IB Environmental Systems and Societies Internal Assessment

To what extent has the 1990 extensive amendments to the *Clean Air Act* been successful in reducing the levels of six principal air pollutants in the United States of America - CO, Pb, NO_2, O_3, PM10, and SO_2?

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I. IDENTIFYING THE CONTEXT

Research Question:
"To what extent has the 1990 extensive amendments to the *Clean Air Act* been successful in reducing the levels of six principal air pollutants in the US - CO, Pb, NO_2, O_3, PM10, and SO_2?"

Environmental Issue:
Air pollution, caused by the six biggest air pollutants, in the US between 1900 and 1970.

Back in the first quarter of this academic year, when we were discussing the London Smog and Beijing Smog in the 6.3 subsection - Photochemical Smog - of ESS, it really surprised me how the governments controlled these massive pollutions. This then inspired me to look for other similar cases that have been handled well by authorities. During the research, the one that caught my attention was the huge mid-20th-century air pollution of the US, which has been resolved thanks to the Clean Air Act program.

Between 1900 and 1970 due to industrial growth and increased number of motor vehicles in the US, emissions of the six principal pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM10), and sulfur dioxide (SO_2) significantly increased. This then resulted in many major cities such as New York and Los Angeles (Figure 1) being filled with toxic smog linking to several environmental and health problems.

Figure 1. New York Smog (left), 1966 and Los Angeles Smog (right), 1975

Source: New York Times (left), Timeline (right)

To combat this issue at the city, state, and national levels the Clean Air Act was introduced in 1963 as a national program specifically targeting those six principal air pollutants mentioned above. This is usually recognized as one of the most influential environmental laws of the United States considering its impacts (US EPA, "Evolution of the Clean Air Act").

After 1963, there have been several amendments to the act, but the most significant one and the one this paper focuses on is the 1990 amendment. This is the last and most extensive amendment to the Clean Air Act, which focuses mainly on toxic air pollution, acid rain, and ozone depletion.

Link of Environmental Issue to Research Question:
Since millions of people's lives are directly involved, it is crucial to analyze the success of this act and its 1990 amendments because if it has been successful, then it can be introduced to other major cities of the world suffering from air pollution and if not, the government must start considering alternative solutions. Therefore, this paper focuses on the trend of the six pollutants before and after the 1990 amendment.

II. PLANNING

Sampling Strategy:

All the data on the levels of six pollutants were extracted from the United States' official Environmental Protection Agency website at www.epa.gov with the time range of 1980-2019, except for the PM10 for which the data were found only from 1990 onwards. Afterward, the data were divided into two time-ranges: 1980-1989 and 1990-2019. This sampling was chosen because it would give a chance to better compare and contrast the rate of decline before and after the 1990 amendment. And this website was chosen because it is the official website of the US for all matters related to the environment, so it is a reliable source.

Procedure:

1. Extract the records on six air pollutants - CO, Pb, NO_2, O_3, PM10, and SO_2 - from the United States' EPA website.
2. Open a new Google Spreadsheet list and save all the data under their respective categories.
3. Leave one cell empty between 1989 and 1990 data values for each pollutant except for PM10.
4. To make it easier for the later calculations, reduce all the data down to at least 6 decimal places.
5. Draw two line graphs for each air pollutant except for the PM10: one for 1980-1989, another one for 1990-2019, and for PM10 draw one line graph for 1990-2019.
6. Using Google Spreadsheets, add a best-fit trend line to each line graph.
7. Calculate the annual average percentage decrease before and after 1990 (with the formula given below).
8. Calculate the total percentage decrease for 1980-2019 (with the formula given below).

Variables Identification:

Independent: Years (1980-2019); Type of pollutants

Dependent: Levels of pollutants

Controlled: Location - United States; Data source - US EPA website, www.epa.gov

Safety and Ethical Considerations:

No safety and ethical considerations were needed during the data collection for the following reasons: 1. All the data were collected from a reliable source - United States' EPA official website; 2. Since the EPA database is open to the public, all the data were collected legally; 3. The use of data did not cause any damage or distress to the environment, animals, or humans.

III. RESULTS, ANALYSIS, AND CONCLUSION

Data Presentation:

Table 1. Average concentration of pollutants for 1980-1989, except for PM10

	CO (ppm)	Pb (µg/m^3)	NO_2 (ppb)	O_3 (ppm)	SO_2 (ppb)
1980	9.07073	1.944286	111.3334	0.101544	157.3257
1981	8.77927	1.424286	107.5238	0.095933	149.9829
1982	8.30732	1.235714	108.1905	0.094459	138.2829
1983	8.74878	1.352857	97.6667	0.102233	148.8286
1984	8.04634	1.321429	91.4841	0.094373	138.5743
1985	7.54024	1.737143	95.6825	0.093559	141.6743
1986	7.57805	1.015714	97.2857	0.09194	139.9771
1987	6.94878	1.452857	96.8571	0.096035	133.2771
1988	7	1.8	101.1667	0.10534	136.0238
1989	6.76585	0.907143	99.4762	0.090052	134.6619

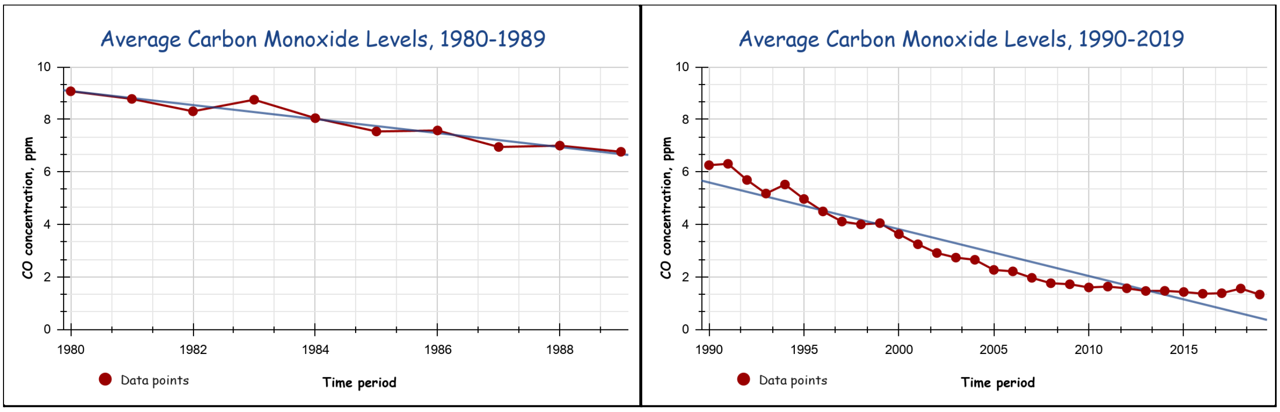
Table 2. Average concentration of pollutants for 1990-2019

	CO (ppm)	Pb (µg/m^3)	NO_2 (ppb)	O_3 (ppm)	PM10 (µg/m^3)	SO_2 (ppb)
1990	6.2561	0.618571	92.8095	0.090155	86.93694	118.0286
1991	6.30732	0.575714	95.1905	0.090733	88.18919	113
1992	5.69268	0.497143	81.8095	0.084573	75.27928	109.7571
1993	5.17561	0.431429	80.2857	0.087381	75.19819	101.3619
1994	5.51951	0.665714	82.8095	0.087168	72.31982	101.8381
1995	4.96829	0.461429	82.9048	0.091456	73.62613	88.2429
1996	4.49512	0.418571	74.7619	0.086363	65.75676	83.7571
1997	4.10976	0.355714	70.8095	0.085658	65.81081	89.4571
1998	4	0.348571	68.0952	0.091036	62.28228	87.1143
1999	4.04878	0.394286	73.1667	0.088451	67.78078	89.5619
2000	3.62927	0.362857	65.3334	0.082391	64.66667	78.9524
2001	3.2439	0.458571	65.4524	0.08429	64.07207	83.7429
2002	2.91219	0.332857	63.0952	0.088544	62.56306	74.5524
2003	2.73659	0.265714	62.8095	0.082876	65.20721	78.3334
2004	2.65366	0.438571	56.9603	0.075394	56.91892	72.2

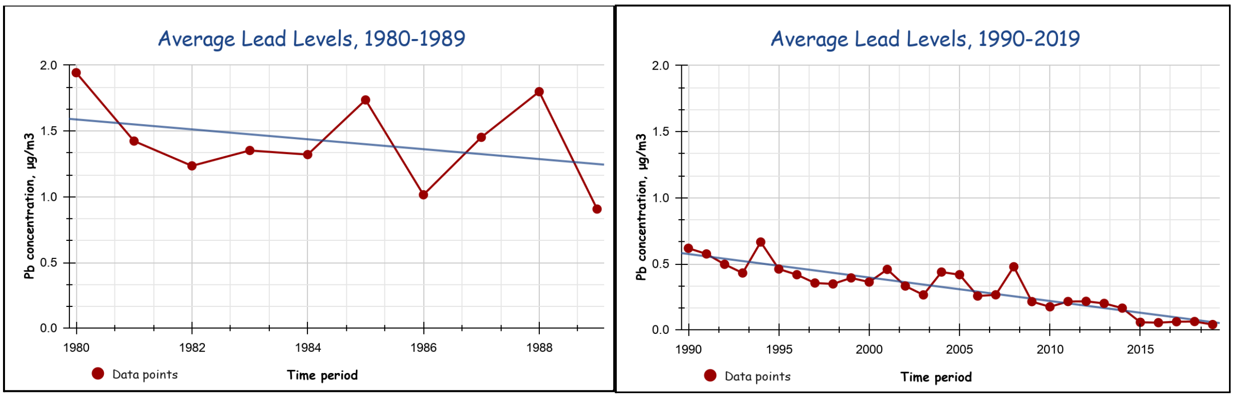
2005	2.26829	0.418571	55.6587	0.080495	58.54955	74.5381
2006	2.21219	0.257143	54.9048	0.079744	58.47748	65.9619
2007	1.96585	0.266429	54.1905	0.079793	63.68468	62.0571
2008	1.76098	0.478571	53.2857	0.075435	57.25225	52.4619
2009	1.72195	0.215	48.6809	0.070161	51.58559	46.3852
2010	1.6	0.175714	47.5809	0.073637	49.98198	40.2057
2011	1.63171	0.215714	47.6976	0.074777	54.85586	33.7971
2012	1.56707	0.217143	44.8048	0.076202	53.48649	31.3248
2013	1.46585	0.201429	45.7246	0.067489	58.79279	27.3957
2014	1.47073	0.165714	47.5659	0.068252	56.05405	27.3381
2015	1.42683	0.058571	44.3381	0.069315	54.04505	22.9486
2016	1.36098	0.055714	43.0905	0.069803	51.77477	15.9629
2017	1.38049	0.062857	43.4429	0.069044	57.68468	14.3843
2018	1.55854	0.064286	43.2619	0.070067	64.88739	14.2286
2019	1.32927	0.041429	41.9524	0.066492	47.34234	12.7514

Graphical Representation of Data:

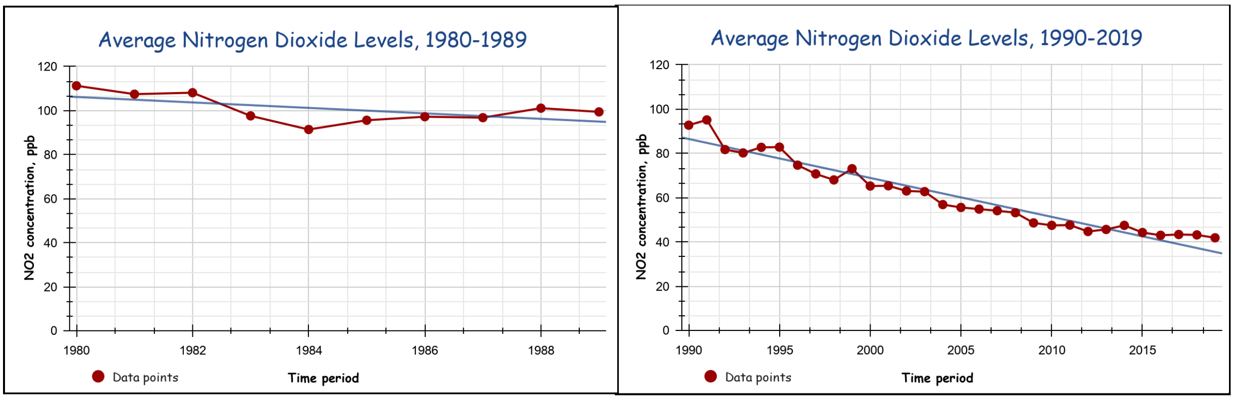
Graph 1. Line graphs showing Carbon Monoxide trends, 1980-1989 (left), 1990-2019 (right)



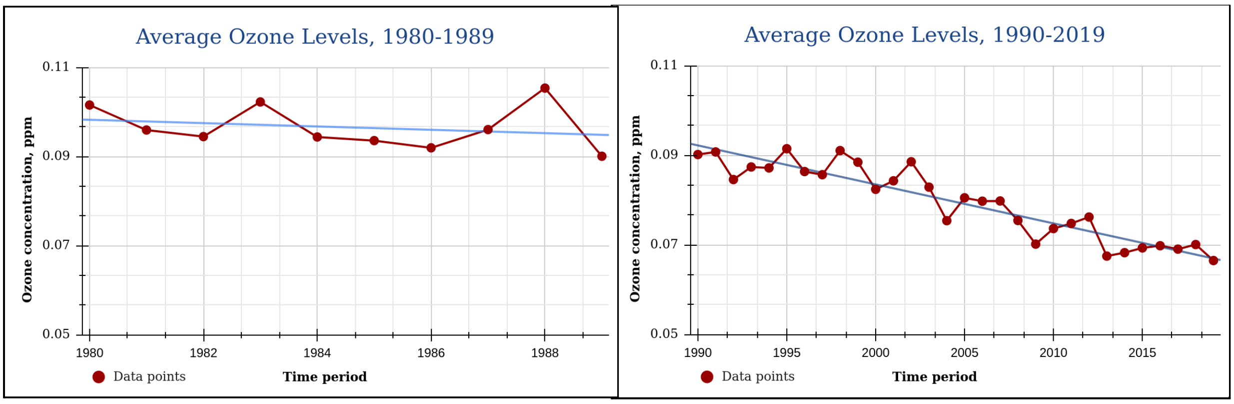
Graph 2. Line graphs showing Lead trends, 1980-1989 (left), 1990-2019 (right)



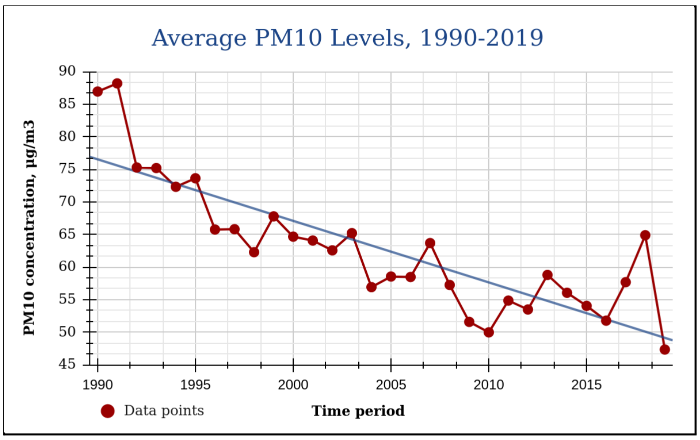
Graph 3. Line graphs showing Nitrogen Dioxide trends, 1980-1989 (left), 1990-2019 (right)



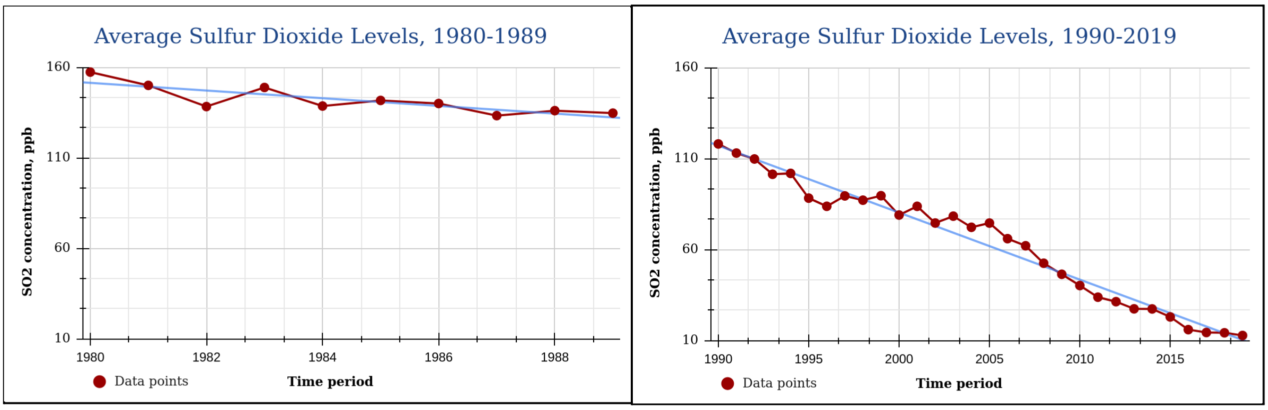
Graph 4. Line graphs showing Ozone trends, 1980-1989 (left), 1990-2019 (right)



Graph 5. Line graph showing PM10 trend, 1990-2019



Graph 6. Line graphs showing Sulfur Dioxide trends, 1980-1989 (left), 1990-2019 (right)



Annual Percentage Decrease Comparison:

The average percentage changes for each time range were calculated with the formula below:

$$\frac{\left(\left(\frac{\text{final value}}{\text{first value}}\right)-1\right)\times 100}{\text{number of years between first and final value}}$$

Table 3. Annual average percentage change for each time range

	CO (%)	Pb (%)	NO_2 (%)	O_3 (%)	PM10 (%)	SO_2 (%)
1980-1989	-2.82	-5.93	-1.18	-1.26	---	-1.6
1990-2019	-2.72	-3.22	-1.89	-0.91	-1.57	-3.08

Keys:

	Category of variables
	The rate of decline has slowed down after the 1990 amendment
	The rate of decline has speeded up after the 1990 amendment
	No data are given for 1980-1989 to compare to 1990 onwards

Total Percentage Decrease:

The total percentage change for all pollutants except for PM10 over the 1980-2019 time period, with 1990-2019 for PM10, was calculated with the formula below:

$$\text{Total Percentage Change} = \left(\left(\frac{\text{final value}}{\text{first value}}\right) - 1\right) \times 100\%$$

Table 4. Total percentage change for each pollutant for 1980-2019, except for PM10

	CO (%)	Pb (%)	NO_2 (%)	O_3 (%)	PM10 (%)*	SO_2 (%)
1980-2019	-85.35	-97.87	-62.32	-34.52	-45.54	-91.89

*Percentage change is only for 1990-2019 time range

Interpretation of Data:

From all the line graphs, the general trend of decline can be noticed, and while comparing the two time-ranges, one might assume that the trend started declining faster after 1990 compared to the trend of 1980-1989 because the trend lines, blue lines, are steeper for the graphs of 1990-2019.

Therefore, to see the average decline rate in exact numeric values, the annual percentage decrease comparison was carried out, which showed that only for NO_2 and SO_2 the percentage changes are higher after 1990 compared to 1980-1989. In numeric data, the levels of NO_2 were declining at an annual average rate of 1.18% from 1980 to 1989, whereas starting from 1990 the rate of decline got faster, 1.89% annually. Similarly for SO_2, the level of this air pollutant was declining at an annual average rate of 1.6% from 1980 to 1989, which almost doubled with a 3.08% decline rate from 1990 onwards.

However, for CO, Pb, and O_3 the rate of decline was higher before, and hence it slowed down afterward. In numerical terms, CO levels were decreasing at an annual average rate of 2.82% from 1980 to 1989, whereas from 1990 onwards it slightly slowed down to 2.72%; the Pb levels were decreasing at an annual average rate of 5.93%, whereas it slowed down to 3.22% from 1990 onwards; similarly, for O_3 the annual average rate of decline was 1.26%, which reduced to just 0.91% afterward.

It is important to note that for PM10 since there was no data found for levels before 1990, it can not be compared whether the rate of decline was higher or lower before 1990. However, the rate of annual decline starting from 1990 was found to be 1.57% on average.

Lastly, to analyze the effect of the Clean Air Act as a whole from 1980 to 2019, a total percentage decrease calculation was carried out, which showed highly positive results: there was an 85.35% total decrease in national CO levels, 97.87% decrease in Pb levels, 62.32% decrease in NO_2 levels, 34.52% decrease in O_3 levels, and 91.89% decrease in SO_2 levels in the course of 39 years, 1980-2019. Additionally, for PM10 levels, there was a 45.54% total reduction from 1990 to 2019.

Therefore, all the findings indicate that the 1990 amendment, in particular, was successful in fastening the decrease of only NO_2 and SO_2 levels, whereas for CO, Pb, and O_3 it was not efficient enough. This means that the government must introduce more efficient amendments specifically targeting those three pollutants: CO, Pb, and O_3. However, the Clean Air Act in general was quite successful in reducing the levels of all six principal air pollutants in the course of 1980-2019, and 1990-2019 for PM10.

IV. DISCUSSION AND EVALUATION

Conclusion Evaluation in Context of Environmental Issue:

The conclusion validates that the extensive 1990 amendment to the Clean Air Act has been successful partly, but there is still place for improvement. It has accelerated the reduction of nitrogen dioxide and sulfur dioxide; however, it has affected the reduction of carbon monoxide, lead, and ozone negatively. Therefore, if this act were to be implemented in other countries suffering from air pollution, it would be recommended to reconsider some of the policies leapfrogging the flaws of the Act in specific fields. However, these flaws might not be negative in the context of other countries considering their geographic location, strictness of policies, difference in human behaviors, and many other factors. Lastly, even though the 1990 amendments have not been efficient enough to speed up the reduction of all air pollutants, the Clean Air Act, in general, has been quite effective in controlling the hazardous air pollution of the United States in such a short period of time.

Strengths, Weaknesses, and Limitations of Methodology:

One strength of this investigation was the source of the data, the United States' EPA website, which was reliable since it is the main source of information regarding environmental matters in the US. The effectiveness and easiness of the procedure was another strength to some extent since it allowed me to quickly and efficiently investigate my research question. However, there were some weaknesses and limitations in the methodology which might have affected the results. The amount of data available on the website is one of them, which covered only the 1980-2019 time range, and even less for PM10. This gave only a little information, records of only 10 years, about the levels of the pollutants before the 1990 amendment, which might have affected the findings on annual percentage decreases, and therefore the whole conclusion. Another limitation, which is linked to the previous one, is the fact that there was no data available for PM10 levels before 1990, which totally limited the analysis of effects of 1990 amendments on PM10 levels.

Method Modifications:

It would have been better to find older data from other sources with a little more research, which is quite hard since the government reporting started from 1980. Therefore, maybe looking for sources from private researches of different institutions would be the better option to get more data on the levels of pollutants dating back to the very beginning of the Clean Air Act declaration, 1963, or even before that. Something else that would allow me to better analyze the success of the 1990 amendment is to carry out the investigation with data from multiple reliable sources simultaneously to see if there was any bias, coverage, or human error in recording one source.

Further Areas of Research:

I would like to carry out the same investigation for certain cities in the US which suffered from air pollution prior to the Clean Air Act program. This then will allow me to analyze the effects of the Clean Air Act for those cities specifically rather than the whole country. Because some cities might suffer more than others, and yet, all the data investigated were the averages of the whole country. And also, it would be really interesting to investigate the effects of these pollutants on human health and what has changed with the Clean Air Act being in action since 1963.

V. APPLICATIONS

There has been an enormous decrease in concentration levels of almost all the air pollutants from 1990 to 2019. However, to determine if all these changes were made solely by the 1990 amendment is nearly impossible. Because, as we can see both from data and the line graphs, the trend of pollutants had already started decreasing even before 1990, and after 1990 it just got faster for some pollutants and slower for others. But the Clean Air Act in general has been really successful to reach the lowest levels of all six air pollutants in a short period of time, which makes it valid to apply to other regions of the world with the same problem.

However, looking at the declining trends of all pollutants and the findings, we can say that the ozone levels have decreased by a relatively small percentage, 34.52%, compared to other pollutants. This indicates that the act has not been successful enough to reduce the level of this pollutant as it did for other pollutants.

Ozone in the ground level mainly comes from motor vehicle exhausts and industrial emissions, and levels above the limit can be really harmful to human health. For example, it might damage the human lung tissue when inhaled; it might cause eye irritation; and it can worsen asthma, bronchitis, and heart diseases (UCAR). Therefore, more has to be done to target this specific air pollutant. However, it is a secondary pollutant and formed when chemical compounds such as nitrous oxides, NO_X, or volatile organic compounds, VOCs, react with the sunlight, which makes it harder for governments to decide on specific regulations over ozone reduction (Moses). Some of the possible solutions include increasing the number of public transportations, stricter regulations over factories' emissions, or encouraging cleaner fuels to vehicles. For instance, the government can launch a program such as "Hoy No Circula" of Mexico, which has been really successful in reducing the number of cars traveling (Angloinfo Mexico). To follow this, the government will have to declare specific days of the week or a month as no-driving days for specific car brands or vehicles older than a certain year. This will eventually reduce the number of cars traveling during the day, which is one of the main sources of ground-level ozone. However, there are several limitations for this type of program, such as corruption on paper works of vehicles, or people might even start having two cars with different brands so that they can drive anytime they want. And hence, if these limitations are not controlled well, the increased number of motor vehicles might increase the ozone levels back.

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