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# ROLE OF POLICY INTERVENTIONS IN LIMITING EMISSIONS FROM VEHICLES IN DELHI, 2020–2030

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**Abstract**

Urban India, particularly metros, is a major hotspot of air pollution with a PM2.5 concentration level ranging above the permissible limits defined by the WHO for most of the year. Unsurprisingly, special efforts have been made by the Government of India in recent years to improve air quality. Since the transport sector is a major source of air pollution in urban India, the Government of India adopted BS-VI emission standards in 2016 in principle for all major on-road vehicle categories. The rollout of Euro 6 in India began with the capital city Delhi. Furthermore, India's policymakers have been proactive in introducing clean fuel such as CNG, as well as electric vehicle and hydrogen fuel vehicles for urban transport. In this paper, we analyze the interplay between the policy shifts on transport and the level of emissions for Delhi for the next 10 years. We devised three scenarios, starting with the Optimistic Scenario (OPS), which assumes that all of the set policy targets of the Government of India will be realized as planned. A Pessimistic Scenario (PES) assumes implementation of the Optimistic Scenario with a delay of three years, and finally, the Business as Usual Scenario (BAU) assumes no policy interventions in the transport sector and a status quo to be in operation for the coming decade. We predict a significant decline in the emissions of particulate matter (PM), hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxides (NOx) in the OPS/PES scenarios due to the proposed introduction of BS-VI and battery electric fuel vehicles. We find a 20.67% decrease in the overall PM emissions level in the city by 2030. By contrast, our BAU scenario predicts that emissions will increase significantly if no policy intervention is undertaken. In sum, policy interventions may lead to a substantial reduction in emissions in Delhi and thereby a longer life for Delhi inhabitants.

**Keywords:** air pollution, transport policy, auto industry, emissions, particulate matter, India

**JEL Classification:** F64, H23, I18

# Contents

# 1. INTRODUCTION

India is one of the countries with the highest exposure to particulate matter (PM), at PM2.5, in the world. The mean PM2.5 level was 89.9 µg/m³ in 2017, with pollution being highest in Delhi followed by Uttar Pradesh, Bihar, and Haryana (Balakrishnan et al. 2019). In almost all the states of India, the concentration of PM2.5 is found to be above the permissible limits of 10 ug/m3 set by the World Health Organization (WHO). In a recent study, it was shown that an average person in India could continue to live for an additional 5.2 years if the global air pollution standards were maintained (Health Effects Institute 2019).

Apart from an increased mortality rate, the air pollution severely affects labor productivity and crop yields as well as impacting a multitude of sectors. In effect, it resulted in an economic loss of approximately 1.4% of GDP (Pandey et al. 2021).

While air pollution is an issue all over India, the condition is more serious in urban India due to rapid unplanned urban growth. During the last 50 years, the urban population of India has grown nearly five times (around 400 million people live in cities, in sharp contrast to 60 million in 1947). About 140 million people had moved to the cities by 2020 in India, and another 700 million are expected to move by 2050 (Shrivastava et al. 2018). The rapid increase in population results in rapid consumption of energy and other resources, which is contributing to urban pollution. India's urban areas contain high levels of criteria pollutants (e.g., particulate matter, SO2, and NOx), greenhouse gases, ozone precursors, and aerosols.

Among India's cities, the conditions found in Delhi and the National Capital Region (NCR) are alarming. The air pollution levels have been consistently above 100 µg/m³ in the last 10 years, which is more than 10 times the permissible limit. Consequently, if Delhi's air were cleaned, the gain in life expectancy could be to the tune of an additional nine years (Gandhiok 2020). Amongst the sources of air pollution in Delhi, fossil fuel-based vehicles contribute nearly 39% of the total pollution in Delhi. This is followed by road dust (18%), industries (14%), and construction activities (8%).

To ensure that the nation's air, including that in the capital, is clean, multisectoral policy interventions are probably the only solution. Over the years, the Government of India has constituted multiple institutions and policies for monitoring and promoting air quality. Notable among them is the tightening of the emission limits for particulate matter from the transport sector. Over the past two decades, initiatives focusing on introducing cleaner fuel for fossil-based vehicles were brought into the policy space. The first clean fuel in India (Bharat Stage I) was launched in the year 2000, which was followed by Bharat Stage II in 2001, Bharat Stage III in 2005, and Bharat Stage IV in 2010. In a significant move in February 2016 following deteriorating air pollution in urban India, the Ministry of Road Transport and Highways (MoRTH) of the Government of India superseded BS-V-level emission standards and adopted a more stringent level of emission standards, namely BS-VI for all vehicles manufactured on or after 1 April 2020. This will bring India's motor vehicle regulations in direct alignment with the European Union regulation on emission standards ("ICCT – 2016 – India BS-VI Standards"). Simultaneously, India plans to roll out Euro 6 fuel all over India. This is in addition to the earlier measure of 2001 that adopted compressed natural gas as the fuel for all public transport in Delhi. Recognizing the gravity of the issue of air pollution, further targets towards electrification of public transport fleets are proposed by NITI Aayog in their policy document for building a new India (NITI Aayog 2018).

In the light of these policy changes, this paper attempts to understand the extent to which the level of emissions in the capital city Delhi changes due to these policy interventions. Our focus is primarily on Delhi because Delhi has been the city where policy efforts to reduce air pollution originating from the transport sector first began, and further, Euro 6 fuel was introduced first in Delhi and subsequently in other cities. The next section describes the methodological framework and the data for our analysis. The subsequent section discusses the policy scenarios that are attempted to identify the role of policy interventions aimed at reducing the emissions level in Delhi. Section 4 analyzes the results of our policy scenarios. Finally, Section 5 concludes with policy recommendations from our analysis.

# 2. METHODOLOGY AND DATA

Table 1 provides an overview of studies that have estimated emissions from the transport sector under different scenarios in the context of India.

**Table 1: Overview of Studies in the Context of India**

| Study | Objective | Scenarios | Findings |
|---|---|---|---|
| Goel et al. (2015) | Estimating emissions from vehicles for Delhi using International Vehicle Emissions (IVE) model for the time period 1986–2030. | Business as usual | PM and CO reached peak during late 1990s. Reduced significantly after 1990 and reached the peak levels again in 2030.<br>NOx and CO2 show an increasing trend throughout the period. |
| Goel and Guttikunda (2015) | Surveys to gather information about age, mileage, fuel type, and odometer readings of vehicles in order to forecast emission in Delhi using the IVE model for the year 1990 to 2030. | Business as usual | Emissions from PM, oxides of sulfur (SOx), and CO reached their peak during late 1990s through early 2000s.<br>Study predicts that the current regime of vehicle technology, fuel standards, and the high growth rate of private vehicles is likely to nullify all the past emission reductions by the end of the 2020s. |
| Guttikunda and Mohan (2014) | Forecasting emissions from vehicles in India (2010–30) while considering the introduction of BSV fuel regime. | 1. Business as usual.<br>2. BSIV implementation in 2015.<br>3. BSV implementation in 2015.<br>4. BSIV in 2015, BSV in 2020.<br>5. BSV implementation in 2020.<br>6. BSV implementation in 2015 and 25% decrease in personal vehicle travel.<br>7. 25% decrease in personal vehicle travel. | PM emissions doubling in business as usual scenarios by 2030.<br>Best-case scenario is implementation of BSV and 25% reduction in passenger travel where emissions remain the same till 2030. |

*continued on next page*

**Table 1** *continued*

| Study | Objective | Scenarios | Findings |
|---|---|---|---|
| CPCB (2015) | Forecasting emission from vehicles in six cities of India (Ahmedabad, Hyderabad, Kolkata, Lucknow, Patna, and Solapur) for the period 2015–2025. | 1. Business as usual.<br>2. BSV introduction in 2015.<br>3. BSVI introduction in 2015.<br>4. Use of diesel particulate filter.<br>5. CNG introduction for three-wheelers, buses and half of car population.<br>6. Improvement in inspection of vehicle emissions.<br>7. 50% decrease in personal vehicle travel. | Use of BSV and BSVI fuel can reduce emissions by up to 45% by 2025.<br>Increased use of CNG can reduce emissions by up to 15%. |
| Sharma et al. (2018) | To forecast overall level of pollutants in the air in Delhi for the five-year period between 2017 and 2022 using time series models. | | Increase in PM and NOx with reduction in benzene and SOx in the coming years. |

By and large, most studies adopted the methodology developed by the IVE model (Davis et al. 2005) to forecast the emissions originating from the transport sector. The latter assumes that the total amount of emission is a function of the number of vehicles by type, the emission levels of these different types of vehicles, and the average distance covered every day by these vehicles. That is,

$$X_{v,f,p} = N_v * A_v * E_{v,f,p}$$

$$TE_p = \sum X_{v,f}$$

where $TE$ is the total emissions; $X$ is the emission from fossil-based vehicles; N = number of vehicles; E = emission levels of these vehicles; A = average operation distance; *v* = vehicle type; *f* = fuel type; *p* = pollutant.

Below, we describe the variables in detail with reference to our data availability for the study.

# The Data

## Emissions Level

The emission data on PM, CO, NOx, and HC levels are drawn from the Center for Pollution Control Board (CPCB 2015). We acknowledge that understanding emissions might require knowledge of the driving patterns of the city, altitude variation, driving time, and idle time of vehicles, among other factors. But the paucity of real-time information on such indicators leads us to assume that vehicles of all ages have the same emissions level.

### Number of Vehicles by Type

To predict the number of vehicles on Delhi roads, we have used the latest registration data on vehicles from the Economic Survey of Delhi (Government of Delhi 2019). We have estimated the CAGR of vehicles between 2005 and 2019 and have adjusted the same based on the decline in vehicle sales due to the economic slowdown in 2019 and the coronavirus pandemic.

### Vehicle Sales under Economic Slowdown and Coronavirus Pandemic

Since the second quarter of 2018–2019, the economic growth has been sluggish in India. On top of that, the pandemic has hit the economy hard. It is still too early to understand the ultimate effect of coronavirus on the economy and on the transport sector's growth. However, we have attempted to incorporate both of these downturn effects in our model. We have used the vehicle sales figures for 2019–2020 from the Society of Indian Automobile Manufacturers (SIAM), which show a sales decline of 18% (Economic Times 2020). On the other hand, we have used the projection of a 30% decline in automobile sales for 2020–21 as postulated by Moody's Investors Service for India (Panday 2020). The scenarios built into the model show growth picking up gradually towards the normal trend in subsequent years.

### Retirement Rate of Vehicles

The retirement rate of vehicles is defined as $1/retirement\ age\ of\ the\ vehicle$, which denotes the percentage of vehicles getting retired every year. We have collated data from a fuel station survey and secondary sources to estimate the retirement age of vehicles following the approach adopted by Goel et al. (2015). To be specific, the following assumptions are made:

- Three-wheelers and light-duty vehicles (LDVs) are retiring at a rate of 6.6% of the stock of vehicles per year (based on vehicle life of 15 years);
- Two-wheelers are retiring at a rate of 7.1% of the stock of vehicles per year (based on vehicle life of 14 years);
- HDVs are retiring at a rate of 5.5% of the stock of vehicles per year (based on vehicle life of 18 years);
- Buses are retiring at a rate of 7.6% of the stock of vehicles per year (based on vehicle life of 13 years).[1]

### Average Operational Distance (Daily)

This variable gives us the average distance covered by different categories of vehicles on a daily basis. The nature of its use and ownership pattern (commercial or private) dictates the average operational distance (Goel and Guttikunda 2015). Based on earlier literature, we consider the following parameters for different types of vehicles in use:

- Two-wheelers have an average mileage of 12,500 km, which amounts to 35 km per day travel;
- Three-wheelers have an average mileage of 55,000 km, implying 150 km per day operation;

[1] These are based on the observed trend in the context of Delhi.

- Four-wheelers have an average mileage of 12,500 km, amounting to 35 km per day travel;
- Private buses are assumed to travel the same distance as that of public buses, which is 200 km per day;
- Since heavy-duty vehicles (HDVs) are used largely for intercity operations, we assume that HDVs cover 40 km per day on average inside the city boundary. Although HDVs bring freight to wholesale markets, goods are distributed within Delhi by LDVs.

### Vehicle Usage

Delhi went through a lockdown due to the outbreak of the deadly coronavirus, when only essential services were permitted. This led to the reduction of vehicle use in Delhi. To assess the extent of reduction in the use of vehicles, we have used information from the COVID-19 Community Mobility Report by Google. We have assumed a 40% average decline in vehicle usage during the six-month period from February 2020 to July 2020. We expect this trend will continue for a year until the pandemic subsides or vaccination is available.

# 3. THE POLICY SCENARIOS

In this paper, we have attempted to forecast the emission levels from the transport sector in Delhi for three hypothetical scenarios. The scenarios differ in their expected realization of the targeted policy objectives set forth by the Government of India. The details regarding the assumption of the three scenarios and their interplay with the policy framework are given below.

### Scenario 1: Optimistic Scenario (OPS)

In this scenario, we assume that the recommendations set forth by the nodal agencies, namely MoRTH, will be realized as per the targeted date specified in the policy document. The two primary policies that are discussed here are the promotion of clean fuels (BS-VI) for the automotive sector and transition to electric vehicles. To facilitate the transition to clean fuel for vehicles in India, significant investment has been made in the refinery sector so that they are able to meet the challenge of supplying clean fuel all over India by 2020. To encourage the growth of electric vehicles, the central government has introduced the Fame I and II policy, which provides subsidies to buyers to purchase electric vehicles (EVs). Additionally, many state governments also followed with their own policy documents. The Delhi government in 2019 came up with a draft electric vehicle policy through which it supported the electric vehicle subsidy model and set up targets for the next five years. Scenario 1 follows the same policy recommendations and assumes they are implemented as per time scale and continued forward at the same pace in the future.

### Scenario 2: Pessimistic Scenario (PES) – Implementation of OPS with a Delay of Three Years

In this scenario, we assume that the implementation of PES did not take place as per schedule but got delayed for three years. The principal motivation for this scenario is that all plans invariably get delayed in India’s bureaucracy setup. Secondly, the slowdown in the economy hit the transport sector hard, which was already reeling through the downturn. This reduced the pace of the automotive sector’s capacity to produce electric vehicles, leading to a tardy growth of electric vehicles. Furthermore, the government's efforts to promote electric vehicles with tax incentives do not seem to shift consumers' sentiment towards electric vehicles. No doubt the lack of charging facilities in the city and the government/private sector's inability to set up the same across the city is a factor in consumers' lack of interest in electric vehicles.

### Scenario 3: Business as Usual (BAU) Scenario

Scenario 3 assumes a business as usual scenario in which we freeze the policy paradigm in 2020 and assume no new policy interventions from the government. Therefore, after the introduction of BS-VI vehicles, this scenario assumes that there would not be any further policy intervention towards electric vehicles.

The proposed policy targets are shown in Table 2. The assumptions in respect of scenarios 1 and 2 are drawn from the Economic Survey of Government of Delhi (2019). It is, however, important to note that the government document only lays down its goals for the next five years, i.e., until 2024. We have extended the goal until 2030 assuming the same pace is followed in the subsequent period (2025–2030).

**Table 2: Proposed Policy Targets and Assumptions on their Realization Patterns**

| Optimistic Scenario *OPS* | Pessimistic Scenario *PES* | BAU Scenario |
|---|---|---|
| • 50% of the DTC bus fleet are assumed to be electric by 2024 (3000 buses) and 100% by 2029 (6,000 buses)<br>• 25% of the new two-wheeler and three-wheeler sales are assumed to be electric by 2024<br>• 55% of the new two-wheeler and three-wheeler sales are to be electric by 2030 | • 50% of the DTC bus fleet are assumed to be electric by 2027 (3,000 buses) and 100% by 2032 (6,000 buses)<br>• 25% of the new two-wheeler and three-wheeler sales are assumed to be electric by 2027<br>• 40% of the new two-wheeler and three-wheeler sales are to be electric by 2030 | • No new policy intervention apart from BS-VI vehicles |

Source: Computed by the authors.

We have assumed that there is no policy intervention to control PM emissions in other sectors (residential, industry, agricultural burning, and dust), which contribute 61% to the total emissions in Delhi. Thus, the growth of emissions from those sectors is assumed to follow the rate of growth trend.

Furthermore, the transition rate of vehicles is a parameter in our analysis for which we need assumption regarding its parametric values. To be specific, the transition rate is the incremental rate at which the share of sales of new vehicle progressively translates into a new type of vehicle. For example, a 5% transition rate of EV two-wheelers means that 5% of initial year sales are of EV two-wheelers and this progressively increases by 5% every year. So, the sale of EV two-wheelers in the second and third year would be 10% and 15%, respectively. In our analysis, we have assumed a transition rate of 5% for electric two-wheelers and three-wheelers. On the other hand, we have assumed for LDVs a transition rate of 4% to CNG-fueled LDVs and 2% for electric LDVs.

# 4. ANALYSIS OF RESULTS

At the outset, we used registration data on vehicles from 2005 to 2018 to predict the number of vehicles on Delhi roads by estimating the long-term compound annual growth rate (CAGR). The estimated growth rates are found to be 6.6% for two-wheelers, 3.1% for three-wheelers, 6% for light-duty vehicles, 4.2% for heavy-duty vehicles, and 1.7% for buses (Table 3). This constant growth in the vehicle population will lead to the overall number of vehicles in Delhi growing from 1.13 crore in 2019 to 2.16 crore in 2030.

**Table 3: Growth of Vehicles in Delhi**

| Vehicles | Two-wheelers | Three-wheelers | Light-Duty Vehicles | Heavy-duty Vehicles | Buses |
|---|---|---|---|---|---|
| CAGR | 6.6% | 3.1% | 6.0% | 4.2% | 1.7% |
| Number of Vehicles (2030) | 14,707,781 | 154,931 | 6,336,670 | 378,302 | 38,301 |

Source: Computed by the authors.

Table 4 below shows the composition of vehicles and the projected evolution over a decade in the city of Delhi according to different scenarios formulated in this paper. As Table 4 shows, the share of electric vehicles in the Optimistic Scenario (OPS Scenario) will turn out to be only 24% of the total stock of vehicles in 2030. In the PES Scenario, the share of electric vehicles will constitute 13% of the total stock of vehicles, while BS-VI vehicles will constitute 77% of the vehicles in 2030. By contrast, the absence of policy intervention (BAU Scenario) will lead to a share of 93% (7%) of BS-VI (BS-IV) vehicles in Delhi by 2030.

**Table 4: Distribution of Vehicles by Types in %**

| | | Scenario 1 (OPS) | | | Scenario 2 (PES) | | | Scenario 3 (BAU) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **2021–2022** | **2025–2026** | **2029–2030** | **2021–2022** | **2025–2026** | **2029–2030** | **2021–2022** | **2025–2026** | **2029–2030** |
| **Two-Wheeler** | **BS-III Petrol** | 13.85 | 0.00 | 0.00 | 13.85 | 0.00 | 0.00 | 13.85 | 0.00 | 0.00 |
| | **BS-IV Petrol** | 46.88 | 28.03 | 3.21 | 46.88 | 28.03 | 3.21 | 46.88 | 28.03 | 3.21 |
| | **BS-VI Petrol** | 5.39 | 30.55 | 43.28 | 5.99 | 36.13 | 52.77 | 5.99 | 38.86 | 64.50 |
| | **Electric** | 0.60 | 8.32 | 21.22 | 0.00 | 2.73 | 11.73 | 0.00 | 0.00 | 0.00 |
| **Light-Duty Vehicle** | **BS-III Petrol** | 5.21 | 0.00 | 0.00 | 5.21 | 0.00 | 0.00 | 5.21 | 0.00 | 0.00 |
| | **BS-IV Petrol** | 13.21 | 9.26 | 2.10 | 13.21 | 9.26 | 2.10 | 13.21 | 9.26 | 2.10 |
| | **BS-VI Petrol** | 1.52 | 8.02 | 10.28 | 1.68 | 9.73 | 13.15 | 1.68 | 10.81 | 17.72 |
| | **BS-III Diesel** | 1.30 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 |
| | **BS-IV Diesel** | 3.30 | 2.31 | 0.53 | 3.30 | 2.31 | 0.53 | 3.30 | 2.31 | 0.53 |
| | **BS-VI Diesel** | 0.38 | 2.01 | 2.57 | 0.42 | 2.43 | 3.29 | 0.42 | 2.70 | 4.43 |
| | **CNG** | 4.93 | 7.03 | 10.68 | 4.83 | 5.82 | 8.63 | 4.83 | 4.92 | 4.83 |
| | **Electric** | 0.10 | 1.37 | 3.45 | 0.00 | 0.45 | 1.90 | 0.00 | 0.00 | 0.00 |
| **Heavy-Duty Vehicle** | **BS-III Diesel** | 0.81 | 0.23 | 0.00 | 0.81 | 0.23 | 0.00 | 0.81 | 0.23 | 0.00 |
| | **BS-IV Diesel** | 1.17 | 0.94 | 0.43 | 1.17 | 0.94 | 0.43 | 1.17 | 0.94 | 0.43 |
| | **BS-VI Diesel** | 0.13 | 0.84 | 1.32 | 0.13 | 0.84 | 1.32 | 0.13 | 0.84 | 1.32 |
| **Three-Wheeler** | **CNG** | 0.94 | 0.79 | 0.57 | 0.95 | 0.84 | 0.66 | 0.95 | 0.87 | 0.76 |
| | **Electric** | 0.01 | 0.08 | 0.18 | 0.00 | 0.03 | 0.10 | 0.00 | 0.00 | 0.00 |
| **Bus** | **CNG** | 0.25 | 0.20 | 0.16 | 0.26 | 0.21 | 0.16 | 0.26 | 0.22 | 0.19 |
| | **Electric** | 0.01 | 0.02 | 0.03 | 0.00 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 |

Source: Computed by the authors.

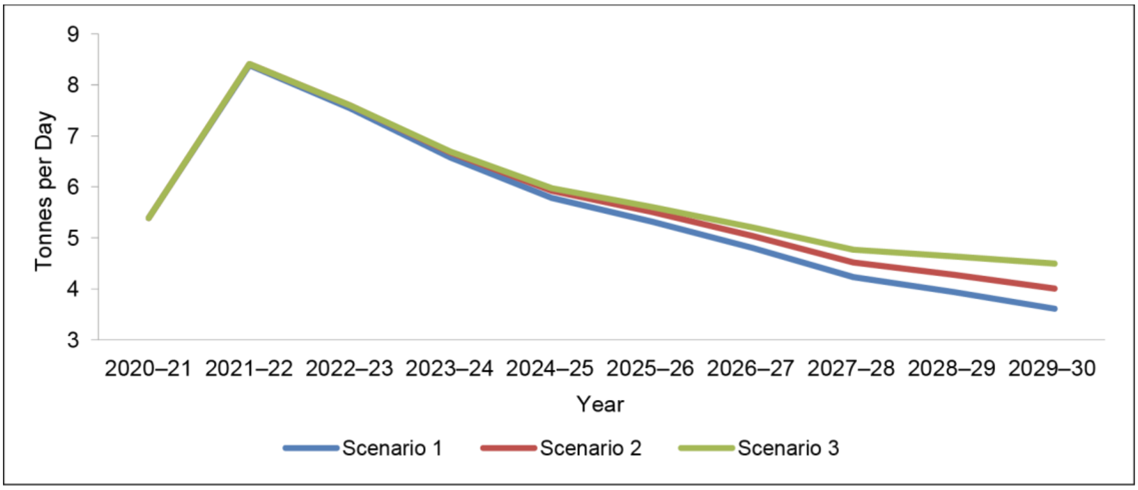
## Forecasting Emissions

Figure 1 shows estimates of PM emissions from vehicles for our three scenarios. As this figure shows, the introduction of BS-VI fuel technology with effect from 2020 will lead to a reduction in emissions in the post-2021 period. The year 2020 was not a normal year as it shows a 40% reduction in the emissions level from the normal year due to the effects of the coronavirus pandemic. A 53% decline in PM emissions in 2030 is expected in the OPS Scenario compared to 2021 levels, whereas a 49% reduction in PM emission may occur in the PES Scenario.

Note that our scenarios 1 and 2 (OPS/PES scenarios) assume the presence of BS-VI and battery-operated electric vehicles in Delhi. Naturally, a relatively higher reduction in emissions will occur post 2025 as compared to the BAU Scenario where no such policy intervention is modeled. The transition of two-wheelers into electric vehicles seems to be the major driver behind the 9% difference in emissions between the OPS and BAU scenarios.

In sum, Figure 1 exhibits the role of fuel technology in keeping our air clean.

**Figure 1: PM Emissions from Vehicles (2020–2030)**



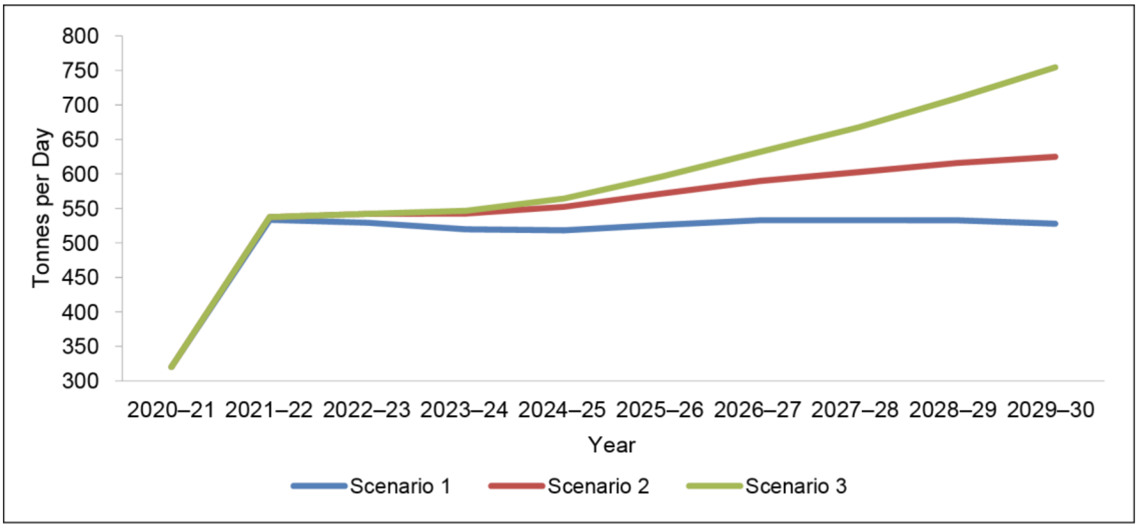

Source: Computed by the authors.

### Carbon Monoxide Emissions from Vehicles

Carbon monoxide emissions from the transport sector in scenario 1 stabilizes throughout the 2020s while the same follows an upward trend in scenarios 2 and 3 (Figure 2). CO emission levels are expected to rise by 16% and 40% from the 2021 level in scenarios 2 and 3. However, they decline by about 1% in scenario 1.

The transition of two-wheelers and LDVs into electric vehicles is the major driver behind the 41% difference in emissions between scenarios 1 and 3.

**Figure 2: CO Emissions from Vehicles (2020–2030)**

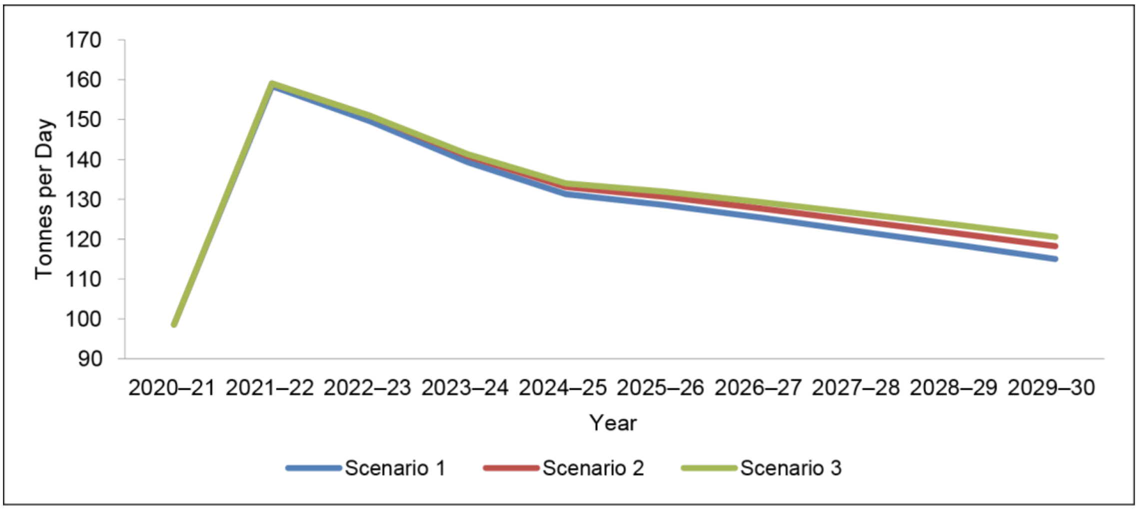



Source: Computed by the authors.

## Hydrocarbon Emissions from Vehicles

Hydrocarbon (HC) emissions from the transport sector in all the scenarios follow a decreasing trend. The HC emissions level is expected to reduce by 27%, 25%, and 24% in the year 2030 from the 2021 levels in scenarios 1, 2, and 3, respectively (Figure 3). The emissions uniformly fall until 2024 in all the scenarios and thereafter exhibit a slight divergence trend.

**Figure 3: HC Emissions from Vehicles (2020–2030)**




Source: Computed by the authors.

## NOx Emission from Vehicles

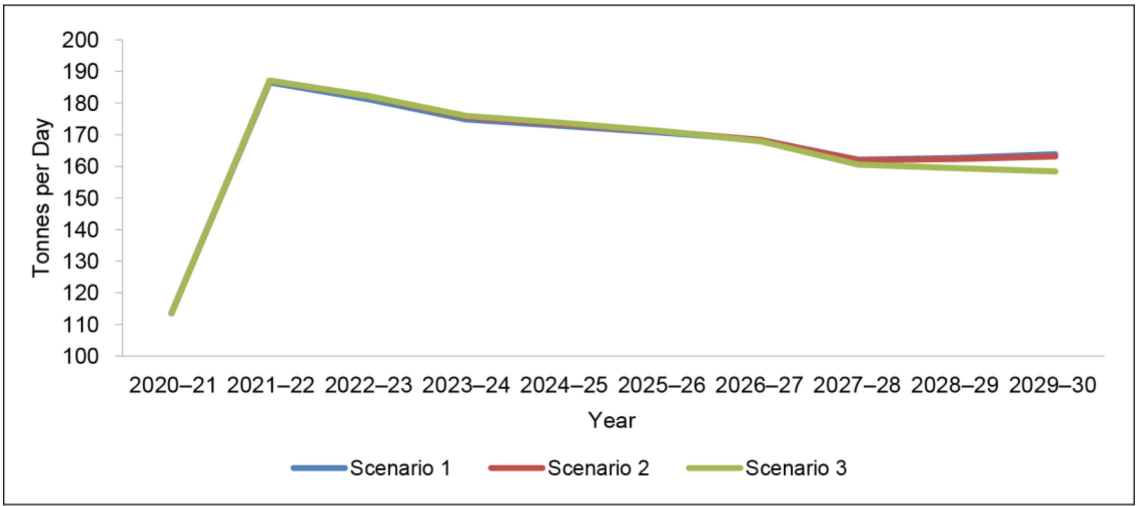
Figure 4 shows NOx emission pathways for the scenarios. A continuous decline is observed during the period 2021–2022 to 2027–2028.

In scenarios 1, 2, and 3, $NO_2$ emissions declined by 12.1%, 12.8%, and 15.3%, respectively, in 2030 from the 2021 levels (Figure 4).

HDVs contribute the most to the NOx emissions in the transport sector. The other contributors with an increasing trend are LDVs and two-wheelers despite their transitions towards electric vehicles.

Note that there is a steady decrease in emissions from HDVs and two-wheelers due to their transitions into BS-VI vehicles during the period. On the other hand, a sharp increase in the number of vehicles on Delhi roads led to a sharp rise in emissions from LDV vehicles.

**Figure 4: NOx Emissions from Vehicles (2020–2030)**




Source: Computed by the authors.

In sum, we find a significant decline in all types of emissions (PM, HC, and NOx) in our scenarios due to the introduction of BS-VI and EV vehicles. Our analysis suggests that emissions from PM, CO, HC, and NOx levels will fall by 53%, 1%, 27%, and 12%, respectively, in our OPS Scenario by 2030 (Table 5). A reduction of 53% in PM emissions from the transport sector in scenario 1 (OPS Scenario) amounts to a 20.67% decrease in the overall PM emissions level in the city by the year 2030. Similarly, a 44% reduction in PM emission levels in the BAU Scenario translates to a 17.16% decrease in the overall PM emissions level in the city by the year 2030.

**Table 5: Percentage Change in Emissions from Vehicles (2020–2030)**

| | Scenario 1: OPS | Scenario 2: PES | Scenario 3: BAU |
|---|---|---|---|
| PM | –53 | –49 | –45 |
| CO | –1 | 16 | 40 |
| HC | –27 | –26 | –24 |
| NOx | –12 | –13 | –15 |

Source: Computed by the authors.

# 5. CONCLUDING REMARKS

Bearing in mind the emerging technologies, policymakers should focus on a goal to make Delhi's air clean in the medium/long term and should attempt to make the transport sector emissions neutral in the long term. As our analysis indicates, a significant reduction in emissions can be achieved if the proposed transport vision for Delhi is fully implemented. However, multi-front action is needed for successful implementation of these policies. There is a need to discourage personal use of vehicles among citizens through various incentive/disincentive mechanisms, namely increased parking fees, increasing tax on fuel/vehicles, pedestrian-friendly policy, encouragement of a nonfossil-based transportation system, and increased reach of public transport. Carpooling as an alternative should also be endorsed. The government should promote public transport through aggressive subsidization of the Delhi Transport Corporation (DTC) and Metro services (Lalwani 2019). While the Delhi Metro is going through significant expansion, the number of buses in the DTC has been stagnant for the last decade due to procurement issues (Barman 2019). Delhi's government needs to resolve these issues and move forward with the procurement of electric buses. Electric vehicles have the potential to be the major driving force towards emission reduction in the coming years. There is a need for government to subsidize electric vehicles, promote investment in the critical battery technology, and find innovative ways to expand the fast battery-charging network in the city to promote electric vehicles. But the slowdown in the economy has hit the transport sector hard, and it was already reeling through the downturn. This has reduced the automotive sector's ability to invest in technologies for electric vehicles. Consequently, the auto sector has depended on imports of critical components for some time now (Velayanikal 2020). Recently (September 2021), the Government of India announced a large-scale Production-Linked Incentive (PLI) scheme for the auto sector amounting to Rs 26,058 crore (USD3,540 million).[2] The focus of the auto sector PLI scheme is primarily to promote the manufacture of electric vehicles and hydrogen fuel cell vehicles. This is definitely a positive step towards reducing emissions from the transportation sector in cities like Delhi.

In the last couple of years, five important policy interventions have taken place: (1) the introduction of BS-VI fuel in India; (2) registration of only BS-VI-compatible engines in LDVs in metros; (3) the promotion of EVs through various schemes such as the PLI scheme, and the reduction of registration fees for EVs; (4) the introduction of a scrappage policy for old vehicles concomitant with financial incentives; and (5) the expansion of metro networks in many other cities of India. It would be worthwhile revisiting our analysis in future to understand how these policy interventions would affect the pollution landscape in India's metros.

2 https://pib.gov.in/PressReleasePage.aspx?PRID=1755062, accessed on 17 September 2021.

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