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Policy instruments surrounding urban air quality: The cases of São Paulo, New York City and Paris

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ABSTRACT

Fifteen years of major policies and programs on air pollution control in New York City, São Paulo and Paris were reported in order to draw attention to each city's management tendencies. The study highlighted the strategies implemented, showing that overall levels of atmospheric pollution have decreased in the three cities, but they continue to be above WHO recommendations. While regulatory approaches are commonly embraced to lower air pollution levels, the three cities differ in the way and extent to which they have prioritized control technologies, mobility, public transport accessibility and energy matrix. Despite all sharing the technological capacity to develop cleaner fuels and foster non-motorized transport modes, disparities in transportation options, infrastructure and commuting distance appear to have an impact on the use of privately owned vehicles and pollution levels. This is partly due to the lack of public transportation and to local political choices. The three examples show how regulatory approaches alone are not enough to ameliorate air quality and suggest that each city should incorporate programs that account for people's travel choices. For policymakers, prioritizing air quality offers the potential to have a positive short-term impact on health and on the local environment, particularly in low and middle-income countries.

1. Introduction

While sources and contributions to air pollution vary across the world, in urban centers, they mainly originate from commercial and residential emissions, fixed (industries) and mobile sources (heavy and light duty vehicle emissions) (Hitchcock et al., 2014). From 2008 to 2015, in more than 80% of urban areas, people were exposed to contaminant levels of particulate matter above the WHO[1] recommendations (WHO, 2016). Indeed, air pollution continues to be one of the greatest threats to global health, accounting for 7 million premature deaths worldwide in 2012, of which 3.7 million were attributed to outdoor air pollution (WHO, 2014). The OECD has reported that the health cost associated with air pollution amounts to 1.6 trillion dollars per year, of which 50% is attributed to road transports (OECD, 2014), one of the primary sources of urban air pollution.

Cities concentrate 55% of the world's population and the number of mega-cities (population > 10 million) has jumped from 10 in 1990 to 28 in 2014 (UN, 2014). Given their significance, the role of urban centers in global environmental health degradation and the continuous increase of motorized transports of cars and heavy-duty vehicles in cities has called for action to control health impacts (World Bank, 2014). The negative health effects from exposure to urban traffic-related air pollutants have been demonstrated in extensive research (Colvile et al., 2001; World Bank, 2014; MacDonald-Gibson and Frey Sexton, 2013; Progiou and Ziomas, 2012) and alarming air pollution peaks in cities located in growing economies has raised global and local concern. Scholars have identified that long-term exposure to air pollution can be associated with negative health and birth outcomes, particularly in early-life exposure (Alderete et al., 2017; Brauer et al., 2008; Currie et al., 2014). Cohort studies have associated long-term exposure to traffic-related air pollution with increased mortality, circulatory and respiratory diseases, breast cancer and atherosclerosis (Escamilla-Nunez et al., 2008; Jerrett et al., 2009; Kaufman et al., 2016; Kim et al., 2017). In Ontario, Canada, a study supported the hypothesis that long-term exposure to traffic-related air pollution increases the incidence of mortality from cardiovascular diseases (Chen, 2011).

There is still a critical gap to qualitatively and comparatively assess what kind of initiatives and approaches have been undertaken in cities and the role played by policies to mitigate air pollution. This research examines three major cities to appraise some of the most important policies and approaches developed. The article highlights the initiatives that have most contributed to ameliorating air pollution levels, and

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[1] World Health Organization

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those that could be duplicated in other cities, struggling to maintain clean air. It brings a global and local contextualization framework in which these policies have been created, emphasizing the need to incorporate these different dimensions concerning their impacts on air quality.

This research was designed as an in-depth, multiple-case study of the period from 2000 to 2015 of the three cities São Paulo, Brazil, New York, USA and Paris, France. These locations were chosen because:

1) They share a common challenge, in that vehicular emissions are a major source of air pollution. Since 2000, these three cities reduced overall concentrations, although they still face levels above WHO air-quality guidelines (for particulate matter and ozone), and struggle with the global trend of vehicular density and emission growth.
2) Each city has been innovative in developing public policies, strategies and programs that make them unique and potentially replicable cases.

Observing policy choices surrounding air pollution control is essential to identifying best practices that could lead the way to growing cities lacking policy instruments to cope with alarming levels of air pollution and increasing motorized transport.

2. Profile of studied cities

São Paulo, the capital of São Paulo State, Brazil has a population density of 7858 people/km^2. It is the 11th most populated city in the world, with 11.9 million inhabitants (IBGE, 2013) in 1521 km^2. Greater São Paulo has approximately 20 million people, being the third largest metropolis in the world, after Mexico City and Mumbai. It holds the nation's greatest job center and economic hub. The automobile industry in Brazil accounts for 65% of the GDP and is the eighth largest worldwide (MDIC, 2014).

Like São Paulo, New York City is the largest city of its state and, combined with Newark, makes the world's ninth largest metropolis (UN, 2014). Its five boroughs – Manhattan, Bronx, Queens, Brooklyn and Staten Island – have a population of 8.5 million inhabitants in 789 km^2, with a density of 10,800 people/km^2. Although food, education, professional and technical services employ the greatest number of people, it is actually securities, commodities contracts and investment jobs that register the highest average annual income in New York City ($405,000) (NYC Dept. of Labor, 2015).

Paris, the oldest of the three cities, is the smallest, with 105.4 km^2, and the highest population density, 21,289 people/km^2. The capital of France, Paris, is located in the Île de France region. The center city of Paris, or "Paris intra-muros," had a population of 2.3 million in 2014, similar to 1999 (French census), when it totaled 2.1 million. Over the last fifteen years, Paris' demographic profile has remained unchanged, with the largest share of its population over 65 years old. In Paris, transport, services and commerce represent 68% of jobs (INSEE, 2013) (Fig. 1).

3. Frameworks surrounding air quality

3.1. Historical legal context

The first and most important regulatory action passed was the Clean Air Act (1963) in the United States, followed by Europe, which established standards for vehicle exhaust emissions in 1970. With evidence that air pollution crossed borders, the international community adopted, in 1979 the Convention on Long-Range Transboundary Air Pollution (LRTAP), hosted by the UNECE.[2] The LRTAP formalized the fact that sources of air pollution might be distant from where the pollution ends up, which forced both global and local communities to address the issue. The Convention was signed by 51 member-countries and became the genesis of most protocols that guide local regulations and policies.

In the 1980s and 1990s, UN Protocols helped set global awareness to reduce emissions of pollutants, such as the 1985 Helsinki Protocol on the reduction of sulfur and VOCs,[3]; the 1987 Montreal Protocol on substances that deplete the ozone layer; the 1988 Sofia Protocol on nitrogen oxide emissions control or their transboundary fluxes and the Gothenburg Protocol in 1998 on acidification, eutrophication and ground-level ozone (UNEP, 1987; UNECE, 1988, 2014). It was only in 1997 that the Kyoto Protocol established the UN framework on climate change (UN/FCCC, 1997), currently outdated by the Paris Climate Agreements to regulate greenhouse gases (UN/FCCC, 2015).

In Europe, the revision and development of emission standards came in the early 1990′s, implementing standards for heavy and light-duty vehicles (Fig. 2). In 1996, the European Commission adopted the 96/62/EC Directive on Ambient Air Quality (EUR_LEX, 1996), followed by what is known as the "four daughters' directive&#8221[4]; establishing limits for some of the most harmful air pollutants.

The above directives, in turn, guided French regulations and led to the 1996 Federal Law on Rational Use of Air and Energy (LAURE), followed by the 1998 Federal Law on conditions for air pollution alert procedure (Legifrance, 1997). LAURE established the conditions of air quality surveillance and information that created local monitoring agencies, such as Airparif for the Île de France region and Paris. LAURE fostered several additional French plans on air quality and mobility.

Another major European guideline is the 2001 EU Directive on National Emissions Ceilings, and the EU Directive on Air Quality Standards, that generated the Clean Air for Europe Program in 2008 (EUR_LEX, 2008). The 2008 directive followed the WHO air quality guideline reviews of 2005. Two major sets of United Nations global goals are worth citing: the 2000 UN Millennium Development Goals and the 2030 Sustainable Development Goals, as they bring to countries' agendas the need to address poverty and environmental quality, such as clean air (UN, 2000, 2015)

French regulations are bound to European legislation. The different EURO standards applied to vehicle emissions, from the 2004 and 2008 directives, have a direct impact on the French regulations that use the EURO VI standards since 2014. Other important French laws are Grenelle I and II, addressing the federal environmental engagement of 2009 and 2010. New vehicles in Paris follow the EURO 6 Norm. In 2012, 52% of the fleet was equipped with the EURO 4 Norm (Airparif, 2013). The Grenelle laws originate several federal and regional plans on environmental health, climate and energy.

In France, the alert for air pollution episodes was reviewed and adopted in 2014, motivated by Paris' recent critical air pollution peaks. The 2015 Energy Transition Law enabled France to focus on cleaner sources of energy for vehicles and new programs, such as circulation restriction of Heavy-Duty Vehicles (2015), air quality certificate for vehicles (2015) and the revision of the PPA.,[5] Similarly to United States and Brazil, France established transport laws such as the 1982 Domestic Transport Act, legalizing the right to low-cost public transport and encouraging urban transport plans.

The United States was the first of the three countries to regulate air with the 1963 Clean Air Act and 1970 National Ambient Air Quality Standards. The 1977 and 1990 amendments to the Clean Air Act provided two measures for air quality: the New Source Review, for industries, and the banning of leaded gasoline for motor vehicles (EPA, 1977). Importantly, the state of California has been a pioneer in

[2] United Nations Economic Commission for Europe

[3] Volatile Organic Compounds

[4] European commission legislation

[5] Plan de Protection de l'Atmosphère, French for Air Protection Plan

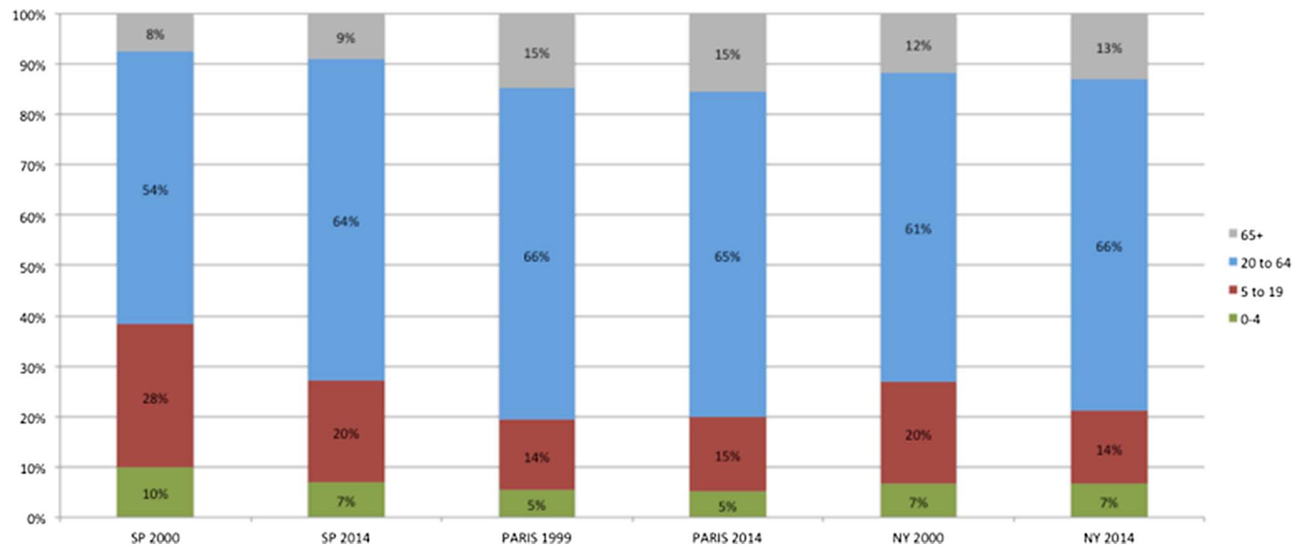

Fig. 1. Population profile of São Paulo, New York City and Paris: 2000–2014.
Elaborated by AD Slovic
*1999 was the year considered for Paris
Sources: INSEE (Paris), Census Track (NYC), IBGE (São Paulo)

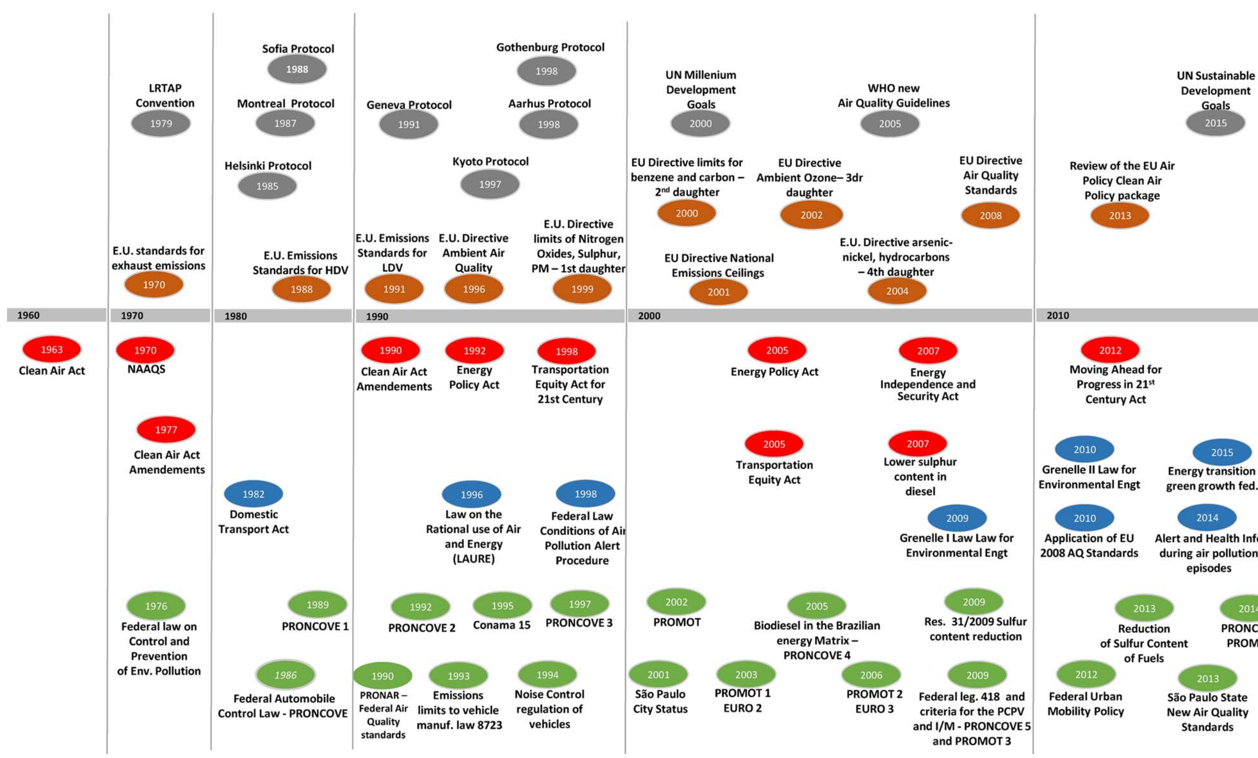

Fig. 2. Legal air quality framework: Brazil, United States and France – 1960/2015.
Elaborated by the AD Slovic and SL Oliver
Sources: EU Commission, EPA, Brazilian MMA, WHO, UNECE, French Environmental Ministry, Legifrance

developing policies related to vehicular emission. Starting in the 1980′s, the State passed acts such as the Toxic Air Contaminant and Control Act (1984) and the Air Toxics Hot Spots Information and Assessment Act (1987), identifying and controlling exposure of toxins for operators at risk associated facilities (CA.gov, 2016). In 1993, California adopted 187 “hazardous air pollutants” that were cited in the 1990 Clean Air Act, establishing its role as a leader for the rest of the states to follow in its path (Propper et al., 2015). The country, then, concentrated its regulatory efforts on energy and emission improvements from vehicle exhausts via the 2005 Energy Policy Act for diesel emission reductions (U.S. Congress, 2005), the Energy Independence and Security Act and the Moving Ahead for Progress in the 21st Century Act (U.S. Congress, 2007, 2012). It was only in 1998 and 2005 that the Transportation Equity Acts for the 21st Century addressed transport infrastructure as a tool for improving the environment and controlling air quality (U.S. Congress, 1998, 2005). Tier 4 standards were established on May 11, 2004 by the Environmental Protection Agency (EPA), and phased-in from 2008 to 2015 (EPA, 2017). These standards mandate the reduction of PMs and NO_x by 90%, more than the levels established in Tier 3 (EPA, 2014).

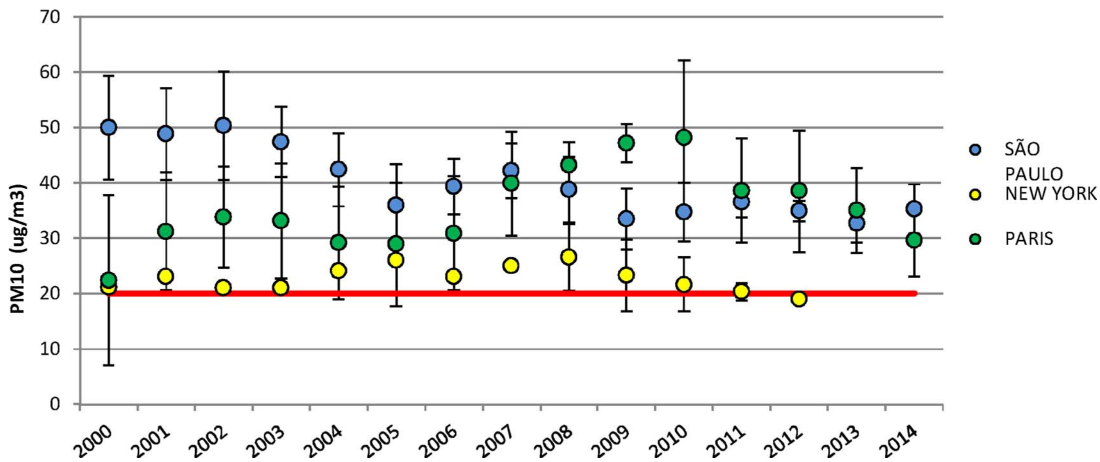

Fig. 3. PM_{10} yearly average concentrations − São Paulo, New York City and Paris: 2000/2014.
Elaborated by AD Slovic.
Source: CETESB, Airparif, NYSDEC Bureau of Air Quality and EPA

Brazil's legal settings follow the same international trends as France and the United States. The 1976 Federal Law on Environmental Pollution Control and Prevention was implemented in the state of São Paulo under Law 997, starting with the industrial pollution control program (ALESP, 1976). In 1990, the Brazilian Government implemented the PRONAR[6] defining ambient pollution standards still currently applied (MMA/Pronar, 2009). In 2013, the State of São Paulo implemented new standards by state decree 59113/2013, setting intermediary objectives and a final goal (to meet WHO air quality guidelines) to improve air quality (Cetesb, 2014a). Currently, São Paulo applies the MI1 standards (intermediary goal one) with no information on when step two (MI2) will be introduced.

In 1986, Brazil started controlling mobile air pollution sources. This regulation, called PROCONVE,[7] set emission standards for Otto[8] and Diesel vehicles[9] (MMA/Proconve, 2013). PROCONVE was implemented in stages, and played a major role in reducing vehicular emissions, while it brought Brazil extensive advancements in car technology (Ribeiro and Assunção, 2005). In its second stage, from 1992 to 1996, PROCONVE mandated the introduction of catalytic converters and electronic fuel injection permitting the use of ethanol and gasoline in Otto vehicles. Stage three continued to reduce emissions by implementation of the oxygen sensor in motors, while stages four and five focused specifically on reduction of HC and NOx (MMA/Proconve, 2013). Another advancement in vehicular emission control was the 2009 Federal Law 418, that set the path for PCPV[10] and Inspection & Maintenance Program (MMA, Conama, 2009). In 2002, PROMOT[11] was introduced in Brazil, following EURO standards. PROMOT faced several adjustments and revision of emission standards, similar to EURO 4.

The Pro-Alcohol Program, introduced in 1975, was a way to cope with the world petroleum crisis (FAPESP, 2016). A series of engineering modifications, including modified tubing and gasoline co-injection in cold weather, were developed in Brazil, and allowed hydrated sugar cane ethanol to enter the fuel market. While the Pro Alcohol program officially ended in 1990, today, 47% of cars in Brazil are flex (ethanol and gasoline) and all gasoline contains 27% ethanol (Sindipeças, 2017). In Metropolitan Region of São Paulo flex vehicle represent almost 50% of the fleet (Cetesb, 2015a,b).

In addition to the use of ethanol in Otto vehicles, biodiesel, formed from the esterification of vegetable-based fatty acids, has had an important role in reducing the use of petroleum in diesel fuel for heavy-duty vehicles. Introduced in Brazil by the 2005 Law 11.097, biodiesel is currently mandated at 7% (Camara dos Deputados, 2005). Finally, two major regulations passed in 2009 and 2013 have reduced the sulfur content of diesel to reach 10 ppm in gasoline and 50 ppm in diesel for private and light duty vehicles (Cetesb, 2015a,b). In comparison, the USA the regulation fixes the sulfur content in gasoline at 10 ppm and 15 ppm for diesel vehicles while in France the content is fixed at10 ppm in diesel (European Commission, 2015).

3.2. Air pollution trends in São paulo, new York city and Paris: PM10 and O3

An overview of PM_{10} and O_3 levels was used to illustrate the results of the policies on pollution levels in the three cities. These two pollutants were chosen because of their health impact including respiratory, cardiovascular diseases and lung cancer (WHO, 2016) and because they are studied in the three centers ($PM_{2.5}$ levels not collected in São Paulo during this period so are not presented). An analysis of PM_{10} levels for the period 2000–2014, Fig. 3, shows that the three cities struggle to maintain levels below WHO recommendation of 20 μg/m^3. New York has remained around 20 μg/m^3 with yearly decrease as of 2008 and no available data after 2012. In São Paulo, the levels in 2000 were the highest, until 2003. The following years saw a steady decrease (except for 2006–2007) and a stabilization that remained at 35 μg/m^3 per year. Paris had a steady increase in PM_{10} from 2000 to 2003 and a decrease between 2004 and 2006. From 2006–2010, Paris presented a sharp increase in emissions and reached historical high levels in 2009. From 2010 on, emissions maintained a consistent decrease of about 5 μg/m^3/year, returning to 2001 levels of 30 μg/m^3.

Ozone levels in the three cities were analyzed by comparison of the average numbers of days when the 8-h maximum exceeded the WHO limit of 100 μg/m^3 per station for 2012–2014. São Paulo had the highest number of exceeded days in 2012 and 2014 (59 and 66 days) with the exception of 2013 when Paris had the highest number. This problem is accentuated on weekends consequent to less diesel vehicles and less NO_x produced (Carvalho et al., 2015), with no major reductions over the last years in São Paulo (Kumar et al., 2016). Thus, in the

[6] Federal Air Quality Control Program

[7] Programa de Controle de Poluição do Ar por Veículos Automotores, Portuguese for Program for the Control of Air Pollution from Auto Vehicles

[8] Defined by Cetesb as "internal combustion engine, which employs the thermodynamic cycle of the Otto type. The main feature of this engine is the spark plug that causes combustion. It is typically used in automobiles, motorcycles and some commercial vehicles using gasoline C, hydrated ethanol or CNG as fuel − used in flex-fuel vehicles". (Cetesb, 2014b, p.25)

[9] "Internal combustion engine whose fuel burning occurs due to temperature rise caused by compression of the air. This engine uses diesel as fuel and has no spark plug. It is usually used in trucks, buses and partly from commercial vehicles". (Cetesb, 2014b, p.25)

[10] Plans of vehicular pollution control

[11] Program for Air Pollution Control for motorcycles and similar vehicles

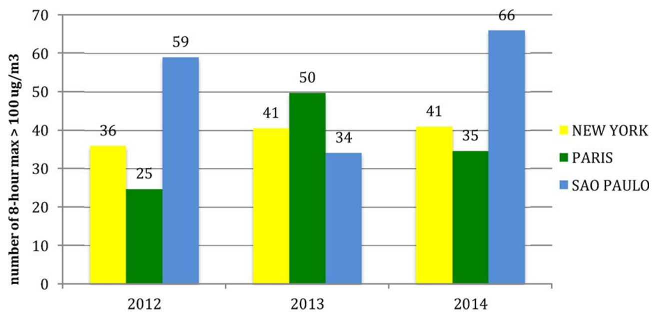

Fig. 4. – O_3 levels: São Paulo, New York City and Paris: 2012/2014.
Elaborated by A. Slovic
boroughs with the exception of Manhattan. The percentage of walking trips for work was for the years of 2005 to 2007.
Source: Airparif, EPA, CETESB

three cities, ozone continues to peak above WHO limits (Fig. 4).

4. Identifying air pollution strategies

The historical background of air pollution policies and levels of PM_{10} and O_3 helped contextualize the global and local situation in which these cities implemented their programs. In this article, the OECD classification was adopted for approaches to air pollution control: regulatory, economic incentive and others, with three sub-classifications (Slovic et al., 2015):

A: Circulation restriction initiatives;
B: Alternative initiatives;
C: Fuel/technology initiatives.

Overall, the three cities addressed vehicular emissions most frequently using regulatory approaches, focusing on circulation restriction and fuel and technology initiatives (Table 1). Economic incentive approaches were used for targeting fuel and technology initiatives. However, the last decade saw an increase in "other" approaches with a common emphasis on alternative incentives for the three cities. From a governance perspective, New York and São Paulo had more local initiatives (Municipal and State level) as opposed to Paris, but São Paulo was the city where programs and plans incorporated the least number of alternative initiatives.

4.1. São Paulo

The regulatory approaches on fuel and technology reflected the Brazilian government's choice of developing the Pro-Alcohol program. Although not motivated by environmental issues, benefited the Brazilian agricultural sector, economy and energy matrix (Giesbrecht, 2013). It facilitated the introduction of biodiesel in the Brazilian vehicle fleet in 2004 and the production of flex cars. Flex-vehicles today account for respectively for 64% of cars, 50% LDV and 15% of motorcycle fleet in the municipality of São Paulo (Cetesb, 2015a,b). As mentioned in Section 3.1, PROCONVE and PROMOT were Brazil's main policies to address vehicular emission pollution, which enabled the State of São Paulo to start its first Vehicular Emission Control Plan (PCPV) in 2011. These programs had a significant impact on air pollution reductions but remain insufficient to address the city's air pollution challenges (Andrade et al., 2017). Sulfur reduction of fuel content and the Inspection/Maintenance (I/M) represented two milestones towards reducing emissions in the city. These programs helped to:

– Reduce black smoke;
– Start municipal inspection and maintenance in the municipality;
– Contribute to emission inventories for the State of São Paulo.

The I/M program was an initiative developed at the city level, which had no power to control vehicular emissions from the surrounding cities/state. Currently suspended, due to political reasons, it might be reinstalled by the current Mayor. Another initiative, the license plate-based final digit restriction program, "Rodizio," started in 1997 adapted today to impede 20% of the vehicle fleet to circulate once a week during peak hours. At first, there was a positive impact on circulation flow during congestion peak time, but over time it produced the unexpected consequence of reversing the positive and fostered the purchase of additional vehicles, often older (Kumar et al., 2016).

Of all the programs developed in Brazil, only two included an economic incentive and reflected the National government's intervention in the automobile industry, including tax reductions on industrialized products (IPI), (2008–2010, 2012 and 2013) (MF, 2015) and energy sector via:

– The 2004 Federal Biodiesel Production/Use program (MME, 2005);
– The 2015 tax reduction on imports of electric and hydrogen vehicles (MDIC, 2015).

Implementing alternative programs began with the 2001 São Paulo Transport Master Plan. As part of a global rise in consciousness of urban mobility challenges, tackling air pollution began to include integrated approaches in different fields. The 1997 and 2007 surveys on origin–destination evaluated how São Paulo inhabitants commute (Metro, 2012) and contributed to the 2006 São Paulo Metropolitan Urban Transport Integrated Plan (PITU) (STM-SP, 2006). PITU adhered to the importance of improving public transportation, with initiatives like new bus corridors, introduction of the electronic passes (which reduced public transport costs) and the connection of different transport modes. More recently, the development of the São Paulo Strategic Plan (PMSP, 2015a,b) and the São Paulo Mobility Plan (STM-SP, 2015) focused on more sustainable travel means.

4.2. Paris

The use of regulatory and other approaches was mostly combined with alternative incentives via the inclusion of public and non-motorized transportation improvements such as the Urban Travel Plan of the Île de France region (DRIEA, 2000).

Thus, following European Commission directives, the French government implemented Atmosphere Protection Plans (PPA) aimed at guiding and empowering local administrations to develop air quality action plans in municipalities greater than 250,000 inhabitants (DRIEE, 2005). Such measures include speed limitations on vehicles, evaluation tools and the authorization to launch the Air Pollution Alert Plan. This Plan, a result of the Grenelle laws, was reviewed three times (2005, 2010 and 2013) and respects the Regional Climate, Air and Energy Plan (SRCAE) (DRIEE, 2015). Another derivative of the Grenelle law, aimed at vehicular emissions, was the creation of priority zones called ZAPAS – whose main goals were the reduction of particulate matter and nitrogen, enabling local administrations to directly act and reduce the costs associated with air pollution (Legifrance, 2010).

Paris' air pollution episodes of 2013 and 2014 motivated the city to revise its strategies and acknowledge the remaining air quality challenges. In 2015, city authorities re-implemented regulatory measures (circulation restrictions with license plate-based prohibition during critical air pollution episodes). However, the "return" of restrictive measures was accompanied by economic incentives strategies (Mairie de Paris, 2014). Since 2010, strong emphasis has been given to buyers of hybrid and electric vehicles and has motivated the renewal of the car fleet (Legifrance, 2015).

A reorganization of the public space and the closing of circulation axes for pedestrian use accompanied these measures, giving back public spaces to pedestrians as well as improvements in its extensive public transportation network. Of the three cities, Paris was first to develop bicycle and electric automobile sharing programs, later replicated in São Paulo and New York City. Today, the city of Paris provides financial

Table 1
OECD strategy choices: São Paulo, New York City and Paris: 2000–2015.

YEAR	LOCATION	NAME	REGULATORY			ECONOMIC INCENTIVE			OTHERS		
			A	B	C	A	B	C	A	B	C
2001	SAO PAULO	São Paulo Transport Master Plan	✓	✓						✓	
2003	BRAZIL	Introduction of Flexible Fuel Otto Vehicles			✓						
2003	BRAZIL	PROMOT (stages: 2003, 2006, 2009, 2014)	✓		✓						
2003	SAO PAULO	VIGIAR Program on information on health effects of air pollution and climate								✓	
2004	BRAZIL	Federal Biodisel Production and Use Program			✓			✓			
2006	BRAZIL	SP Metropolitan Urban Transport Integrated Plan - PITU							✓	✓	✓
2006	BRAZIL	Emission ceilings for fixed sources of Air Pollution			✓						
2009	SAO PAULO	Inspection and Maintance Program started (city only)	✓		✓						
2009	BRAZIL	Brazilian National Air Quality Plan								✓	✓
2011	SAO PAULO	1st State Vehicular Emissions Control Plan 2011–2013	✓		✓						
2012	SAO PAULO	São Paulo State Biofuels Program			✓						
2012	SAO PAULO	São Paulo bycicle sharing program								✓	
2013	SAO PAULO	São Paulo State Emission Sources Reduction Stationary Plan - 2013			✓						✓
2013	BRAZIL	2nd São Paulo State Vehicular Emission Control Plan 2014–2016	✓		✓						
2013	SAO PAULO	Sao Paulo Air Quality Standards Revised	✓		✓					✓	
2013	SAO PAULO	Goal Program for the City of São Paulo 2013–2016								✓	✓
2014	SAO PAULO	São Paulo Strategic Master Plan								✓	
2015	SAO PAULO	São Paulo Mobility Plan							✓	✓	
2015	SAO PAULO	No tax on importation of electric and hydrogen vehicles						✓			
1992	FRANCE	Inspection and Maintance Program			✓						
1996	FRANCE	Creation of Acredited Assoc. for Air Quality Surveillance and Monitoring							✓		
2000	PARIS	Urban Travel Plan - Ile de France Region		✓						✓	
2003	FRANCE	National Plan of Pollutant Emission Reduction (PREPA)									
2005	FRANCE	1st Atmosphere Protection Plan (PPA)	✓	✓	✓						
2007	FRANCE	Ecological bonus for greener vehicle purchase						✓			
2007	PARIS	Paris bike sharing service "Velib"					✓			✓	
2007	FRANCE	Regional Climate, Air and Energy Plan		✓						✓	✓
2010	FRANCE	Federal Inventory System of Air Pollutant Emissions			✓						
2010	FRANCE	2nd Atmosphere Protection Plan (PPA)	✓	✓	✓						
2011	PARIS	Paris car sharing service					✓			✓	✓
2012	FRANCE	Automobile Plan						✓			
2012	FRANCE	Regional Climate, Air and Energy Plan		✓						✓	✓
2012	FRANCE	Priority Zone of actions for air	✓		✓						
2013	FRANCE	3rd Atmosphere Protection Plan (PPA)	✓	✓	✓						
2013	FRANCE	Biofuels Aid Policy						✓			
2014	PARIS	Urban Travel Plan of the Ile de France Region								✓	✓
2014	FRANCE	Particulate Matter Plan - 2014	✓								
2014	FRANCE	Info. and warning in case of air pollution episode and the measures							✓	✓	
2014	FRANCE	Action plan for active mobility								✓	
2014	FRANCE	Plan for the development of hybrid and electric vehicles			✓			✓			
2015	PARIS	Launching of accompanying measures to fight air pollution	✓				✓				
1997	NEW YORK	NYS Chemical and Pollution Control Programs			✓						
1998	NEW YORK	Fuels Program: Alternative, Mixture and Nitrogen			✓						
2003	NEW YORK	Assessing and Mitigating Impacts of PM10 Program -2003			✓						
2004	USA	Smart Way Program									✓
2005	USA	Diesel Emissions Reduction Program Grants			✓			✓			
2005	NEW YORK	Ultra low sulfur diesel fuel ("ULSDF") and the best available retrofit technology ("BART") for vehicles program			✓						
2005	USA	Renewable Fuel Standard (RFS) program						✓			
2005	NEW YORK	Bicycle Data Collection Program								✓	
2005	NEW YORK	2005–2030 Regional Transportation Plan								✓	
2006	NEW YORK	NYSDEC Guidelines on Dispersion Modelling Proc. for Air Quality Impact Analysis								✓	
2007	NEW YORK	1st Plan NYC	✓	✓	✓				✓	✓	✓
2008	NEW YORK	NYC Strategic Plan " Sustainable Streets"									
2009	NEW YORK	Reg on the amount of time of vehicle iddling near a school	✓								
2009	NEW YORK	Mobile Source Civil Penalty Policy - 2009	✓								
2010	USA	Diesel Emission Reduction Act Grants						✓			
2010	NEW YORK	Car Sharing Zoning Tax Amendement					✓				
2011	NEW YORK	2nd Plan NYC	✓	✓	✓				✓	✓	✓
2011	NEW YORK	NYC Air toxics Monitoring Begins			✓						
2012	NEW YORK	NYC Noise Monitoring Starts								✓	
2012	NEW YORK	New York City Department of Transportation's Mobility Management Program							✓	✓	
2013	USA	Fuel Economy Label			✓						
2013	NEW YORK	Regional Transportation Plan -2013								✓	
2013	NEW YORK	Coordinated Public Transit Human Service Transportation Plan - 2013		✓							
2013	NEW YORK	Transportation Enhancements Programs - 2013							✓	✓	✓
2013	NEW YORK	Economic and Technical Analysis for Reasonable Available Control Technology			✓						
2013	NEW YORK	Bycicle Share Program "Citi Bike"									
2013	NEW YORK	Revision of the NYC Air Pollution Code							✓		
2015	NEW YORK	Thrid Plan NYC: One New York the Plan for a Strong and Just City	✓	✓	✓				✓	✓	✓
2015	USA	EPA Clean Power Plan		✓	✓						
2015	NEW YORK	Regional Freight Plan		✓	✓						

incentives to Parisians to encourage their use (Mairie de Paris, 2017).

4.3. New York City

New York City mostly follows regulatory approaches under fuel and technology initiatives. Programs from 1997 to 2005 were designed to improve fuels, such as ultra-low sulfur content, best retrofit technology and fuel mixtures (EPA, 2005). The reduction of sulfur content appeared in New York prior to São Paulo, in 2005, with an economic incentive under the emission reduction grant program. New York's initiatives bear four major characteristics:

- The "late" development of an environmental plan, focused on air quality. Indeed, PlanNYC was only launched in 2007 (NYC Mayor's Office, 2010);
- "Economic incentives" at the local and Federal levels primarily targeted industry, such as the Smart-Way Program, as opposed to Paris, which developed initiatives oriented towards users/consumers. The Smart-Way program, a public-private partnership, focuses on the transport freight industry and its supply chain, reducing fuel cost and environmental impacts from emissions (EPA, 2004);
- Plans are more neighborhood-focused or targeted at specific problems than those seen in the other 2 cities. In 2009, legislation was approved to regulate the amount of time of vehicle idling near schools, different air toxins and noise monitoring actions focused on specific parts of the cities (NYC Dept. Environmental Protection, 2009);
- The inclusion of environmental justice aspects into air quality with the *One New York City: the plan for a strong and just city* (NYSDEC, 2015).

Alternative incentives related to public transportation, appeared five years after Paris and São Paulo. Indeed, transportation plans were launched in 2005 and enhanced in 2013 as part of the New York Regional Transportation Plan and included actions such as the change in the New York City vehicle administration fleet (like police vehicles and buses). Non-motorized initiatives included early development and spread of bicycle lanes and pedestrian spaces, but only in 2013 did New York City start its first bicycle-sharing program, six years after Paris and closed some major traffic axes for exclusive pedestrian use, such as Times Square (NYC Mayor's Office, 2011).

4.4. Reproducing best practices

Finding common solutions to ameliorate air quality is a challenge. Looking at different initiatives allows the positive and negative outcomes undertaken to be stressed. For instance, the license plate circulation restriction during peak hours showed limitations in São Paulo and has encountered strong resistance when temporarily instituted in Paris to cope with pollution peaks (Airparif, 2014). In Delhi, India, it was found that the impacts of short-term traffic restriction had limited effect on reducing $PM_{2.5}$ levels as in São Paulo, alone was not enough to positively impact air quality (Chowdhury et al., 2017). Paris adopted restricted circulation zone, which catalyzed the development of an emission quality stamp mandatory for cars for eliminating the most polluting vehicles (IPSOS, 2017). In the three cities, the change to cleaner fuels has, positively impacted pollution levels by reducing the sulfur content, for all type of vehicles or integrating biodiesel program or flex technology as seen in Brazil. Despite the differences of emission standards in the three cities, PM_{10} and O_3 standards, or sulfur content regulations, they are insufficient if not developed at the federal level and particularly without vehicle fleet renewal. Regulations are only the first step to control air pollution. Unless mobility and transport accessibility issues are simultaneous developed they loose efficiency.

Offering alternative to the use of cars is essential in the fight against one of the world's leading causes of death. Metro extension is essential. In the three centers, São Paulo with 74. 8 km of metro line extension (Metro, 2012) falls far behind New York City and Paris with 337 km and 214 km respectively (MTA, 2017; RATP, 2017). Encouraging active transportation and non-motorized transport, is seen as one of the most efficient ways to cope with the increased motorization of cities (Tainio et al., 2016). Origin destination surveys to better comprehend locals travel choices are essential and should be incorporated with public transport availability and accessibility. Reducing commuting time in public transport is an important factor for discouraging the use of cars. Among the cities, São Paulo shows the highest commuting time in public transport, 67 min compared to New York City and Paris with an average of 38 min both (Metro, 2012; Mairie de Paris, 2013; NYC Dept. City Planning, 2010). Within New York City shortage in public transport accessibility was found in some of the poorest parts (NYC Dept. City Planning, 2010) a trend found in Paris and São Paulo where transport accessibility is higher in the center. Encouraging research that will incorporate all these aspects is key for the development and implementation of successful policies that will favor the greatest number of people.

5. Conclusion

This cross-case study integrated 15 years of policies and programs in three of the world's most important cities. From the description and analysis of major actions, it was revealed that choosing the right policy is a complex task, which requires knowledge, access to technology, policy enforcement and adherence. The implementation of regulation approaches temporarily benefited the three cities, but have not yet been sufficient to meet WHO air pollution recommended standards.

As suggested by Yin, case studies methodologies constitute an important qualitative tool for comparative research (Yin, 2014). Part of the steps to build the comparative framework and applied in this study, consisted of the standardization of the data, which was a challenge. Availability and data quality differed from city to city, possibly reflecting local policymaker's agenda. Data homogenization should not only be encouraged locally but globally. Findings in this study suggest the need for further research to bridge the homogeneity gap related to air pollution and a systematization of integrated evaluation mechanisms.

The three cities share a vision for enabling initiatives that encourage non-motorized transportation and regain of public spaces by pedestrians through the closing of major road axes. This change is revolutionary in many ways as vehicles lost their share of space in the city and should be encouraged worldwide.

Contrary to cities in less developed countries, São Paulo, New York City and Paris not only have the technology to fulfill this gap but have already opened the path to programs and initiatives that could benefit a greater number of cities.

On a global scale, the Paris Agreements on Climate Change and the Sustainable Development Goals offer the opportunity for policymakers to develop air quality initiatives that contribute to mitigate the effects of climate change and ameliorate urban health. Controlling air pollution can and should work together with climate change action plans. This can only work together with government́s willingness and comprehension of the challenge ahead. Otherwise, it is very likely that these initiatives will fail and will slow down current progress made by cities.

To conclude, although there are significant initiatives being undertaken in São Paulo, New York City and Paris, they can be replicated only if studies take into consideration local governance, socioeconomic context and a global common vision of how beneficial air pollution policies can be.

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