Policy Path to Improve Urban Air Quality in Medellín, Colombia

Columbia University
School of International and Public Affairs
Capstone Project
Spring 2017

Client: La Ciudad Verde

Advisor: Adam Hinge
Team: Shawn Bush, William Jordan, Jeewon Kim, Yen Le, Debashree Poddar, Cameron Torreon

Abstract

The air quality in Medellín, Colombia has worsened in recent years reaching red alert levels in the spring of 2015, 2016, and now 2017. Increased automobile usage and the unique topographical and meteorological characteristics of the Aburrá Valley contribute to higher concentrations of harmful pollutants, causing public health concerns. La Ciudad Verde, a non-profit think tank focused on mobilizing civil society to influence the creation of sustainable policies, has challenged a Columbia University School of International and Public Affairs (SIPA) Capstone team to identify a potential policy path to improving Medellín’s air quality.

The team has mapped the governance structure of Medellín and the greater Aburrá Valley, conducted stakeholder interviews, and analyzed the costs and benefits. The team concludes that the cost of inaction outweighs the costs incurred by society in the long-term. The team identifies and recommends a proactive policy scenario in which Medellín prioritizes seven critical transportation sector-related intervention measures based on feasibility and effectiveness.
Table of Contents

Spanish Acronymns Used in This Report 5

Executive Summary 6
  Problem 6
  Methodology 6
  Solution 6
  Next Steps 8

1. Background 9
  Introduction 9

Sources of the Pollution Problem 9
  Topography 9
  Manmade Sources: Transportation and Industry 10
  Seasonality 10
  Climate Change & El Niño 10

Environmental Governance 10
  Colombian National Government 11
  Department of Antioquia 12
    Secretary of Environment – Department of Antioquia 12
  Área Metropolitana del Valle de Aburrá 13
  Municipal Government of Medellín 14
    Secretary of Environment – City of Medellín 14
    Secretary of Mobility – City of Medellín 14

Interactions between the Government and Academia 14
  Governance Culture 14
  Role of Academic Institutions 15
  Current Research 16
  SOS Por el Aire 16

2. Current Policies 17
  Pico y Placa 17
  Bus Rapid Transit 17
  Fuel Quality Standards 18
  Vehicle Standards 18

Challenges 19
  Transportation 19
Industry
Methodology
Maps

Tables

Table 1: Overview ................................................................. 7
Table 2: BRT Specifications in Medellín .................................................. Error! Bookmark not defined.
Table 3: Value of a Statistical Life: USD $1.3m, $1.2m, $0.4m ................................. 26
Table 4: Stages of Policy Intervention and Relevant Policy Measures .......................... 28
Table 5: Overview ................................................................. 29
Table 6: Emergency Measure Overview .................................................... 31
Table 7: AMVA Air Quality Rating System .................................................. 30
Table 8: Restrictions on Vehicle Selection Overview ......................................... 33
Table 9: Fuel Quality Improvement Overview ................................................. 35
Table 10: Change Consumer and Rider Behavior Overview .................................... 36
Table 11: Promote Bicycle Ridership Overview ............................................... 37
Table 12: Heavy Duty Vehicles (HDV) Restrictions Overview ................................ 38
Table 13: Vehicle Retrofit Financing Program Overview ....................................... 39
Table 14: Policy Path Alternatives: Medellín Air Quality ....................................... 40

Figures

Figure 1: Environmental Governance in Colombia ........................................... 11
Figure 2: Support for change and influence among stakeholders in Medellín ............. 15
Figure 3: Monthly Mean of Average PM2.5 across time in the Aburrá Valley .............. 24
Figure 4: Monthly Mean of Average PM10 across time in the Aburrá Valley .............. 24
Figure 5: Source of PM2.5 pollution, comparing transport sector and industry .......... 46
Figure 6: Source of CO2 pollution, comparing transport sector and industry .......... 46
Figure 7: Source of NOx pollution, comparing transport sector and industry .......... 47
Figure 8: Source of SOx pollution, comparing transport sector and industry .......... 47
Figure 9: Breakdown of PM2.5 sources in the Aburrá Valley by vehicle type ............ 48
Figure 10: Breakdown of carbon dioxide pollution in the Aburrá Valley by vehicle type 48
Figure 11: Breakdown of nitric oxide pollution in the Aburrá Valley by vehicle type .... 49
Figure 12: Sources of pollution by industry .................................................... 49
Spanish Acronymns Used in This Report

AAU  
*Autoridad Ambiental Urbana* – Urban Environmental Authority

AMVA  
*Autoridad Ambiental Urbana del Area Metropolitana del Valle de Aburrá* – Aburrá Valley Urban Environmental Authority

CAR  
* Corporación Autónoma Regional – Autonomous Regional Corporation

CDS  
*Corporación de Desarrollo Sostenible* – Sustainable Development Corporation

DANE  
*Departamento Administrativo Nacional de Estadística* – National Administrative Statistics Department

DNP  
*Departamento Nacional de Planeación* – National Department of Planning

IDEAM  
*Instituto de Hidrología, Meteorología y Estudios Ambientales* – Institute of Hydrology, Meteorology and Environmental Studies

MADR  
*Ministerio de Agricultura y Desarrollo Rural* – Ministry of Agriculture and Rural Development

MADS  
*Ministerio de Ambiente y Desarrollo Sostenible* – Ministry of Environment and Sustainable Development

MAVDT  
*Ministerio del Ambiente, Vivienda y Desarrollo Territorial* – Ministry of Environment, Housing and Territorial Development

MME  
*Ministerio de Minas y Energía de Colombia* – Ministry of Mines and Energy of Colombia

SIATA  
*Sistema de Alerta Temprana* – Early Warning System of Medellín and the Aburrá Valley

SINA  
*Sistema Nacional Ambiental* – National Environmental System
Executive Summary

Problem
The air quality in Medellín, Colombia has worsened in recent years reaching red alert levels in the spring of 2015, 2016, and now 2017. Increased automobile usage, combined with the unique topographical and meteorological characteristics of the Aburrá Valley, contributes to higher concentrations of harmful pollutants, causing public health concerns. La Ciudad Verde, a non-profit think tank focused on mobilizing civil society to influence the creation of sustainable policies, has challenged the SIPA Capstone team to identify a policy path to improving Medellín’s air quality.

Methodology
The team investigated the sources and costs related to Medellín’s air pollution by interviewing experts, politicians, and stakeholders in Medellín. Prominent officials the team interviewed include Medellín’s Secretary of Health and Secretary of Environment, sub-secretaries from Área Metropolitana del Valle de Aburrá (or AMVA, the regional environmental and transportation authority), and professors from Universidad de Antioquia and Universidad Nacional, among others. These interviews provided insight into the source of the air pollution, the political and governance structures of the city, popular opinion, current mitigation and outreach efforts, and relevant research.

Solution
The team mapped the governance structure of Medellín and the greater Aburrá Valley to identify key actors associated with the management of air quality in the region. The analysis concludes that regional environmental and transportation authorities like AMVA have the most political authority, with respect to developing and implementing air quality measures. AMVA, for example, has the ability to create standards that are stricter than national ones. The challenge, however, is in enforcement at the local level.

Stakeholders in Medellín including politicians, academics, and industry leaders widely recognize that the major contributing sources of air pollution are trucks, dump trucks, and motorcycles – all of which are minimally regulated. The cost analysis indicates that taking more aggressive steps now to reduce harmful emissions, especially from the transportation sector, will be more cost-effective in combatting the air quality crisis than remaining on the current course. Therefore, the team recommends that Medellín prioritize seven critical measures, based on feasibility and effectiveness. The most impactful response in the short term is to institutionalize the emergency measures during the peak days of air pollution. Further, along each of the three stages following the lifecycle of a vehicle there are two intervention measures: pre-use (vehicle and technology selection before adaptation on the road), in-use (operational and behavioral changes while the vehicles are on the road), and post-use (retrofitting or retiring of existing and aged vehicles). The table below summarizes the recommended interventions and identifies the responsible entities.
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Responsible Entities</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated Relative Impact: <strong>Green = High</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0. Institutionalize emergency measures</strong></td>
<td>Junta Metropolitana; SIATA</td>
<td>Transition the enactment of emergency measures, Pico y Placa, from discretionary to statutory. Currently, measures are decided by the consensus deliberation of the Junta Metropolitana. Firmly connecting air quality to tangible outcomes will help internalize pollution costs for individuals and organizations.</td>
</tr>
<tr>
<td><strong>1a. Regulate motorcycles &amp; second-hand vehicles</strong></td>
<td>City of Medellín; AMVA; Junta Metropolitana</td>
<td>Markets for motorcycles and second-hand vehicles are lightly regulated, but contribute to a significant portion of air pollution and undercut other policy measures. Establishing registration requirements will fill the void and allow authorities to more easily track and manage the fleet.</td>
</tr>
<tr>
<td><strong>1b. Improve fuel quality</strong></td>
<td>MADS, DNP, MME, Ecopetrol, AMVA¹</td>
<td>The City of Medellín and other municipalities belonging to the Metropolitan Area of the Valley of Aburrá should continue to press Ecopetrol for an agreement to improve fuel quality in the Valley to a sulfur content of 10ppm from current levels of 50ppm.</td>
</tr>
<tr>
<td><strong>2a. Promote driver behavior change</strong></td>
<td>AMVA; Medellín Secretary of Environment</td>
<td>The City of Medellín, through initiatives designed and implemented by the Secretary of Environment, should educate drivers on more efficient driving practices, as well as encourage carpooling.</td>
</tr>
<tr>
<td><strong>2b. Promote bicycle ridership</strong></td>
<td>AMVA (Secretary of Mobility)</td>
<td>The individual mayors of each of the ten localities should allocate funds to implement the plans in the POT. Additionally, the mayors and local governments need to effectively coordinate with their respective Herencia de Movilidad Humana (Human Mobility Heritage) to ensure the effective completion of the projects</td>
</tr>
<tr>
<td><strong>3a. Place limits on heavy duty vehicles</strong></td>
<td>Medellin Secretary of Mobility</td>
<td>The Mayor’s office should issue a decree that limits the hours that heavy duty vehicles can drive through the city during non-peak hours. The mayor must then seek support from Junta Metropolitana to encourage them to eventually adopt the same policy.</td>
</tr>
<tr>
<td><strong>3b. Implement vehicle retrofit financing program</strong></td>
<td>AMVA; Medellín; Private bus companies</td>
<td>City of Medellín should allocate fund to AMVA to implement a vehicle retrofit program (subsidies for catalytic converters) for private bus companies and owners that operate in Medellín</td>
</tr>
</tbody>
</table>

¹ Regional authorities can impose stricter measures beyond national standards, but it would require the cooperation of Ecopetrol.
Next Steps

A continued partnership between La Ciudad Verde and the SIPA Capstone program would provide significant policy value by investigating the specific costs and benefits of implementing the seven policies outlined in this report. This includes evaluating emissions data from the different sectors and sources and analyzing the effect current policies have on consumer behavior.

.....

In the following report, Section 1 outlines the air quality problem in Medellín; Section 2 discusses current policies that address the issue, as well as associated challenges; Section 3 provides a literature review and estimations of health and economic costs resulting from air pollution; and Section 4 offers recommendations for cost-effective and feasible mitigation efforts. The Conclusion summarizes the report’s findings and details possible next steps.

*Special thanks to Carlos Cadena Gaitán and Alejandro Alvarez Vanegas at Universidad EAFIT for their support throughout the project.*
1. Background

Introduction

It is the many successes of Medellín over the past three decades that make it possible for the city to take on the environmental challenge of air pollution. While the homicide rate ticked up by nearly eight percent in 2016 (Alsema 2017), current levels of urban violence remain a fraction of what they were in the 1980s and 1990s. Once ranked first in the world for murders per capita, in recent rankings it does not even fall in the top fifty (World Atlas 2017).

Over this period, the city has also undergone a dramatic physical transformation. It has become world-renowned for its innovative approaches to land use, sustainability, transportation, and mobility (Toderian 2014). Taking inspiration from ski slopes and shopping malls the city’s planners have reconnected the elevated outer city to the core using gondolas and escalators. New schools, libraries, and parks have helped to reinvigorate communities.

As old challenges recede, new ones arise. Despite huge advances in the city’s transport system – just in 2015 the city added a streetcar system to its repertoire – the number of vehicles in the city continues to rise. The additional vehicles, combined with the unique topographical and meteorological characteristics of the Aburrá Valley where Medellín is situated, have contributed to air pollution crises during the Spring of 2015, 2016, and now 2017. Overall, policies aimed at reducing air pollution in the valley succeeded in doing so between 2008 and 2011, but the trend reversed in subsequent years (Medellín Cómo Vamos 2016).

As air quality has worsened, the city has begun to confront the dynamics that have largely precipitated the problem: a legacy of societal norms resulting from the preceding decades of insecurity, the unavoidable topographical characteristics of the Aburrá Valley, and underlying socioeconomic factors, including inequality. However, while the problem has garnered greater attention over the last few years, the case for addressing the issue is still developing in the public sphere.

At its core, air quality management attempts to solve a classic problem of public goods: the cause and effects of air pollution are widely dispersed and individuals have little incentive to change their behavior. The circumstances are eminently more challenging for Medellín when considering the topography, disproportionate impact on the poorest and least politically powerful citizens, and a tradition of entrenched special interests.

The need for the government to intervene in the problem is clear, but these additional layers of social, geographic, and economic complexity make any public policy effort in Medellín even more reliant on political will. Given that the movement to address the air quality problem is in its early stages, the role of this report will be to outline findings illustrating the costs to the status quo and the benefits to a more proactive and robust government approach. The report then seeks to provide the most sensible and beneficial prioritization of the immediate interventions available.

Sources of the Pollution Problem

Topography

Similar to other cities where pollution is notable, like Los Angeles, Santiago, and Mexico City, Medellín is located in a narrow valley, surrounded by sloping mountains. This topography, combined with low wind speeds, prevents the dispersion of pollution (See Appendix: Map).
Manmade Sources: Transportation and Industry

According to the 2013 Atmospheric Emissions Inventory of the Aburrá Valley, between 70–80 percent of emissions came from mobile sources, excluding SOx, which primarily came from industry. This would help explain why the pollution problems appear to have worsened in recent years: despite the introduction of policies such as Pico y Placa, aimed at reducing the number of cars on the road, the number of cars grew by 3.1 percent between 2014 and 2015, or from 1,234,946 cars to 1,273,223 (Roldán 2017). This includes a 4.1 percent growth in the number of cars and a 2.1 percent growth in motorcycles. Over the past decade the increase is significant: there are 67 percent more cars in Aburrá Valley, 280 percent more motorcycles, 54 percent more taxis and buses, and 50 percent more trucks (AMVA 2013). While the mix of fuels has improved in Colombia since 2004, it still does not meet the quality recommended by the World Health Organization (WHO).

Seasonality

Prevailing weather conditions during the February to April period contribute to poor air quality. During this time, as well as between October and December, the region transitions between the wet and dry seasons. This leads to increased humidity, low-lying clouds, and low incidence of solar radiation on the ground, all of which help to “trap” the pollution in the Aburrá Valley (Medellín Cómo Vamos 2016a).

Climate Change & El Niño

Climate change has affected weather patterns and increased the intensity of El Niño in Colombia. In 2015, the national meteorological institute classified El Niño as a “strong phenomenon,” the highest category on the scale. The effect of El Niño varies based on timing and location – it can lead to increased frequency in rainfall or prolonged drought. In the western part of the country where Medellín resides, El Niño has led to extreme drought and higher temperatures. Lack of rain has resulted in increased particles in the air, as well as low or lack of wind velocity (Dennis 2015).

Environmental Governance

The structure that governs environmental policy is a complex weave of overlapping jurisdictions and hierarchies. The federal, departmental, regional, and municipal levels of government are all capable of affecting environmental policy, and bear some responsibility for ensuring regulations are enforceable and consistent. This report seeks to demystify the hierarchy, processes, and jurisdiction of environmental policymaking in Medellín.

Environmental policies, as defined in the Colombian Federal Law 99 of 1993, are the rules and measures that “the environmental authorities implement for the regulation of the use, management, exploitation, or mobilization of renewable natural resources; or for the preservation of the natural environment, even if they limit the exercise of individual rights and public liberties for the preservation or restoration of the environment.”

The three most important levels of government for air quality management in Colombia are the national government, regional or metropolitan environmental authorities, and municipal governments. The departments, or provinces, encompass numerous regional authorities, but play only an advisory role in environmental governance. Minimum standards are set at the national level, while regional authorities are responsible for execution and implementation. However, if the region would like to seek more

---

2 Detailed breakdown of the source of the air pollution can be found in the Appendix.
stringent regulations than those set at the national level it must consult the local municipal governments. In addition, municipal governments sometimes participate in consultation and communicating policies to citizens.

Figure 1: Environmental Governance in Colombia

Colombian National Government

The Constitution of 1991 laid the groundwork for the modern national environmental management system in Colombia, which was articulated in more detail with Law 99. Previously, national and local health authorities were responsible for air quality management (Sánchez-Triana et al 2007). Law 99 led to the creation of the National Environmental System (SINA), which encompasses the key regulatory institutions for the environment in Colombia: the national Ministry of Environment (MMA, now the Ministry of Environment and Sustainable Development, or MADS) and the regional environmental authorities (Urban Environmental Authorities, or AAUs; Autonomous Regional Corporations, CARs; and Sustainable Development Corporations, or CDSs). This system establishes a structure for relevant stakeholders, such as NGOs and research institutions, to interact with government entities and delineates the legal mechanisms for licensing, planning, financing, and public participation. Specifically, MADS is responsible for generating national rules and norms for air quality management, while the CARs and AAUs are responsible for implementation. However, regional authorities can set stricter requirements than those set at the national level. Generally, environmental management in Colombia is collaborative, with the continuous involvement and consultation of lower levels of government along with academic institutes, non-profits, and the private sector.
Department of Antioquia

Environmental policy and air quality rules and regulations adhere to a hierarchical order, with policies of the Departments of the Governor of Antioquia falling below the Ministry of the Environment (MADS). Title IX of Law 99 outlines the functions of the Departments of environmental matters:

1. Promote and implement national, regional and sectoral programs and policies in relation to the environment and renewable natural resources;
2. To issue, subject to higher standards, special departmental provisions relating to the environment;
3. Provide budgetary, technical, financial and administrative support to the Regional Autonomous Corporations (CARs), municipalities and other territorial entities that are created at the departmental level, in the execution of programs and projects and in the tasks necessary for the conservation of the environment and renewable natural resources;
4. To exercise, in coordination with the other entities of the National Environmental System (SINA), and subject to the legal distribution of powers, functions of control and monitoring of the environment and renewable natural resources, in order to ensure compliance with the duties of the State and private individuals in environmental matters and to protect the right to a healthy environment;
5. Develop, with the advice or participation of the Regional Autonomous Corporations, programs of cooperation and integration with the neighboring and neighboring territorial entities of the neighboring country, aimed at promoting the preservation of the common environment and bilateral renewable natural resources;
6. To promote, cofinance or execute, in coordination with the governing bodies and executing agencies of the National Land Adjustment System and the Regional Autonomous Corporations, works and projects of irrigation, drainage, land reclamation, flood defense and regulation of Channels or streams of water, for the proper management and use of watersheds;
7. Coordinate and direct, with the advice of the Regional Autonomous Corporations, the activities of inter-municipal environmental control and surveillance, carried out in the territory of the department with the support of the public force, in relation to the mobilization of processing, use, exploitation and marketing of renewable natural resources.

Because the regional environmental authorities (the CARs discussed above, along with AAUs) implement national environmental policies, departmental governments in Colombia play a limited role in this area. The departmental government also assists in research and prepares reports on the state of environmental resources across the departments many regions.

Secretary of Environment – Department of Antioquia

Federal law emphasizes the coordination of the Department of the Environment with regional authorities and municipalities. Including through advising, financing, and assistance with implementation, the Department of the Environment is legally obligated to support Área Metropolitana del Valle de Aburrá (AMVA) in its endeavors to improve the environment, and air quality by extension.

3 The term Department here refers to a state or a province.
Área Metropolitana del Valle de Aburrá

Created in 1980, AMVA is the Autonomous Urban Authority (AAU) that represents ten (those municipalities located in the Aburrá Valley) of the 125 municipalities in Antioquia. Medellín is the capital and largest city in the metropolitan area and comprised 72 percent of its population as of 2005 (DANE 2005).

AMVA is governed by an entity called the “Junta Metropolitana,” which consists of:

- the ten mayors of the region (with the mayor of Medellín as president);
- a representative for the Municipal Councils;
- a representative from the Governor of Antioquia;
- a representative elected by environmental non-profits;
- a representative from the National Government; and
- the Director of Planning of the Department of Antioquia (AMVA 2016).

It is worth noting that the Medellín City Council has an additional representative on the Junta, while the remaining municipalities share a single representative. In addition, the Mayor of Medellín is largely responsible for selecting the Junta’s director.

AMVA oversees the urban planning process of the region and acts as an environmental and mass transit authority, which includes the metro and cable car systems and the Bus Rapid Transit (BRT) (AMVA 2017a).

AMVA has been designated the mass transit authority that plans, controls, monitors, regulates, and sanctions activities related to the different modes of transportation (taxis, buses, Metro, Metroplus) in its jurisdiction. Laws 105 and 99 of 1993, 336 of 1996, 1625 of 2013 and decrees 2660 of 1998, 170, 172, 175 of 2001 and 3366 of 2003 determine the power of the Authority with regard to the field of public passenger transportation system (AMVA, and Consorcio de Movilidad Regional 2009). Its many functions include defining fees and authorizing tenders.

AMVA is empowered to administer laws within its jurisdiction regarding the environment, renewable resources, and sustainable development, as long as they conform with the legal dispositions and policies of the Ministry of the Environment. AMVA must adhere to the minimum environmental policing standards and measures of federal law and has the discretion to enact stricter measures (Law 99 of 1993).

Moreover, following the Air Quality Protection Program in 1998, AMVA is responsible for preparing the Plan de Descontaminación and presenting it to the nine (now ten) incorporated municipalities for adoption (AMVA 2009). The most recent plan was released in 2009, and an updated plan is anticipated to be released in 2017.

AMVA’s funding is largely provided by property taxes within each metropolitan area, plus other contributions such as donations and sale of services. The city of Medellín provides the majority of this funding, which is the largest and most well-funded of the municipalities. The budget items are allocated voluntarily in the annual budget. Its 2012-2015 Pura Vida management plan had an investment of USD$350M (AMVA 2017b). All programs or projects to be applied to the region must be approved by all ten municipalities.\(^4\)

\(^4\) AMVA’s budget allocation can be found at: http://www.metropol.gov.co/institucional/InformacionFinanciera/RESULTADO percent20DE percent20LA percent20GESTI percentC3 percent93N percent20PRESUPUESTAL percent202016.pdf
**Municipal Government of Medellín**

The mayor of Medellín has jurisdiction over the policies of the city, regarding air quality or otherwise, so long as they are not more loosely regulated than at the next highest level. However, Medellín’s mayor, in particular, has outsized influence at higher levels of government. As mentioned, Medellín has additional representatives on AMVA’s board, of which it is imbued with the power to select its leadership (the director of AMVA).  

**Secretary of Environment – City of Medellín**

While the website of Medellín’s Secretary of Environment would indicate that the office is tasked with “leading the implementation of national, regional and local environmental policies and renewable natural resources with the different actors,” senior-level representatives stress that, with regard to air quality, the office is limited to the education of students below university age. Representatives from the Secretariat visit schools to teach students about the principles of sustainability and environmental stewardship, including providing information about air pollution.

**Secretary of Mobility – City of Medellín**

Currently, the Secretaries of Environment and Transport, under the National Transit Code Law 769 of 2002 and Articles 28, 50, 51, 52, 53, 54, and Resolutions 3500 of 2005 and 2200 of 2006 require technical mechanical review of a vehicle. In theory, the first mandatory mechanical review of private vehicles is conducted after six years of purchase, then every year; at two years and every year for public vehicles; and at two years and then every year for motorcycles (Secretaría de Movilidad de Medellín 2014). The review process evaluates the vehicle’s bodywork, brake status, steering, suspension, visual and audible signal system, rims and safety assembly, and gas emissions. These mechanical and gas technical reviews must be carried out in automotive diagnostic centers (CDA) authorized by the Secretary of Transport and the Secretary of Environment. If a vehicle fails to comply with the latest standards, the driver incurs a fine of 15 legal minimum daily salaries, and the authority can order vehicle immobilization (or in colloquial terms, “llevar el carro a los patios” or “carry the car to the courts”).

**Interactions between the Government and Academia**

**Governance Culture**

In Medellín, the level of private sector and community participation appears to be high. Before the implementation of any policy, the principal agency seeks to garner voluntary consent from all stakeholders. On occasions when consent seems difficult, the agency enters into negotiations with the stakeholder. Even though this seems like a very inclusive approach, negotiations often work in favor of the more influential stakeholders. This method of policy adoption and implementation becomes even more complicated and eventually stagnant in the case of issues involving public goods and a high level of externalities – cases where there are clear winners and losers.

---

5 City of Medellín’s budget can be found at: [https://www.Medellín.gov.co/irj/portal/Medellín?NavigationTarget=navurl://dea8ca8796a2f10f2642b5ff7065efce](https://www.Medellín.gov.co/irj/portal/Medellín?NavigationTarget=navurl://dea8ca8796a2f10f2642b5ff7065efce)

6 Veronica Cotes & Paola Zapata (Secretariat of the Environment, Medellín, Office of Oscar Hoyos Giraldo), in discussion with the authors. March 2017.
Role of Academic Institutions

Academic institutions play an influential role with regards to policy formulation and adoption. Some institutions are part of SINA, and academic research is usually carried out as a pretext for the passage of new standards or legislation.

While independent research across the universities is common, research teams prefer working in collaboration with government bodies and public institutions. Some academics believe that research would only be circulated and noticed if the bodies directly responsible for implementing recommendations have some stake. In addition, there is a strong notion that there exists a wide gap between academic and public language that can only be bridged when public institutions are involved.

---

7 Luis Belalcazar. (Professor at Universidad Nacional–Bogota), in discussion with the authors. March 2017.
8 Sergio Orrego. (Professor at Universidad Nacional–Medellin), in discussion with the authors. March 2017.
On the other hand, government bodies and public institutions reach out to research teams across the 30 universities in Medellín for the purposes of validating their policies or designing policies (backed heavily by academic models, data analysis and research). The partnership with academic institutions lends increased credibility to the agency in charge of taking action.

**Current Research**

Regarding air quality in Medellín, the Antioquia Secretary of Health, through the Undersecretary of Environmental Health, is using data provided by the largest hospitals in the area to generate a report titled “Epidemiological Surveillance of Health Effects Associated with Air Quality.” This report aims to more directly connect air quality and health effects. By collecting data on individuals, such as smoking habits, cooking methods, and whether or not there is a household pet, the Undersecretary hopes to clarify the correlation between air quality and health. Currently, the data gathered and processed represents only three percent of the total of the population. The office estimates that in a year they will gather and process all historical data from the last five to seven years in order to form a baseline. The report will not be made public until 2018, according to a representative of the office.

The Universidad de Antioquia is working on a joint research project with the AMVA. The overall goal of the project is to understand the complexity of the health issues associated with air quality challenges and to identify key indicators that would help extricate the exact effect of air pollution on health. One of the objectives of the research is to calculate the costs of Medellín’s air pollution. This would involve quantifying the number of hospital admissions related to respiratory illnesses (caused by exposure to air pollution). The research team uses data mining procedures to advance their efforts. The research team expects to release the report in the summer of 2017. According to one member of the research team, Juan Pineros, one of the key constraints the team faces is a lack of monetary resources.

The Universidad Nacional (both the Bogotá and the Medellín campuses) has teams working on various aspects of air pollution and climate change. These include exposure to air pollution (Nestor Rojas), emission inventory and life cycle policies (Luis Balcazar), and research related to the effect of coal mines in the north. Sergio Orrego, a professor at the university’s Medellín campus, is working on a time-series analysis of PM 2.5 emissions, changes in transportation method, and respiratory diseases in Medellín in order to check for significant trends.

*Estado de los Recursos Naturales* publishes an annual report. The report for 2016 is forthcoming (Contraloria General De Antioquia 2016). The report takes stock of all the current natural resources in the state, comments on changes, and makes projections and analyses policies that would impact the current stock of resources.

*SOS Por el Aire*

“SOS Por el Aire” is a collective of academics formed with the objective of uniting the various universities and knowledge centers across the city in their effort to combat the air pollution crisis. One of the tasks that the group has set out for itself is to scrutinize the forthcoming Plan de Descontaminación and validate it by critiquing the various measures included in the report.

---

9 Juan Pineros. (Professor at Universidad de Antioquia), in discussion with the authors. March 2017.
10 Juan Pineros. (Professor at Universidad de Antioquia), in discussion with the authors. March 2017.
11 Alejandro Alvarez. (Process engineer at Universidad EAFIT), in discussion with the authors. March 2017.
2. Current Policies

Medellín has been recognized as a transport policy leader in Latin America because of its traffic congestion reduction efforts and public transport initiatives. These initiatives include Pico y Placa and Metroplus public transportation system.

Pico y Placa

In 2005, the city of Medellín introduced Pico y Placa to reduce vehicle congestion for both passenger cars and motorcycles. The policy, also adopted by nearby cities in the Aburrá Valley, Itagüí, Envigado and Bello, restricts number of vehicles on the road by only allowing half of registered cars, enforced based on the licenses plates numbers, to drive on any particular day during rush hour (7:00-8:30 AM and 5:30-7:00 PM). Even and odd license plates numbers rotate on an every-other-day basis. There is a similar rotational program for taxis. Drivers who violate the Pico y Placa regulation are fined 386,850 Colombian Pesos, the equivalent of USD $135 (Información del Pico y Placa en Colombia 2017).

Research by Cantillo and Ortuzar (2014) indicated that the policy reduced congestion, but only for a short period of time. This also remained true for pollution with immediate short-term reductions overcome by an eventual return to previous levels. The city returned to previous levels of pollution by 2007.

Bus Rapid Transit

Colombia developed the National Urban Transport Program to develop and expand Bus Rapid Transit (BRT) throughout the country. The first Colombian BRT, TransMilenio built in Bogota in 2002, was considered a success. The BRT reduced commute time by 32 percent and increased property values along the lines by 15-20 percent. With respect to air quality, TransMilenio reduce SO2 by 43 percent, NOx by 18 percent, and particulate matter by 12 percent (Turner et al 2012).

In Medellín, there are currently two BRT lines in operation; the first line opened in 2011 and the second in 2013. Specifications are found in Table 2 below.
Table 2: BRT Specifications in Medellín

<table>
<thead>
<tr>
<th></th>
<th>Line 1</th>
<th>Line 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>12.5km</td>
<td>13.5km</td>
</tr>
<tr>
<td>Stations/Stops</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Buses</td>
<td>25</td>
<td>47</td>
</tr>
<tr>
<td>Time</td>
<td>45 min</td>
<td>60 min</td>
</tr>
<tr>
<td>Speed</td>
<td>16km/hr</td>
<td>13km/hr</td>
</tr>
<tr>
<td>Wait time</td>
<td>2'55 min</td>
<td>6 min</td>
</tr>
<tr>
<td>Capacity/hour</td>
<td>3,018 people</td>
<td>1,350 people</td>
</tr>
<tr>
<td>Open</td>
<td>12/22/2011</td>
<td>4/22/2013</td>
</tr>
</tbody>
</table>

Metroplus BRT lines transport 60,000 commuters daily and 90 percent of the bus route is in a bus-right-of-way lane. The buses are 18 meters long and have a capacity of 160 passengers. They are powered by natural gas and reduce fuel costs by 40 percent. The buses also feature state-of-the-art technology – GPRS and Wi-Fi connections for vehicle location and data transmission – which improves the commuter experience (Global BRT Data 2017).

Fuel Quality Standards

Fuel standards in Colombia are regulated by the Ministry of Mines and Energy, and the largely state-owned Petroleum Enterprise (Ecopetrol) manages the refining capacity in the country. The primary refinery is in Cartagena and production is sufficient to meet domestic gasoline demand. However, 55 percent of diesel demand must be met through imports (Gomez 2016). Ecopetrol is planning to invest USD $4.5 million to update two state refineries focused on diesel production.

Since 2001, the government has been strengthening fuel quality standards and increasing the mix of biofuels in gasoline. The current requirements for biodiesel and ethanol blending is 8-10 percent depending on the region. In 2013, Colombia completed a process of strengthening its standard on sulfur emissions and reduced sulfur in diesel to 50ppm and in gasoline to 300ppm (UNEP 2014).

Vehicle Standards

Colombia has banned the import of used vehicles. Vehicles that are imported must meet the following criteria:

1. Be of a model of the same year;
2. Have a catalytic converter, a filtration system for reducing vehicle emissions.

New lightweight and heavy duty vehicles must comply with Euro 1 emission standards; the notable exception is buses, which must comply with Euro 2 standards.

The regulations are lax for existing vehicles in the fleet. Heavy duty vehicles, for example, must comply with the equivalent of US Environmental Protection Agency (EPA) 1994 standards for buses and 1991 standards for all other vehicles (UNEP 2014).
Challenges

There are multiple challenges to improving air quality across various areas, including transportation, political, and institutional governance, implementing behavioral changes, and data gathering.

Transportation

Public Transportation

The transportation sector contributes 80 percent of PM2.5 emissions in Medellín. Named one of the top transit systems in the world by the Institute for Transportation and Development Policy (ITDP), and voted City of the Year by the Wall Street Journal and Citi in 2012, Medellín boasts the most advanced public transit system in Colombia (Institute for Transportation and Development Policy 2012). The metro and gondola systems were praised as instruments to fast-track into upward mobility, with two metro lines running north and south through the valley along the river, and three “Metrocable” (gondola) lines stretching up and down the valley.

Despite drastic improvements, public transportation is still associated with security concerns of previous years. This is especially true in the bus system, with inefficient and insufficient coverage serving the public, especially in the higher altitudes. Unlike the Metro system, the buses are largely owned and operated by private companies, further promoting inefficiency in coordination.

Motorcycles

Motorcycle ownership has continuously been on the rise in developing urban areas across the world due to affordability and ease of use when maneuvering heavy traffic. According to AMVA, the automobile fleet ownership in Medellín approximately doubled from 271,000 to 546,768 from August 2005 and August 2015, but number of motorcycles increased five times from 139,000 to 710,186 (AMVA 2015). Moreover, there is little regulation or record-keeping when consumers purchase a motorcycle. One only needs to show a government-issued ID in order to purchase a motorcycle.

This upward trend in vehicle number is not only prevalent in Medellín, but also in many rapidly developing countries such as Thailand and Vietnam, and is associated with the rising socioeconomic statuses of the citizens. Asian countries have implemented regulations modeled after the European Union (EU), although they are not as frequently updated as EU standards evolve. While there is wide perception that two-wheelers are more energy efficient per passenger-mile than four-wheelers, the two-wheelers fall between automobiles and buses.

There are possible interventions across three stages in a lifetime of a vehicle: new purchases, continuous regulation of existing vehicles, and retrofitting or scrapping of outdated models. Two-wheel or sometimes three-wheel vehicles (or, motorcycles in general) and related emissions characteristics have historically received less regulatory attention. The motorcycle market has faced fewer regulations or incentives to ensure low emissions for new vehicles.

Trucks

Heavy duty fleets, especially dump trucks known as volquetas, are the most severe polluters, with approximately 80 percent of vehicles ranging from below Euro I to Euro III, and only 20 percent meeting the Euro IV standard.\(^{12,13}\) Currently, standards for heavy-duty pickup trucks and vans are rarely

---

\(^{12}\) Sergio Giraldo Posada & Jorge Toro, (Former consultants, Transporte Publico de Medellín - TPM) in discussion with the authors. March 2017.
enforced (AMVA 2009). Many of the vehicles run on low-quality diesel (ACPM) and could potentially be switched to run on natural gas, or scrapped and replaced altogether.

The challenge for Medellín and the Aburrá Valley is that many of the trucks that contribute to the pollution in the region are not locally registered, but instead, are passing through the area and transporting goods to other parts of the country. The infrastructure and road networks in the region require truck drivers to enter and drive through the valley. There are no alternative routes to avoid the valley if the driver needs to reach the opposite side.14

Political & Institutional Issues

Overlapping Jurisdictions & Passing of Responsibilities

Diffusion of responsibility among a host of government agencies at the federal, state, and municipality level complicates coordination and policy making. Though it is not uncommon for a country to have a complex governmental structure, policies surrounding air pollution and transportation in the Valle de Aburrá require unanimous support. The number of government entities – from the municipalities, to the regional authority, to the city of Medellín itself – comprise an overlapping and regulatory jurisdiction framework. This makes it difficult for complex issues, like air quality, where sources are widely diffuse, but the entities responsible for regulation and enforcement are a mosaic of interconnected hierarchies and organizations. The lack of a streamlined governance structure presents a challenge to enacting effective policy measures. It can be unclear, even to policymakers, which government entities interact and how they interact to regulate the transport industry.

Coordination Issues & Data Sharing

AMVA, the Secretariats of Mobility, Environment, and Health, and other stakeholders meet once a month to discuss a variety of issues. Nonetheless, there appears to be a continued lack of coordination on air quality policy.

Skepticism About Commitments

Through Public Transportation of Medellín (Transporte Publico de Medellín - TPM), AMVA is currently undertaking initiatives to improve air quality through improvements to the transportation system. However, these initiatives are slow-moving and raise skepticism about AMVA’s commitment to fully implementing the proposed initiatives.

Political Will

Public support plays a critical role in informing policymakers and politicians. Short of vocal support from academia, nonprofit organizations, and families, as well as the business sector, political organizations, and activists, the political capital needed to move robust legislation may be more than vulnerable parties are willing to expend for the sake of improving the city’s air quality.

13 The European Union (EU) regulates emission standards from road transport, and are generally adopted as part of the EU framework. Current EU standards for light duty vehicles (passenger cars and vans) are at Euro 6 (Regulation 2016/427), while heavy duty vehicles fall under Euro VI (Commission Regulation 582/2011). (European Commission 2016)

14 Natalia A. Restrepo Velez & Francisco Alejandro Correa Gil, (Representatives for AMVA), in discussion with the authors. March 2017.
Enforcement Challenges

Capacity issues persist in a public sector with limited resources. In the current era of loose regulation, cars and motorcycles became nearly ubiquitous, with average occupation rates of cars currently around 1.3 people per vehicle. Enforcing new regulations on all of these vehicles would likely require a shift in how ordinary citizens view regulatory authorities as well as greatly increased capacity for those authorities.

Behavioral Dynamics

Behavior is at the core of the air quality problem. Nearly everyone in Medellín contributes to the problem but few internalize the costs or have enough of an incentive to change individual behavior. As a result, increasing awareness and changing norms through education will be as vital a component to resolving the air quality challenges as much as developing effective public policy measures.

Legacy Norms

Medellín has developed a hard-won reputation as a city known for its innovative and progressive transportation. The general public holds certain transportation modes in high-esteem as Medellín is the only city in Colombia with a metro and the cable car system was a groundbreaking project not just for Colombia but for Latin America as a whole. Both systems are a widely hailed point of pride and ridership continues to steadily increase for each. However, this attitude is not pervasive. Norms dissuading the use of other forms of transportation including bus, biking, and even walking are still firmly entrenched. This is largely due to the legacy of preceding years where safety was the driving and preeminent concern for citizens. As the city has developed, this has had a compounding negative effect as car ownership has become increasingly expected and desired, and the city has generally geared much of its infrastructure to accommodate this norm.

Existing Efforts

Currently, the city maintains some programs to educate and bring awareness to the populace about the overall state of air quality. Since 2010, the Mayor’s office has partnered with AMVA to sponsor an air quality alert program known as SIATA (Sistema de Alerta Temprana). Eight monitoring stations positioned throughout the Aburrá Valley provide real-time information on air quality and issue warnings when PM2.5 levels reach dangerous thresholds. The system issues alerts through social media platforms, its website, and a widely used mobile application. While the alert system is a function of set thresholds for air quality that are developed in conjunction with a number of non-governmental constituencies, extreme alerts including and past red must be agreed upon by the Junta Metropolitana before being issued. The governmental partnership funds the program but a network of universities and academic institutions maintains and manages it.

In addition to the monitoring program, the Department of the Secretary of Environment (Secretaría del Medio Ambiente) within Medellín conducts educational programs geared toward elementary, middle, and high school students. The educational programs focus on teaching the younger generation in the city about sustainability and the value of the environment and includes different activities including workshops and theatre. The ultimate goal of the program is to create new habits in order to the change the culture toward things like car ownership and public perceptions toward public transportation. As representatives from the Department stated, public awareness in Medellín is important and lack of awareness is perhaps the biggest obstacle to addressing the air quality problem. The program intends

15 Luis Belalcazar. (professor at Universidad Nacional–Bogota), in discussion with the authors. March 2017.
to achieve cultural change by targeting the youth with the hope that the message is passed on to adults and the older generation.  

What’s Missing

While the existing programs illustrate the government’s acceptance of air quality as an immediate issue, the lack of dedicated awareness and education programs for the largest demographic that actually contributes to the pollution underscores the reluctance to fully embracing the problem. The major issue with the aforementioned programs is the lack of any immediate impact. While the SIATA protocols are developed to adhere to widely accepted standards of air quality, the issuance of alerts is not connected to any larger tangible effect that constrains increased driving or provides incentives for alternative modes of transportation or otherwise. The education programs, while laudable and an entirely necessary long-term platform, target the only demographic that does not largely contribute to the generation of particulate matter on a wide-scale.

Information & Data Gathering

Most of the public institutions interviewed explicitly stated their concern about the issue of air pollution but at the same time had apprehensions about the actual costs of air pollution. They claimed that no data or evidence was available that would be able to attribute a specific number of deaths or health issues directly to air pollution. Health impacts that are indicative of poor air quality, according to these government bodies could also be compounded or caused by personal habits, meteorological effects, occupational hazards and the levels of exposure. While resources and time have been exerted on research to come up with an exact number the results have mostly been inconclusive or contested. This ‘lack of information’ remains one of the main reasons cited for inaction.

Keeping in mind the context of the governance culture in Medellín, government bodies seek this data – that which is specific and full-proof – to be able to wield it as an instrument during negotiations and as leverage. While the intentions are good, it is impossible to get so specific due to the presence of numerous uncontrollable variables and changing conditions. Additionally, research methodologies are always prone to criticisms and key assumptions could always be opposed.

---

16 Veronica Cotes & Paola Zapata. (Secretariat of the Environment, Medellín, Office of Oscar Hoyos Giraldo), in discussion with the authors. March 2017.

17 Natalia A. Restrepo Velez & Francisco Alejandro Correa Gil. (Representatives for AMVA), in discussion with the authors. March 2017.

18 Enrique Henao & Carolina Agudelo. (Secretariat of Health, Sub-Secretariat of Environmental Health, Antioquia), in discussion with the authors. March 2017.

19 Elkin Martinez. (Epidemiologist and Professor of Public Health at the Universidad de Antioquia), in discussion with the authors. March 2017.
3. Rationale for Additional Government Intervention

Urban air pollution in recent years has been on the rise, along with the city’s GDP. It is a classic case of economic activities producing externalities – where private actors do not factor in costs and impact to society during decision-making. As is the case with many public goods problems, the only solution for internalizing these external costs (to society) is through strong government intervention. However, a World Bank review published in 2015 found that air pollution was still given “Low Priority” across developing countries (Awe et al 2015). The interviews conducted with various government agencies in Medellín reflected a similar attitude.

The reason for this governmental inaction stems from the complexity of evaluating the costs of air pollution and benefits of investments made to improve air quality – as was seen in the case of Medellín. Nevertheless, even if there is no specific number on this return to investment, the reasons for immediate and tough government involvement are economically and ethically compelling.

Public Health

According to the WHO, there is a close relationship between exposure to high concentrations of small particulates (PM10 and PM2.5) and increased mortality or morbidity, both daily and over time (WHO Regional Office for Europe 2013). A number of other studies reach the same conclusion. This has clear implications for policymakers. Adopting policies to reduce PM2.5 and PM10 levels would reduce associated health effects and ultimately translate into decreased public health costs and increased revenue from enhanced productivity. In this section, we will review and analyze existing literature in an attempt to produce a range of estimates for the proximate health-related costs of air pollution in Medellín.

The WHO defines certain threshold levels for the concentration of PM10 and PM2.5. For PM2.5 the level is as 10 μg/m$^3$ (for an annual mean) and 25 μg/m$^3$ (for a 24-hour mean). For PM10 it is 20 μg/m$^3$ (annual) and 50 μg/m$^3$ (24-hour). Concentrations of particulate matter above these thresholds are defined as a health risk. Figures 3 and 4 below indicate that for the AMVA region, the concentrations of both PM2.5 and PM10 have been consistently and on many occasions significantly greater than the WHO threshold levels.
Figure 3: Monthly Mean of Average PM2.5 across time in the Aburrá Valley

![Monthly Mean of Average PM2.5 across time in the Aburrá Valley](image)

Source: AMVA 2015

Figure 4: Monthly Mean of Average PM10 across time in the Aburrá Valley

![Monthly Mean PM10 across time in the Aburrá Valley](image)

Source: AMVA 2015

This demonstrates that unhealthy levels of pollution are persistent problem that likely places a major health burden on the city.

Cost Analysis

In Colombia, health costs (including only morbidity and mortality costs) from urban air pollution have grown considerably over the years. In 2002 these costs represented 0.78 percent of the nation's GDP whereas in 2010 they were equivalent of 1.12 percent of the GDP (Golub et al 2014) It was estimated that mortality represented 79 percent of the total cost.
It is safe to assume that this national aggregated data is, if not completely, reasonably illustrative of the situation Medellín as it only refers to urban air pollution, and Medellín is the second largest city in the country. On the basis of this assumption, it would mean considering that, assuming a GDP for Medellín of USD 17,069 million (Agency for International Cooperation of Medellín 2010), the total health costs due to urban pollution to the city would be around USD 200 million. However, as shown by the analysis below, the costs seem to be much higher for Medellín than this estimated cost.

**Mortality**

There is extensive research linking air quality, particularly the concentration of PM2.5, and instances of fatal diseases. While cardiopulmonary diseases and lung cancer can also be attributed to individual-level variables such as occupation and other habits like smoking, ambient air pollution remains a key factor.

In the AMVA region, cardiopulmonary and lung cancer constitute 36 percent of all deaths, according to World Bank estimates (Golub et al 2014). What remains contested is the exact number of these deaths that can be directly associated with air pollution. A number of studies have been carried out in pursuit of making such a determination, but fewer specific to Medellín’s circumstances. The World Bank’s Country Environmental Analysis revealed that in 2007 there were 6,040 deaths around the country on account of poor urban air quality, of which, 13 percent or 785 cases were from the AMVA region. A more recent report carried out by epidemiologist Elkin Martinez in 2012, which involved a time-series analysis of the causes of death listed on death certificates in Medellín and Colombia-wide, found that, annually, there are roughly 3,000 deaths in Medellín (or 20 percent of total annual mortality) that can be attributed to illnesses usually associated with poor air quality. A separate report released by AMVA pegged the rate at 9.2 percent of total annual mortality, or 1,380 pollution-related deaths based on an overall annual number of 15,000. Currently, researchers at the University of Antioquia in Medellín are conducting a similar study of its own on this subject.  

A second variable in question is the monetary Value of a Statistical Life (VSL). During various interviews conducted, it was found that some studies in the past were not accepted on the basis of the VSL used. However, despite disagreement over this issue, the costs associated with mortality prove to be significant for the region across each estimate. The World Bank and IMHE report estimates that the VSL for Colombia would be within the range of USD 0.4 million to USD 1.3 million. Based on a formula proposed by the U.S Department of Transportation (Rogoff and Thomson 2011) the VSL for Medellín was calculated to be USD 1.2 million. Table 3 below lays out estimates for the cost of mortality for each of the three values of VSL. The estimated number of annual deaths refers to the entire Aburrá Valley region that is under the jurisdiction of AMVA. All GDP estimates were carried out on the basis of Medellín’s GDP in 2010. Since Medellín remains the key economic contributor of the region, it was assumed that the GDP of the Aburrá Valley would essentially mirror the GDP of the municipality.

---

20 Juan Pineros. (professor at Universidad de Antioquia), in discussion with the authors. March 2017.

21 Enrique Henao & Carolina Agudelo. (Secretariat of Health, Sub-Secretariat of Environmental Health, Antioquia), in discussion with the authors. March 2017.

22 Calculated as US VSL * (Per capita GDP in Medellín / Per capita GDP in the US)

US VSL: 9.05 million (U.S Department of Transportation 2011)
Per capita GDP USA: 53,041USD (World Bank 2013)
Per capita GDP Medellín: 7,207 USD (ACI 2010)

23 While carrying out research it was noted that, for many studies and government documents, economic indicators for Medellín were being taken as a proxy for the entire metropolitan area.
It is evident from the tables above, that from the more recent data points (post-2010), even if the most conservative values for VSL and the number of deaths (attributed to air quality) are taken into account, the estimated cost of mortality alone (USD 552 million, or 3.2 percent of Medellín’s 2010 GDP)\(^ {24} \) is still more than double the national aggregate data estimate for total health costs (1.12 percent of national GDP). If costs related to morbidity were added, this number would increase even further.

### Willingness to Pay

A study was conducted by Carlos Gaviria and Daniel Martinez in 2014 (Gaviria and Martinez 2014) with the objective of analyzing citizens’ willingness to pay (WTP) for the reduction of air pollution with the understanding that it would in effect improve their health.\(^ {25} \) The authors found that younger people and people who have suffered an air quality-related illness are more aware about air pollution and have a higher preference for better air quality. The study showed that, on an average, individuals were willing to pay less than US $3 on reducing air pollution and for the group of individuals previously affected by air pollution were on an average willing to pay around US $6.

This finding suggests that people are by and large ignorant about the true costs they would incur if they were affected by air pollution. Looking at the sample the study was conducted on (primarily informal street vendors and individuals belonging to a lower economic strata) it would also be safe to say this that, for this group of people, earning a steady income and spending it on the most immediate needs –

\(^ {24} \) Since the GDP figure used to get these values was from 2010 and not 2015 or 2012 the percentage of GDP forgone due to mortality costs is presumably lower. However, the difference would be negligible and not significant enough to change results. Additionally, this analysis would hold considering the national aggregate data point it is being compared to is also from 2010.

\(^ {25} \) Since the SIATA data indicated that the concentrations of PM2.5 were relatively higher in downtown Medellín, the study was carried out around that area. In addition, this region also proved to be extremely appropriate for the study as it had a large number of pedestrian footfalls (approximately one million people walking by the area per day) as well as a significant number of informal street vendors (approximately 9,000).
such as food and housing would be of the highest priority. They are more worried about survival, and high air quality is comparatively considered a luxury good.

The gap between true costs and citizens’ willingness to pay shows that the economic market of air quality is far from efficient and is therefore in need of a regulatory intervention. Moreover, the fact that air pollution is more likely to affect the poor is a substantial reason for government authorities to take action and abide by their value of ‘social urbanism.’

**Loss of Urban Competitiveness**

The labor force across the world has become more global and more mobile. The livability of cities affects their competitiveness, as firms only establish corporate presence in cities where they find it easier to recruit skilled employees. Evidence shows that, across the globe, pollution is a key factor that hinders the ability of businesses and firms to attract talent. A survey by the American Chamber of Commerce in Hong Kong in 2012 found that one third of the employers were having difficulties recruiting overseas candidates because of air quality concerns (Pak 2013).

Various individuals during the site visit voiced an opinion of not wanting to stay in Medellín for a long period of time due to the air quality. While there is no monetary cost attached to the loss of competitiveness due to air pollution, it is believed that the loss in potential growth, revenues and economic development due to investments and businesses would be significant. There will also likely be lost economic activity if the pollution leads to a reduction in tourism.

**4. Proactive Scenario & Recommendations**

Our research yielded a common theme: across a number of different constituencies and sectors, individuals readily identified the same sources as the primary contributors to the problem. A number of different groups and individuals widely recognized that the major sources were the trucks, dump trucks, and motorcycles. The identification of these primary sources in many ways represented “low-hanging fruit” for public policy efforts, given the apparent solution of either simply enforcing existing laws or enhancing lax regulations. While the underlying air quality challenges will require long-term policy and societal changes, there are a number of steps the municipal and regional government can take to immediately address and reduce the direct impacts of particulate matter pollution.

There are a number of public health and economic impacts associated with increased particulate pollution, including increased mortality and disease rates as well as a loss of economic activity. Over time, these effects compound. As outlined and discussed, the current efforts to mitigate these negative effects constitute an ineffective approach that fails to address the underlying issues. Since the problem is relatively new, these emergency measures may be sufficient in the short-run. However, if the city and region hope to avoid allowing the problem to grow further, they must take more proactive measures. This includes two components: more aggressive initial interventions in the short term, as well as a long-term plan for reshaping how citizens get around the city.

The underlying logic for the proactive policy recommendations is to bridge the short- and long-term components. The policy recommendations are simple, yet assertive enough to immediately reduce pollution while also forming the basis for taking the initial steps toward longer-term plans. Based on the early draft of the anticipated update to the Plan de Descontaminación, which AMVA originally issued in 2009 to establish the steps it would take to address environmental degradation, we have outlined a number of policy recommendations constituting a more proactive approach for the government.
A version of the Plan viewed by the researchers for this report considered 22 measures. Having identified the transportation sector as the most significant contributor to Medellín’s air pollution problem, and in an effort to maximize the use of existing mechanisms, we have selected seven policy interventions that should be implemented based on effectiveness and feasibility from the collection of recommendations. Despite the costs associated with these intervention measures, they heavily outweigh the costs of inaction (or the costs resulting from staying on the current path) that result from exacerbated air pollution in the future, and help foster a more sustainable Medellín, one that can focus on density, diversity, and mobility.

The anticipated Plan de Descontaminacion is expected to be in place from 2017 until 2030. The time frame can be divided into current and short-term (2017-2018), medium-term (2018-2025), and long-term (2025-2030). The most impactful response in the short term is to standardize the emergency measures during the peak days of air pollution. Apart from emergency measures, our recommendations are based on three stages following the lifecycle of a vehicle, each with two intervention measures:

1. Pre-use: vehicle and technology selection before adaptation on the road;
2. In-use: operational and behavioral changes while the vehicles are on the road;
3. Post-use: retrofitting or retiring of existing and aged vehicles.

<table>
<thead>
<tr>
<th>Stage of Intervention</th>
<th>Policy Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. Emergency Measures</td>
<td>0. Institutionalize emergency measures</td>
</tr>
<tr>
<td>1. Pre-Use: Vehicle/Technology Selection</td>
<td>1a. Regulate motorcycles &amp; second-hand vehicles</td>
</tr>
<tr>
<td></td>
<td>1b. Improve fuel quality</td>
</tr>
<tr>
<td>2. In-Use: Operational/Behavioral Changes</td>
<td>2a. Promote driver behavior change</td>
</tr>
<tr>
<td></td>
<td>2b. Promote bicycle ridership</td>
</tr>
<tr>
<td>3. Post-Use: Retrofit Existing Vehicles and Take Old Vehicles Off the Road</td>
<td>3a. Place limits on heavy duty vehicles</td>
</tr>
<tr>
<td></td>
<td>3b. Implement vehicle retrofit financing program</td>
</tr>
</tbody>
</table>

26 Natalia A. Restrepo Velez & Francisco Alejandro Correa Gil (Representatives for AMVA), in discussion with the authors. March 2017. As of the release of this report on May 3, 2017, the anticipated Plan de Descontaminación has not yet been released.
Table 5: Overview

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Responsible Entities</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. Institutionalize emergency measures</td>
<td>Junta Metropolitana; SIATA</td>
<td>Transition the enactment of emergency measures, Pico y Placa, from discretionary to statutory. Currently, measures are decided by the consensus deliberation of the Junta Metropolitana. Firmly connecting air quality to tangible outcomes will help internalize pollution costs for individuals and organizations.</td>
</tr>
<tr>
<td>1a. Regulate motorcycles &amp; second-hand vehicles</td>
<td>City of Medellín; AMVA; Junta Metropolitana</td>
<td>Markets for motorcycles and second-hand vehicles are lightly regulated, but contribute to a significant portion of air pollution and undercut other policy measures. Establishing registration requirements will fill the void and allow authorities to more easily track and manage the fleet.</td>
</tr>
<tr>
<td>1b. Improve fuel quality</td>
<td>MADS, DNP, MME, Ecopetrol, AMVA</td>
<td>The City of Medellín and other municipalities belonging to the Metropolitan Area of the Valley of Aburrá should continue to press Ecopetrol for an agreement to improve fuel quality in the Valley to a sulfur content of 10ppm from current levels of 50ppm.</td>
</tr>
<tr>
<td>2a. Promote driver behavior change</td>
<td>AMVA; Medellín Secretary of Environment</td>
<td>The City of Medellín, through initiatives designed and implemented by the Secretary of Environment, should educate drivers on more efficient driving practices, as well as encourage carpooling.</td>
</tr>
<tr>
<td>2b. Promote bicycle ridership</td>
<td>AMVA (Secretary of Mobility)</td>
<td>The individual mayors of each of the 10 localities should allocate funds to implement the plans in the POT. Additionally, the mayors and local governments need to effectively coordinate with their respective Herencia de Movilidad Humana (Human Mobility Heritage) to ensure the effective completion of the projects.</td>
</tr>
<tr>
<td>3a. Place limits on heavy duty vehicles</td>
<td>Medellín Secretary of Mobility</td>
<td>The Mayor’s office should issue a decree that limits the hours that heavy duty vehicles can drive through the city during non-peak hours. The mayor must then seek support from Junta Metropolitana to encourage them to eventually adopt the same policy.</td>
</tr>
<tr>
<td>3b. Implement vehicle retrofit financing program</td>
<td>AMVA; Medellín; Private bus companies</td>
<td>City of Medellín should allocate fund to AMVA to implement a vehicle retrofit program (subsidies for catalytic converters) for private bus companies and owners that operate in Medellín</td>
</tr>
</tbody>
</table>

Each policy intervention is further described below. While exact costs of intervention are difficult to calculate, we have laid out relevant costs when possible. Otherwise, we list a number of considerations that factor into calculating possible costs for each policy intervention.

27 Regional authorities can impose stricter measures beyond national standards, but it would require the cooperation of Ecopetrol.
0. Institutionalize Emergency Measures

When air quality has reached dangerous (orange) to extremely unhealthy (red to purple) levels, as adopted from the US EPA, the ten municipal mayors have the discretion to enact certain emergency measures. These measures, viable once air quality progresses into levels past 50 ppm for PM2.5, are defined by standards set forth in 2010 Resolution 610 (AMVA & Universidad Pontificia Bolivariana 2010).

The primary emergency measure, known as Pico y Placa (Peak and Plate), limits the use of vehicles based on license plate numbers and has been an effective policy measure in immediately reducing particulate matter pollution by reducing the number of vehicles on the road and easing up traffic congestion. While Pico y Placa may be a politically unpopular and costly solution, from loss of business and other economic activities, we recommend that emergency measures be transitioned from the discretionary nature of the implementation of Pico y Placa to a standardized statutory regulation. AMVA should create a regulation that effectively ties emergency threshold air quality to the automatic implementation of Pico y Placa. Standardized implementation of these measures would begin to help internalize the cost of inaction.

The Sistema de Alerta Temprana de Medellín y el Valle de Aburrá (SIATA) monitors air conditions in real time and provides the data to the public and the junta of 10 municipal mayors. SIATA is a project founded by AMVA and the Mayor of Medellín in 2011. It is partly funded by the state-owned utility companies EPM and ISAGEN (SIATA 2017). According to a representative from Medellín’s Secretary of Environment, if two stations indicate a red alert for at least 48 hours, then it is declared, though the mayors must agree to implement any actual measures. Possible obligatory measures in the case of a red alert are indicated in AMVA’s “Operational Plan of Critical Episodes of Atmospheric Contamination” place restrictions on particular automobiles, motorcycles, and dump trucks; increase public transportation service; reinforce operatives on the road to control vehicular emissions; and prohibit fixed sources that emit more than 100mg/m3 of particulate matter.

Table 6: AMVA Air Quality Rating System

<table>
<thead>
<tr>
<th>Measures to reduce episodes of contamination</th>
<th>Actions to Protect the Population (AMVA 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>There are no anticipated impacts to health when the quality of air is at this level</td>
</tr>
<tr>
<td>Moderate</td>
<td>People especially sensitive should consider reducing their exposure. Everyone else can perform activities as normal.</td>
</tr>
<tr>
<td>Dangerous to sensitive groups</td>
<td>Sensitive groups should reduce prolonged exposure to the air. Pay attention to the appearance of symptoms such as difficulty breathing.</td>
</tr>
<tr>
<td>Dangerous to health</td>
<td>Sensitive groups should not have prolonged exposure to the air. Everyone should reduce the amount of physical exposure to the air.</td>
</tr>
<tr>
<td>Extremely dangerous to health</td>
<td>Sensitive groups should avoid any exposure to the air. They should move to indoor activities until the air improves. Everyone should avoid prolonged exposure to the air.</td>
</tr>
</tbody>
</table>
Table 7: Emergency Measure Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Emergency Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance (Who)</td>
<td>Junta Metropolitana, SIATA (SIATA provides real-time air quality data to the Junta Metropolitana who then deliberate and decide on enacting emergency measures based on earlier established protocols).</td>
</tr>
<tr>
<td>Mechanism (how)</td>
<td>Junta Metropolitana as a collective would develop and adhere to a new protocol whereby air quality thresholds would be tied to the automatic enactment of certain emergency measures depending on the severity. The network of academics and environmental think tanks managing SIATA would maintain threshold air quality and associated activity and threat levels in accordance with standards developed at the national and international level.</td>
</tr>
<tr>
<td>Level of Political Lift</td>
<td>Medium; Primarily focused on transport sector; must consider Industry emissions as well. The effect of stricter measures on businesses need to be better studied.</td>
</tr>
<tr>
<td>Cost</td>
<td>This measure was included in the proactive scenario strictly as a short term redressal to situations when particulate matter concentrations are extremely high (red and purple alert). While the costs to society are seemingly high in terms of loss of autonomy and other adjustment costs, the cost of not institutionalizing this measure in a stringent manner are estimated to be higher. This is because exposure to such high PM concentrations have detrimental health effects that may be chronic to fatal and that compound over time. We believe it is economically beneficial to incur short term logistical costs than recurrent health costs over a longer timeline. Moreover, it is predicted that as the measure becomes more institutionalized and accepted by the public, behavioral adjustments by individuals would significantly reduce productivity and adjustment costs.</td>
</tr>
<tr>
<td>Relative Impact</td>
<td>High (short term)</td>
</tr>
</tbody>
</table>

28 The government must also keep in mind that this policy measure if employed in isolation may have a negative effect. Without simultaneous efforts for inducing behavioral change, regulating motorcycles and second hand vehicles and promoting alternate modes of transportation, citizens may find it easier to buy more private vehicles to get around the Pico y Placa measure. It is for this reason that the recommended policy interventions outlined in the proactive scenario cannot be adopted singularly, but must be implemented as a bundle.
1a. Regulate Motorcycles and Second-Hand Vehicles

In Medellin, the number of vehicles on the road has grown dramatically in the last decade. The number of passenger vehicles grew by 3.1 percent between 2014 and 2015, or from 1,234,946 cars to 1,273,223 (Roldán 2017). This includes a 4.1 percent growth in the number of cars and a 2.1 percent growth in motorcycles. While motorcycle ownership and usage has been associated with socioeconomic mobility, and this intervention measure may be met with political pushback, curbing the long-term growth of the total number of second-hand cars and motorcycles will address the underlying challenge of vehicles emissions.

While standards exist for car vehicle registration, there are no registration requirements for motorcycles. This has made obtaining a motorcycle an easy workaround undercutting the effectiveness of Pico y Placa and other existing policy efforts. Older motorcycles tend to use two-stroke engines as opposed to a less-emitting (and more expensive) four-stroke engines (Faiz et al 1996). Aggressively implementing Euro 4 and higher standards and requiring four-stroke engines for all new motorcycles sold in Medellin would significantly improve emissions performance of in-use vehicles and infrastructure (Chambliss and Bandivadekar 2014). In addition, the market for the use of second-hand vehicles is lightly regulated. While there are significant capacity issues to regulation and enforcement, beginning to establish regulation around motorcycle and second-hand vehicle registration is an easy step toward mitigating a significant source of air pollution.

The cost of implementation is moderately high, especially in ensuring proper monitoring and enforcement, and factoring in socioeconomic costs. The ICCT estimates that for a 4-cylinder gasoline light duty vehicles with engine displacements of 1.5L, the incremental costs of meeting European standards from Euro 3 to Euro 4 to be $25 (Sanchez et al 2012). The cost increase from Euro 4 to Euro 5 is $10, and $0 from Euro 5 to 6. This is because the emission levels only mandated a 25 percent reduction in Nitrogen Oxide (NOx) for Euro 5 and no change for Euro 6.
### Table 8: Restrictions on Vehicle Selection Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Vehicle Selection Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>AMVA, Junta Metropolitana, City of Medellin</td>
</tr>
<tr>
<td>Mechanism</td>
<td>The Mayor’s office of the city of Medellin should require AMVA and work with the Junta Metropolitana to begin to establish registration requirements for second-hand vehicles and motorcycles.</td>
</tr>
</tbody>
</table>
| Level of Political Lift | Medium/High – expect huge pushback from the automobile sector  
Anticipate socioeconomic mobility tension |
| Cost                | The costs associated with regulating the sale of motorcycles and second hand vehicles are high due to loss of consumer surplus resulting in deadweight loss. Additional costs would include price of newer engines as well as cost of obsolescence of older vehicular parts. However if we factor in averted costs of actual market value of these vehicles, the averted health costs resulting in increased emissions and pollution as well as averted costs due to road accidents (on account of enhanced registration rules) we believe the benefits would far outweigh the costs.  
Of all the people the team interviewed while in Colombia, almost all the interviewees expressed their concerns about the lax rules governing the motorcycle market in Medellin. Research also showed that the rise in PM concentrations correlated with the similar rise in the number of motorcycles. For this reason, the team believes that having stringent registration rules would apart from being a highly impactful policy approach to improving air quality, would be positively received by the larger citizenry as a more visible proactive stance on the part of the government against air pollution especially in the medium and long term time frames.  
It is also anticipated that this policy intervention would have positive spillover effects in terms of behavioral changes with citizens increasing their propensity to use alternate and more environmentally sustainable modes of transportation |
| Relative Impact     | High (Short, Medium and Long-term) |

29 The team anticipates pushbacks in the short term from certain sections of the society
1b. Improve Fuel Quality

While improving fuel quality is an enormous political and economic lift, both on the national and municipal levels, it is the central next step toward a longer term solution in curbing vehicle emissions.

Fuel quality is primarily regulated on the national level. The Fuel Quality Law (Law 1205) passed in 2008 introducing new standards for low-sulfur levels (max 50ppm) in fuel over 5 years. Beginning January 1, 2013, Ecopetrol committed to only distributing diesel fuel throughout Colombia below 50 ppm of sulfur. Indeed, over about 10 years the federal fuel standard was reduced about 96 percent from 1,200ppm. The Law followed a voluntary pact with Ecopetrol to install a new refinery process.

Municipal governments can impose stricter measures beyond national standards. As such, the regional government (Mayor and AMVA) can seek a voluntary arrangement with Ecopetrol and, in fact, such an agreement was important to bringing the quality of fuel delivered to the Aburrá Valley to current levels.

Oil refining capacity, including at the two main petroleum refineries, Barrancabermeja and Cartagena, is managed by Ecopetrol. Though Colombia is a net oil exporter, as recent as 2015, refined petroleum from the United States remained Colombia’s number one import (World Integrated Trade Solution 2017).

The Junta of the municipality’s mayors are currently working with AMVA to reach an agreement with Ecopetrol to allow a review of current fuel quality. This review will provide a baseline and help to determine next steps, like integrating higher-quality fuel. We recommend that AMVA, in particular the Secretary of Mobility, conduct a study that surveys the fuel quality in the city.
Table 9: Fuel Quality Improvement Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Improve Fuel Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>National ministries (MADS, MVCT, DNP) ratify new standards in cooperation with regional authorities (AMVA) and the fuel supplier, Ecopetrol. AMVA and the Mayor of Medellín may also reach an agreement directly with Ecopetrol.</td>
</tr>
<tr>
<td>Mechanism</td>
<td>Following feasibility and cost analysis, the government reaches an agreement with Ecopetrol whereby the company retrofits its refineries in order to reduce the sulfur content of the fuel. Regional authorities may come to specific agreements with Ecopetrol according to their own specific needs and timelines in order to deliver fuel of a higher quality than required by national standards. In this case, AMVA and the Mayor of Medellín should initiate a review of current fuel quality in Aburrá Valley and continue its efforts to pressure Ecopetrol for higher quality fuel.</td>
</tr>
<tr>
<td>Level of Political Lift</td>
<td>High; Upgrading the fuel quality standards will allow new catalytic converters to be installed on vehicles that use the fuel, which leads to significant reductions in vehicle emissions.</td>
</tr>
<tr>
<td>Cost</td>
<td>Costs of retrofitting refineries as well as costs of catalytic converters to be installed in vehicles are high. Costs related to negotiations and tradeoffs could also be included in this. However, this policy would result in considerable benefits accruing out of significant improvements in air quality. When a longer term perspective is adopted, the team believes this policy measure would result in benefits outweighing costs. The team believes in order to make the initial costs more feasible, the government could possibly carry out the retrofitting in phases</td>
</tr>
<tr>
<td>Relative Impact</td>
<td>High (Medium to long term)</td>
</tr>
</tbody>
</table>
2a. Promote Driver Behavior Change

This recommendation seeks to leverage the already existing transportation system in Medellín and encourage consumers to switch their modes of transportation. Attempting to shift cultural behavior will be a gradual effort, but the benefits from education in promoting environmental practices in basic diesel mechanics, good driving practices, preventive maintenance, traffic regulations, to promoting environmental legislation will be manifold. What citizens refer to as “Cultura Metro,” or Metro Culture, is a tremendous source of pride for the residents of Medellín. For many, the system’s functionality, architecture, and cleanliness represent hope and change for a city looking to be among the most technologically advanced Latin American cities. Metro, including affiliated Metroplus and cable cars, is operated by the city in about equal collaboration with the state of Antioquia.

The municipal and regional governments should institute and promote programs that encourage the use of alternative modes of public transportation and increased efficiency of vehicle use – carpooling and better driving habits. Drivers should be provided education and driver training to promote best practices in fleet management and more environmentally friendly measures to optimize fuel efficiency; for example, slower acceleration and deceleration, anticipation of the traffic flow, and maintaining of adequate tire pressure.

Currently, Secretariát de Medio Ambiente oversees the public education process regarding air quality, but specifically targeted toward school children (who are not yet drivers). This education process must be broadened to include any existing, new, and future vehicle operators and managers. With increased funding and private partnership, they can expand the education program to drivers of all ages.

Table 10: Change Consumer and Rider Behavior Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Promote to change consumer and rider behavior through driver education and raising awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>AMVA, Secretaría del Medio Ambiente de Medellín</td>
</tr>
<tr>
<td>Mechanism</td>
<td>The Secretaría del Medio Ambiente de Medellín should expand on its existing education efforts to add vehicle operator and manager education programs prior to and upon vehicle purchase. They should expand their social media efforts to promote Cultura Metro.</td>
</tr>
<tr>
<td>Level of Political Lift</td>
<td>Medium; Changing citizens’ behavior is a long-term project that requires sustained efforts from responsible entities.</td>
</tr>
<tr>
<td>Cost</td>
<td>Costs related to activities directed at changing consumer behavior are low. These involve advertising, social events, curriculum changes, etc. These efforts need to be consistent and recurring throughout the short to medium term and would also include opportunity cost of time and money. However, such initiatives are imperative as they represent a bottom-up approach that would in effect reduce costs of top down policy interventions in the long term.</td>
</tr>
<tr>
<td>Relative Impact</td>
<td>Medium</td>
</tr>
</tbody>
</table>
2b. Promote Bicycle Ridership

The Medellín Department of Planning incorporates measures of mobility in its masterplan (POT) and is currently responsible for city infrastructure. They have already called to increase bicycle infrastructure coverage from 31kms to 80kms. They should continue to promote bicycle infrastructure: construct protected bicycle lanes, make appropriate traffic signals and rules, install clear and consistent signage, etc.

Table 11: Promote Bicycle Ridership Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Promote Bicycle Ridership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>The Medellín Department of Planning incorporates broad level infrastructure changes in its masterplan. The city planning department then decides on the specifications of the project i.e. the location, length, etc. of the bicycle lanes and the Herencia de Movilidad Humana (Human Mobility Heritage) for each of the ten localities is in charge of the implementation.</td>
</tr>
<tr>
<td>Mechanism</td>
<td>Through the Department of Planning, each locality needs to allocate funds for increasing bicycle infrastructure and ensure the timely implementation of the projects.</td>
</tr>
<tr>
<td>Level of Political Lift</td>
<td>Low-Medium; Assuming that the POT goals and objectives were created on the availability of funds and feasibility, funding for the medium term should be available, if not for the short term</td>
</tr>
<tr>
<td>Cost</td>
<td>The costs related to promoting bicycle ridership would mainly be limited to infrastructure costs and cost of real estate or land. These would include, setting up of bike lanes and parking spaces, expanding the bike sharing system, updating signals and signage and cost of operations. While the benefits would not significantly improve the pollution levels, this intervention would be highly beneficial in terms of providing a cost-effective alternative to private fuel consuming vehicles. It is important to have bicycles as an alternative option of transport within the proactive scenario bundle to ensure easier adjustment and to generate awareness.</td>
</tr>
<tr>
<td>Relative Impact</td>
<td>Medium</td>
</tr>
</tbody>
</table>

---

30 El Plan de Movilidad Segura de Medellín 2014-2020. The Secure Mobility Plan aims to achieve the following: “1. Management and inter-institutional coordination strengthening. 2. Safety behaviors, habits and conducts, for road users. 3. Control and supervision of vehicles and safety equipment, for road users. 4. Planning, building and upkeep of road safety infrastructure, for road users. 5. Timely and professional attention to injured parties during and after transit incidents.” (Secretaría de Movilidad de Medellín – Alcaldía de Medellín 2014)
3a. Place Limits on Heavy Duty Vehicles

Heavy duty vehicles (HDVs), which includes trucks and buses, are the largest PM2.5 contributors in the Aburrá Valley. In order to improve air quality standards in the region, there must be measures that address this category of vehicles. The challenge, however, is twofold: 1) the majority of the truck fleet is outdated and would require significant capital to replace, and 2) many of the trucks are not locally registered and are passing through the valley to reach the coast or center of the country.

Given the high costs of retiring vehicles and the inability for either the local or provincial governments of creating restrictions for vehicles registered in other jurisdictions, we have identified that a feasible and impactful solution would be to reduce emissions from heavy duty vehicles would be to set limits as to when trucks could enter the city. The city, under the direction of the Secretary of Mobility, for instance, should set regulations preventing trucks from entering or driving within the city limits during commuting hours, typically 7-9am and 5-7pm.

Table 12: Heavy Duty Vehicles (HDV) Restrictions Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Heavy Duty Vehicle Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>Efficiency and rerouting would involve the Secretary of Mobility on route design and for enforcement of efficiency standards</td>
</tr>
<tr>
<td>Mechanism</td>
<td>Mayor’s office should issue a decree that limits the hours that heavy duty vehicles can only drive through the city during non-peak hours seek support from Junta Metropolitana that they would eventually adopt the same policy.</td>
</tr>
<tr>
<td>Level of Political Impact</td>
<td>Medium-High; Medium-High; Trucks represent a significant labor interest and have demonstrated strong resistance to air quality related regulation. There are, however, similar regulations in place during red alert days, and this would be a natural extension of an existing policy.</td>
</tr>
<tr>
<td>Cost</td>
<td>The cost related to regulating Heavy Duty Vehicles would involve economic opportunity costs and efficiency costs. However, these costs are predicted to ease out over time due to change in operation methods and associated adjustments. The team believes that having these time restrictions on HDV and trucks would reduce pollution levels during peak hours due to decrease in emissions from trucks as well as decrease in emissions from reduction in peak hour congestion.</td>
</tr>
<tr>
<td>Relative Impact</td>
<td>High</td>
</tr>
</tbody>
</table>


3b. Implement Vehicle Retrofit Financing Program

One way to disrupt the lifecycle of same, old vehicles remaining in use is to ensure that old and dirtier vehicles – especially buses – are taken off the road or upgraded to meet more stringent emissions standards.

As such, we recommend that the City of Medellín and its Mayor appropriate fund to AMVA in the form of subsidies for catalytic converters for buses, one of the other major polluters in the City. The fund program would incentivize private bus companies or owners to retrofit their buses to become more energy efficient. In order to maximize its impact, however, there should be collective transit action taken throughout the AMVA jurisdiction, beyond the City of Medellín.

Retrofitting requires heavy political lift in terms of enforcement. Requiring full participation from the private sector will take unpopular and heavy-handed measures. Once the policies are in place, however, the political lift is expected to decrease.

Table 13: Vehicle Retrofit Financing Program Overview

<table>
<thead>
<tr>
<th>Policy Intervention</th>
<th>Vehicle Retrofit Financing Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>City of Medellin, AMVA, Private bus companies that operate in Medellín&lt;sup&gt;31&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mechanism</td>
<td>The City should allocate fund to AMVA to employ a retrofit financing program, especially in form of subsidies to install catalytic converter for buses</td>
</tr>
<tr>
<td>Level of Political Impact</td>
<td>High; Initial buy-in from relevant parties will take heavy political lift. The retrofit program should be robust and attractive enough get participation from private bus companies. (Kassel &amp; Bailey 2005)</td>
</tr>
<tr>
<td>Cost</td>
<td>The cost of retrofitting vehicles is significant, considering the number of vehicles currently with older engines. However, while the economic cost of subsidizing the catalytic converters would be high, the benefits arising from reduction in pollution levels would be significant and immediate.</td>
</tr>
<tr>
<td>Relative Impact</td>
<td>High</td>
</tr>
</tbody>
</table>

Even though buses need to be upgraded to at least Euro 4, current actions require that each bus company only submit a plan. (Oviedo, Jorge Toro and Giraldo, Sergio Posada. (consultants for Transporte Publico de Medellin), in discussion with the authors. March 2017)
5. Conclusion

Table 14: Policy Path Alternatives: Medellín Air Quality

<table>
<thead>
<tr>
<th>Current Path</th>
<th>Proactive Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>The governing entities responsible for city of Medellín and the Aburrá Valley have programs in place that provide a reactive response to spikes in particulate air pollution. There are also plans to implement programs that address the more fundamental issues undermining air quality. However, when compared to the anticipated level of future air pollution, this combination of current and planned policies constitutes a comparative trajectory that will fail to make even modest improvements in the long-term. The following is a non-exhaustive list of the current and planned policies.</td>
<td>In order to address the fundamental issues core to the air quality problem, there a number of feasible policy steps that will alter the comparative trajectory and enable long-term reductions in particulate air pollution. While there are a number of costs associated with each, these set of recommendations will serve as the policy foundation that will provide future benefits that outweigh the immediate costs.</td>
</tr>
<tr>
<td><strong>Current:</strong></td>
<td><strong>Planned:</strong></td>
</tr>
<tr>
<td>● Pico y Placa</td>
<td>● Plan de Descontaminación</td>
</tr>
<tr>
<td>● Bus Rapid Transit (BRT)</td>
<td>● Public health-air quality impact study</td>
</tr>
<tr>
<td>● Fuel Standards</td>
<td>● Transporte Publico De Medellín(TPM)</td>
</tr>
<tr>
<td>● Day without cars</td>
<td>● Electric vehicle promotion</td>
</tr>
<tr>
<td><strong>Proactive Policies:</strong></td>
<td><strong>Benefits:</strong></td>
</tr>
<tr>
<td>● Institutionalize emergency measures</td>
<td>● Reduced mortality rate</td>
</tr>
<tr>
<td>● Improve fuel quality</td>
<td>● Reduced morbidity (air-related disease) rate</td>
</tr>
<tr>
<td>● Regulate motorcycles and second-hand vehicles</td>
<td>● Decrease in public health costs</td>
</tr>
<tr>
<td>● Promote bicycle ridership and changes in commuting behavior</td>
<td>● Increase in economic per capita productivity</td>
</tr>
<tr>
<td>● Limit heavy duty vehicles</td>
<td>● Increase in city-wide relative long-term GDP</td>
</tr>
<tr>
<td><strong>Costs:</strong></td>
<td>● Increase in urban competitiveness</td>
</tr>
<tr>
<td>● Mortality - reference ranges annual deaths:</td>
<td></td>
</tr>
<tr>
<td>○ World Bank CEA: 785 deaths per year</td>
<td></td>
</tr>
<tr>
<td>○ AMVA: 1,380 deaths per year</td>
<td></td>
</tr>
<tr>
<td>○ Academic: 3,000 deaths per year</td>
<td></td>
</tr>
<tr>
<td>● Loss of urban competitiveness - GDP loss</td>
<td></td>
</tr>
<tr>
<td>○ World Bank CEA: -1.8 percent to -6.0 percent</td>
<td></td>
</tr>
<tr>
<td>○ AMVA: -3.2 percent to -10.5 percent</td>
<td></td>
</tr>
<tr>
<td>○ Academic: -7.0 percent to -22.8 percent</td>
<td></td>
</tr>
</tbody>
</table>

Given the timeline, AMVA and the City of Medellín should prioritize intervention measures targeted at the transportation sector based on their feasibility and effectiveness. The cost analysis indicates that taking stringent steps now to reduce harmful emissions, especially from the transportation sector, will be more cost-effective in combatting air quality crisis. The team also recommends that Medellín collect and make publicly available reliable health, socioeconomic, and emissions data. This will enable a more accurate cost analysis.
This research project was the first partnership between La Ciudad Verde and the SIPA Capstone program. Despite a compact timeframe and a brief window to conduct on-the-ground research in Medellín, the project accomplished a number of objectives set forth at the onset. The project established a foundation from which future research and additional policy insights can be developed. From a research perspective, the project sought to articulate the policy landscape underlying the air quality challenges at a number of levels from the micro to macro perspective and from the differing levels of governance from the city of Medellín to the overarching federal bureaucracy. The storied history of the city, the complex weave of government organizations involved in environmental regulation, and the ambiguous data and research surrounding pivotal points regarding air quality and public health required an in-depth and nuanced analysis. While the diagnosis outlined in this report is not exhaustive, it does provide a comprehensive base from which further policy insights can be drawn.

In addition to the policy landscape, the report verified the scope of the problem identifying the major sources of particulate air pollution within the transportation industry. While existing research suggested the prominent role certain sectors, actors, and particular modes of transport have played in perpetuating the crisis, the report helped to verify the provenance. Given the diffuse nature of the sources contributing to the air quality problem and the lack of consensus within the policy realm, the argument for focusing primarily on the transportation sector is one that this report aimed to clarify and reinforce. The report diagnosis correlating certain types of vehicular activity to outsized contributions in particulate pollution lends additional confidence for policymakers and analysts to develop targeted measures.

Resolving the air quality crisis is a daunting challenge. However, as the city has shown, it has a penchant for developing innovative solutions to problems, a governance structure that, for all of its ills, has managed to position Medellín as an economic and social leader in the region, and a populace that is deeply vested in its future well-being. The last point is perhaps the most important. The public policy choices necessary to combat the air quality problem will be deeply unpopular and will inflict short-term economic costs. Only an engaged and well-informed electorate that understands the long-term ramifications of the issue will be able to hold public officials accountable for the choices that will determine the future.

**Potential Next Steps**

The report helped to establish a foundation for future research and a number of potential next steps exist to clarify or answer the gaps to more effectively support the case for proactive government engagement.

There are a number of lingering research questions involving health and economic impacts. A number of follow-on research gaps pertain to the impact on public health from reduced air quality. This includes the analysis of health data including mortality, morbidity, and hospitalizations in the context of the fluctuations in air pollution. From an economic standpoint, the current pollution mitigation measures, most notably Pico y Placa, warrant a level of analysis to determine effectiveness of the lack thereof.

For the policies outlined in the report, a continued partnership between La Ciudad Verde and the SIPA Capstone program could provide significant policy value by investigating in-depth the specific cost and benefits to implementation. This includes evaluating emissions data from the number of different sectors and sources and analyzing the effect current policies have on consumer behavior.
Bibliography


Cantillo, Victor, and Juan de Dios Ortúzar. “Restricting the Use of Cars by License Plate Numbers: A Misguided Urban Transport Policy.” *DYNA* 81, no. 188 (November 1, 2014): 75–82.


Gaviria, Carlos, and Daniel Martínez. “Air Pollution and the Willingness to Pay of Exposed Individuals in Downtown Medellín, Colombia.” Lecturas de Economía, no. 80 (June 2014): 153–82.


Appendix

Sources of Air Pollution

Data from the charts below comes from the 2013 AMVA report, “Inventario de Emisiones Atmosféricas Del Valle de Aburrá.”

Transportation vs. Industry

The transport sector accounts for nearly 80 percent of PM2.5 pollution in the Aburrá Valley. This includes pollution from passenger vehicles, motorcycles, trucks, and buses.

Figure 5: Source of PM2.5 pollution, comparing transport sector and industry

The transport sector accounts for 97.8 percent of carbon dioxide emissions in the Aburrá Valley.

Figure 6: Source of CO2 pollution, comparing transport sector and industry
The transport sector accounts for 82.6 percent of NOx pollution in the Aburrá Valley.

Figure 7: Source of NOx pollution, comparing transport sector and industry

![Diagram showing NOx pollution sources]

Unlike other forms of pollution, industrial activity accounts for 91 percent of SOx pollution in the Aburrá Valley.

Figure 8: Source of SOx pollution, comparing transport sector and industry

![Diagram showing SOx pollution sources]

The textile industry is the main source of CO2, NOx, and SOx pollution coming from industries in the Aburrá Valley.

**Transportation**

Trucks are the primary source of particulate matter pollution in the Aburrá Valley. These vehicles account for 52.7 percent of PM2.5 coming from the transport sector. 4-stroke motorcycles come second with 22 percent of PM2.5 emissions. All motorcycles, both 2 and 4 strokes, account for 26.7 percent of emissions.
Similarly, with PM2.5, trucks are the primary source of carbon dioxide emissions in the Aburrá Valley. These vehicles account for 40 percent of carbon dioxide emissions coming from the transport sector; passenger vehicles come second with 31.9 percent.

Again, trucks are the primary source of nitric oxide emissions in the Aburrá Valley. These vehicles account for 43.4 percent of nitric oxide emissions coming from the transport sector; buses come second with 25.6 percent.
Textile companies are the primary source of carbon dioxide, nitric oxide, and sulfur oxide pollution coming from industry. Second, by nearly half is ceramic and glass manufacturing; and third is the beverage sector.
Methodology

The team investigated the sources and costs related to Medellín’s air pollution by interviewing experts, politicians, and stakeholders in Medellín in March 2017. Prominent officials interviewed included Medellín’s Secretary of Health and Secretary of Environment, sub-secretaries from Área Metropolitana del Valle de Aburrá (AMVA) – the regional environmental authority, and professors from Universidad de Antioquia and Universidad Nacional, among others. These interviews provided insight into the source of the air pollution, political and governance structure of the city, popular opinion, educational efforts, and research that has been or is in the process of being conducted.

List of Interviews:

1. Public Sector
   a. Representatives for AMVA – Natalia A. Restrepo Velez & Francisco Alejandro Correa Gil
   b. Secretariat of the Environment, Medellín, Office of Oscar Hoyos Giraldo – Veronica Cotes & Paola Zapata
   c. Secretariat of Health, Sub-Secretariat of Environmental Health, Antioquia – Enrique Henao & Carolina Agudelo
   d. Medellín City Councilman – Daniel Carvalho

2. Private Sector
   a. Former consultants, Transporte Publico de Medellín (TPM) – Sergio Giraldo Posada & Jorge Toro

3. Academia
   a. Universidad de Antioquia – Elkin Martine
   b. Universidad de Antioquia – Juan Gabriel Pineros Jimenez
   c. Universidad de Medellín – Carlos Echevarria
   d. Universidad de Nacional – Sergio Orrego
   e. Universidad de Nacional (Bogotá) – Luis Belalcazar
   f. Universidad EAFIT – Ana Maria Suarez
   g. Columbia University, Sidewalk Labs – Rohit Aggarwala
   h. Columbia University – Wolfram Schlenker
   i. Columbia University – Sara Tjossem

4. NGO/External/Other
   a. Low Carbon City – Juliana Gutierrez
   b. U.S. Embassy Bogotá – Nate Rettenmayer & Jenniffer Solorzano
   c. Diego Zapata (Activist)
   d. Sebastian Osorio (SIPA Student/Medellín Resident)
Maps

Figure 13: Medellín within Colombia

Figure 14: An Illustration of Seasonality on Air Pollution in the Aburrá Valley. (AMVA 2015)
Figure 15: AMVA Jurisdiction (AMVA 2015)

Figure 16: Ten Municipalities within AMVA