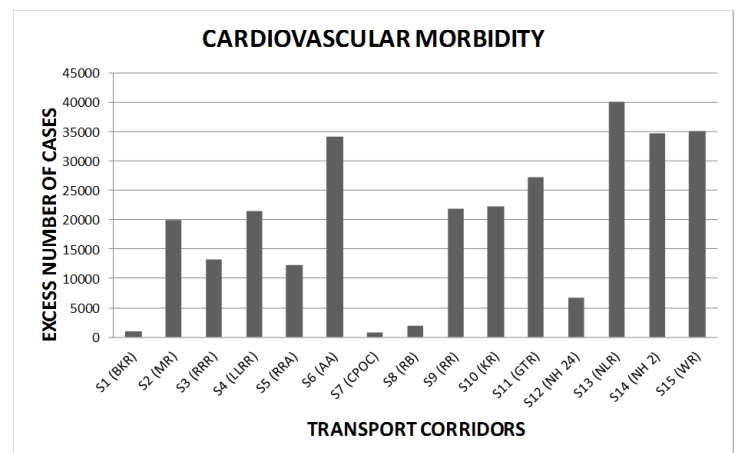


Figure 5: Cardiovascular Morbidity across observed transport corridors in Delhi.

Table 4: Reference for graphs

No.	Transport Corridor	Sub District	Population	Abbreviation Used
1	Bara Khamba Road	Karol Bagh	136,630	S1 (BKR)
2	Mehrauli Road	Vasant Vihar	679,795	S2 (MR)
3	Ring Road (Rajghat)	Shahdara	344,508	S3 (RRR)
4	Lala Lajpat Rai Road	Defece Colony	680,396	S4 (LLRR)
5	Ring Road (Ashram F.O)	Gandhi Nagar	421,497	S5 (RRA)
6	Africa Avenue	Hauz Khas	1,316,305	S6 (AA)
7	C.P. (Outer Circle)	Connaught Place	29,496	S7 (CPOC)
8	Rajokri Border (NH 8)	Chanakya Puri	54,758	S8 (RB)
9	Rohtak Road (NH 10)	Punjabi Bagh	840,542	S9 (RR)
10	Karnal Road (NH 1)	Model Town	636,253	S10 (KR)
11	G.T.Road (Old NH 1)	Narela	863,132	S11 (GTR)
12	NH 24 Bypass	Vivek Vihar	263,648	S12 (NH 24)
13	NOIDA Link Road	Preet Vihar	1,137,366	S13 (NLR)
14	Mathura Road (NH 2)	Kalkaji	920,802	S14 (NH 2)
15	Wazirabad Road	Seelam Pur	1,471,599	S15 (WR)

opposite result. Five corridors show more than a thousand excess number of cases for respiratory mortality showing the seriousness of the scenario, while for cardiovascular mortality two corridors cross the thousand mark. When it comes to morbidity cases, only one corridor shows excess number of cases less than thousand for cardiovascular morbidity and only two corridors in the category for respiratory morbidity. Cardiovascular morbidity goes as high as 40120 for Noida link road and respiratory morbidity goes to 52927 excess cases, again for Noida link road only showing the alarming scenario of the corresponding sub-district region. There are only three corridors showing excess cases below a hundred mark for both the mortalities.

5. Conclusion

For various transport corridors of NCT Delhi, health risks (e.g. mortality/morbidity) have been estimated using Risk of Mortality/Morbidity due to Air Pollution (Ri-MAP) model. About 10026 and 10824 excess numbers of cases of cardiovascular mortality and respiratory mortality respectively, and 292489 and 312992 excess numbers of cases of cardiovascular morbidity and respiratory morbidity respectively, were calculated for various sub-districts in NCT Delhi for the year 2015. Direct relation between the number of vehicles and the Mortality/Morbidity cases was clearly observed in all the sub-districts where large-scale transportation activities are present. Maximum excess numbers of cases of cardiovascular mortality as well as morbidity were observed on Noida link road in Preet Vihar sub-district with 1606 and 40120 respectively. It is observed that Connaught Place (Outer circle) in Connaught place sub-district, New Delhi has the least excess number of cases of cardiovascular mortality and morbidity, most likely attributable to the low population of the sub-district and nearby region. In case of respiratory mortality, Wazirabad road in the Seelam Pur sub-district of North East district recorded maximum excess number of cases at 1450 and for respiratory Morbidity, it was again Noida link road on top at 52927. With respect to least excess number of cases, it was

again the Connaught Place (Outer circle) with 15 and 708 excess number of cases of respiratory mortality and morbidity respectively. It is found that higher ambient concentrations of PM2.5 and NOx are responsible for excess number of mortality and morbidity in various transport corridors of megacity Delhi. Results indicate that particulate matter is responsible for the majority of the excess number of cases of both cardiovascular and respiratory mortality as well as morbidity in the area during the study period (2015). However, very few cases of mortality and few cases of morbidity were observed due to NOx pollution.

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