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Verifying Traffic Ban Effects on Air Pollution

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Abstract Air pollution started to become a problem for human beings with the industrial revolution, but nowadays, with the introduction of laws against emissions (e.g., the EuroX normative), the situa- tion is getting better. Moreover, governments must constantly monitor pollution levels to check policies effects. This article describes a method to verify traffic ban effect claims on air pollution using monitored data. In Lombardia (our region), ARPA (the local EPA) maintains pollution monitoring stations from down- town Milano to remote places near the mountains since 1999. Measured data are "somewhat" available through ARPA's website. "Somewhat" because a CAPTCHA protected download request form must be filled up for every combination of (station, pollutant, time-frame < 1 yr). In 2003 the Lombardia government introduced a vehicle ban to reduce air pollution. Then, more recently (in 2008 and 2012) the Milano City Council introduced a stricter ban. The author implemented an automated (in place since 2004) data collecting "web gatherer" to overcome ARPA's overcomplicated download procedure and, above all, **to verify air pollution reduction claims**. Data are published on the author's website and this paper presents a method to analyse effects on air pollution and to verify policies claims.

Keywords: *open data, public accountancy, pollution, particulate matter, anti-pollution policies, web scraping, vehicle banning*

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1. Introduction

Air pollution started to become a problem for human beings with the industrial revolution [14,19,20]. During the second half of the twentieth century pollution skyrocketed to the extension that some notable high peaks were even given a name such as the "Great Smog of '52" [7]. After the seventies many governments started to legislate [23] to try to reduce industrial (plants, materials, transportation, power generation, etc.) emissions. From then on, air pollution slowly began to decrease as new generations of technologies replaced older ones (see Figure 1 and all the graphs retrievable from ARPA: http://ita.arpalombardia.it/ITA/qaria/img/qaria/graficiInqNew/<province>_<pollutant>.png such as http://ita.arpalombardia.it/ITA/qaria/img/qaria/graficiInqNew/MI_PM10.png). A typical example context is the set of land transportation technologies (i.e., vehicles) we use every day to commute, to travel, to have fun, etc. Since the original "Clean Air Act" [23], cars, motorbikes, buses, etc. makers have been compelled to fulfill ever updated emission requirements. Stricter rules substitute older ones as technologies progress. Europe has followed this trend with the so-called EuroX legislation [10] to impose maximum emission limits for every type of car+engine (gasoline, diesel, 4-stroke, 2-stroke, hybrid-electric, etc.) produced and sold. As an example, for passenger vehicles (cars), EuroX rules define the following pollutants that should be regulated: CO (Car-bon Monoxide), THC (Hydrocarbon), NMHC (Non-methane hydrocarbons), NO_x (Nitrogen oxides), HC + NO_x, PM (Particulate Matter), Px (Particle number, this last one is still in the process of being detailed, it is not part of the rules). It is also important to note (it will be useful later) that EuroX[1] rules do not impose limits to PM for gasoline vehicles, since gasoline (4-stroke) engines do not produce any PM [17] for practical purposes. Moreover, many countries declared laws- e.g. Europe [9] - to limit pollution concentration in the air. Europe legislation was adopted in Italy by defining the following upper bounds, here presented with the measured (see tables in section 2) averages in 2013:

- $SO_2 < 125\mu g/m^3$, 2013 average: < 5[2] (very low)
- $P\ M\ 10 < 50\mu g/m^3$, 2013 average: 38 (almost low, see next paragraph)
- $P\ M\ 2.5$ (it is not yet specified but already mon- itored since EU commission is still debating about it, the proposed limit is 20), average in 2013: 29 (high)
- $NO_2 < 200\mu g/m^3$, 2013 average: 86 (low)
- $C\ O < 10\mu g/m3$, 2013 average: 1.5 (very low)
- $O3 < 180 - 240\mu g/m3$, 2013 average: 30 (very low)
- Benzene (no bounds), 2013 average: 1.4

$P\ M\ 10$ is also monitored in terms of the *number of limit excesses* during the year, and the number of excesses should remain under a fixed number (usu- ally 35). This is

[1] Except for Euro5 that speci_es a PM upper bound emission ony for direct injection gasoline engines.
[2] Monitoring stations print this value under low concen- tration conditions.

because *P M* 10 is a very cyclical pollutant: it raises during the winter and it de- creases during the summer. Currently, in Lombar- dia, even if the *P M* 10 yearly average is below the limit, the number of excesses still exceeds the EU prescription.

Summing up: almost every monitored pollutant is below the upper limit and the only one that should be taken into account is Particulate Mat- ter (*P M* 10 and *P M* 2.5).

Around the year 2000, despite the downward trends in air pollutants, some Italian local govern- ments started introducing legislation restricting the use of private vehicles due to a supposed "upward trend" in pollutants. Many vehicle owners could no longer drive their cars, motorbikes, etc. while still paying ownership taxes and mandatory insur- ance. Even in case of gasoline vehicles that do not produce *P M* 10 and *P M* 2.5. While public trans- port buses with very old (average public vehicles age is about 20 yrs in Italy) diesel engines could pollute without any limitation. The difficulty to understand (engine, pollution, etc.) technologies [18] is probably the source of this "unreasonable" if proven unsuccessful/useless (see sections 2.2 and 3) - ban. In Italy the "principle of law reasonabil- ity and proportionality" [6,8] is one of the most important principles used to (in)validate laws, it states that: "*The reasonability principle (RP) is a corollary of the principle of equality, drafted by the Constitutional Court, inspired by a similar prin- ciple identified by the Anglo-Saxon jurisprudence. The RP requires that the provisions contained in acts having the force of law must be appropriate or congruent to the objective pursued. It is therefore a breach of RP when there is a major contradiction within a law, or between it and the public interest pursued. The RP is therefore a limit to the discre- tion of the legislature, which prevents arbitrary ex- ercise. The verification of RP of a law involves the investigation of its assumptions of fact, the assess- ment of the congruence between means and goals ... In case it is established the irrationality of the law, it will be affected by the vice of excessive legislative power, and, as such, can be held to be unconstitu- tional by the Constitutional Court ...*"

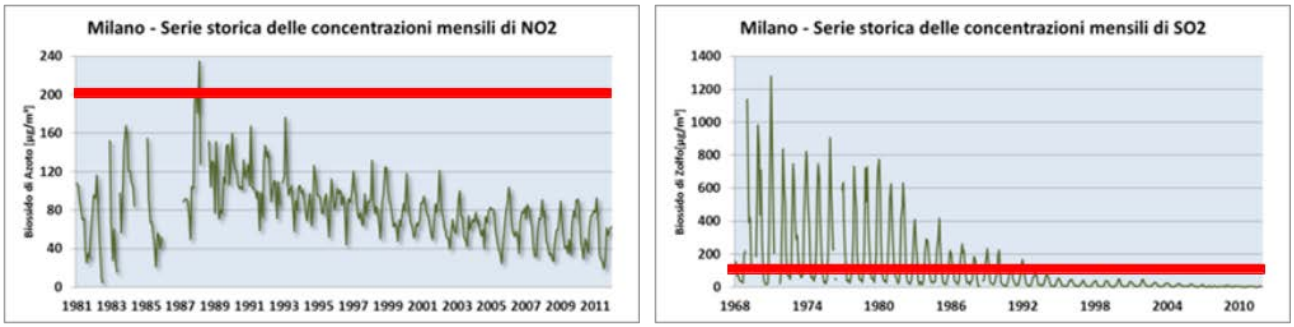

Figure 1. *N* O_2 (since 1990) and SO_2 (since 1970) trends with upper bound (red line), source: ARPA

Of course the ban proposal worried many citi- zens to no small end. In fact, the author of this paper, when reading the proposed banning rules and, above all, the motivations (the aforementioned *supposed* air pollution increase), began searching for information about air pollution and technical data to write an "open letter to the administra- tion" that circulated on media and among citizens. He found out about EuroX legislation, about what other countries did (almost never permanent bans, and banned vehicles could always be upgraded to cleaner ones with aftermarket components, some- thing not allowed by present Italian legislation) and about ARPA air monitoring. The letter disclosed the many incongruosnesses in the proposed ban and brought some technical awareness in politicians and citizens: eventually the Lombardia ban was soft- ened, i.e., applied to very old vehicles and to 2- stroke motorbikes only.

ARPA Lombardia EPA (Environment Protection Agency) maintains a network of pollution moni- toring stations from downtown Milano to remote places near the mountains since 1999. The author accessed the ARPA website to learn if historical data were available as a download, with the intent of seeing for himself what the trends observed by ARPA really were without having to rely on the mass media and other secondary sources. And data were there, available for download and in proper format: CSV (Comma Separated Values) files, i.e., 3 stars [4] Open Data graded. But with some *web- stacle* (web+obstacle crasis) to impede full data ex- ploitation.

If a citizen wanted to collect one data subset he should fill and submit a web form, then data are sent by email (i.e. the procedure is not anony- mous). Moreover, the citizen can only request a data subset for each form submission, i.e.: one sin- gle station, one single pollutant, one single time- frame smaller than one year. Summing up, if a citizen needs the whole dataset he/she should pre- pare him/herself to complete about 80 (stations) x 7 (pollutants per station) x 15 (years of monitoring) requests, by hand. Yes, by hand since the download request web form is CAPTCHA[3] protected. This overcomplicated procedure is the motivation for the author's decision to create an automatic web grab- bing (see 2.1) system, it was then developed and it is working almost continuously since 2005.

In recent years (starting around 2008) the Mi- lan City Council started using very similar meth- ods as those used by the Lombardia local govern- ment in 2003 to justify introducing a congestion charge, first called "Ecopass" and then "Area C", in an 8 km^2 area roughly corresponding to that inside the XVI century Spanish Walls. The name change is very telling, as it was introduced after its air-pollution reducing effectiveness was debated by media and citizens. Still, the legal (and po- litical) justification of "Area C" is heavily based to this day on the idea it's used to fight pollution

3 Completely Automated Public Turing test to tell Computers and Humans Apart.

(http://www.areac.it). This is due to the fact that Italian laws only allow traffic restrictions of this kind in case of a well documented and serious threat to the public health, see [15] [comma b].

1.1. Open Data...

Open Data has become a worldwide movement involving governmental and non-governmental ac- tors. The Open Knowledge Foundation (OKF) was one of the first organizations to define “open- ness” in this context and it has recently given birth to [16] to formalise meta-knowledge about open knowledge. The OKF definition of “open- ness” can be quoted as: “A piece of data or con-tent is open if anyone is free to use, reuse, and redistribute it - only subject, at most, to the re- quirement to attribute and/or share-alike”. More- over, Tim Berners-Lee [4] defined a five star rat- ing for Open Data to highlight the importance of not just legal but also technical aspects of open- ness, for example through the use of open standards and non-proprietary file formats for Open Data publishing. More broadly, Berners-Lee and others [3,5] promoted the concept of Linked Open Data to transform “data on the web” into “the web of data” by encouraging the linking of one’s own data with other datasets. HM Government’s Open Data White Paper [11] states that Open Government Data is “Public Sector Information that has been made available to the public as Open Data” and de- fines Public Sector Information (PSI) as “data and information produced, collected or held by public authorities, as part of their public task”, data that should be accessible (ideally via the internet) at marginal cost and without discrimination, available in digital and machine-readable format, and provided free of restrictions on use or redistribution.

Well, ARPA Lombardia **is** government, it is a public agency owned by Regione Lombardia. The author believes that ARPA should not force citizens to resort to time consuming data gathering methods such as web scraping [24] as he did, but it should publish all the data without any “websta-cle”.

2. Methodology

This section describes the methodology applied to *web scrape* (collect from web), store and analyse ARPA data. The whole system is developed as a set of bash+sqlite3+gnuplot scripts running under Debian GNU/Linux, its main (macro) components are the following:

- ARPA page gathering (download and store), based on wget and crontab
- data extraction (from stored pages), based on a combination of Unix filters (such as grep, sed, tr, etc.), to generate parsable data (i.e., CSV files)
- data analysis, based on sqlite3 and gnuplot

2.1. Data Scraping, Cleaning and Verification

The author took inspiration from http:// archive.org WayBackMachine for this module. The WayBackMachine is a freely available service that saves snapshots of web pages for “trusted ci- tation in the future”. URLs of interesting (to be saved) web pages can be submitted by users. In- stead of relying on the WayBackMachine, the au- thor preferred to write a simple script to get peri- odic snapshots of a subset of ARPA website.

Since ARPA data download form cannot be sub- mitted automatically (see section 1), the author used a different page, the one that displays cur- rent data day by day, for any given Lombardy sub- region. The only “problem” was to reverse engi- neer the correct URL of the page to parametrize it, and to update that URL in the script when ARPA changed (twice since 2003) their website structure

The (indeed small) script is based on wget (http://gnu.org/software/wget) and it has run under crontab every night for about ten years. The URL of the status page is http://ita.arpalombardia.it/ITA/qaria/lista$<01to10>$.asp, the numbers represent different areas in our region. That page contains everything needed to create a complete air pollution database: date (top of page), types of monitored pollutants (middle), values read from stations (table). The page of an area is just saved as a compressed .html.gz file with a full date (YYYYMMDDHHMM) in the filename.

Author’s goal was to create CSV files, aggre- gated by monitoring station, from the set of HTML pages (one for each day). The process of extracting and cleaning raw data from the HTML pages is a bit more complex since ARPA web pages are not even W3C valid. Here tools like tidy (a valida- tor/indenter/cleaner), html2 (a tool from the xml2 package, http://ofb.net/~egnor/xml2) or other well-formed HTML expecting tools fail or behave erratically. Thus the author had to combine some Unix filters by trial and error to achieve acceptable data extraction, such as:

- grep, to select lines in a _le based on pattern
- sed, to substitute strings
- tr, to substitute chars
- vilistextum http://bhaak.dyndns.org/vilistextum/ (less common than the others)\Vilistextum is a HTML to text / ascii converter speci_cally programmed to get the best out of incorrect HTML. It is released as free software under the terms of the GNU GPL Version 2."

The complete GPL licensed sources are available on the author's web site http://arcipelagoareac. it. The procedure generates a set of CSV files containing chronological data.

2.2. Analysis

The Comune di Milano, through its division AMAT (Agenzia Mobilità Ambiente Territo-rio) claims [1,2] (and other documents present on http://www.amat-mi.it/it/documenti/monitoraggio-area-c/, in italian) the following “measured" effects:

- exhaust PM10 = -58% (wrt 2010)
- total PM10 = -40% (wrt 2010)
- Elemental Carbon = -61% (wrt 2010)
- Organic Carbon = -33% (wrt 2010)
- Ammonia = -48% (wrt 2010)
- NO_x, volatile organic matter, benzopirene = unquantified decrease (wrt 2010)
- CO_2 = -29% (wrt 2010)
- Methane = -19% (wrt 2010)
- NO_2 = -24% (wrt 2010)
- unspecified decrease of air pollutants inside. “Area C” **compared to** the area outside.

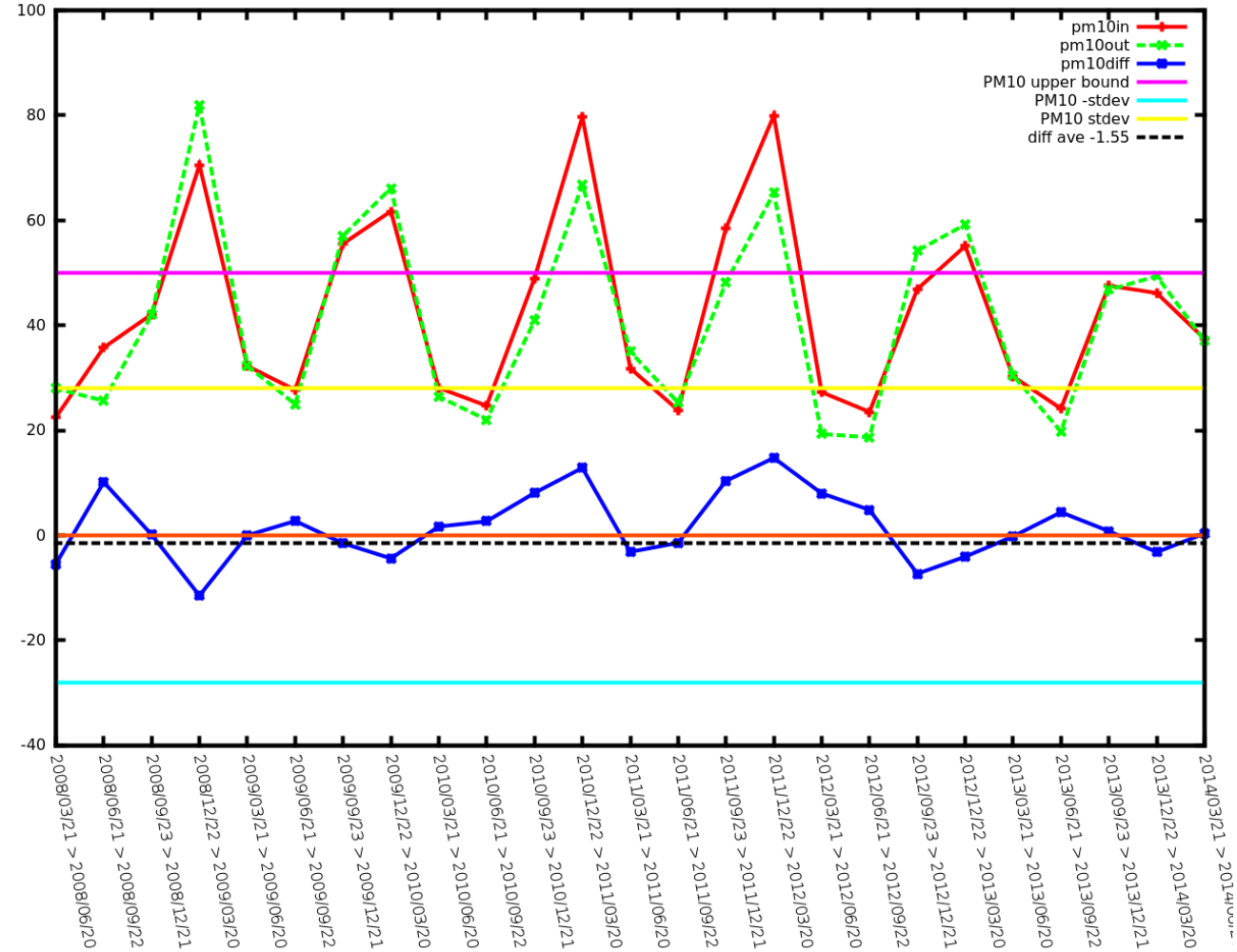

Figure 2. Values and di_erence season averages

Please bear in mind that the above claims are **not based on air pollution measurement** but **on computed figures only**, AMAT declares[4] to use the COPERT [13] method to associate an “emis- sive weight” to every vehicle, then it *multiplies* that weight by the number of vehicles entering “Area C” (!). AMAT and the *Comune di Milano* do not own/maintain permanent and EU certified air pol- lution measuring stations. While ARPA does, of course.

Moreover, AMAT lists a non-standard - accord- ing to EU norms [9] - set of to-be-evaluated air elements:

- one item is not considered a “pollutant", CO_2 is a “greenhouse gas" and it is neither monitored nor limited
- some elements (Carbon, Ammonia, Methane) are not EU regulated so there are no specified upper bounds to comply with and they are not continuously monitored, i.e., there is no publicly available downloadable historical data[5]
- “exhaust" and “total" PM10 cannot be discerned easily/directly [21] and, again there is no separate EU prescription
- they do not take into account EU prescribed pollutants such as CO and Benzene (!)

I.e., AMAT uses a non-standard model.

In general, ARPA stations can monitor the fol- lowing **EU specified** pollutants: SO_2, *PM* 10, *PM* 2.5, NO_2, *CO*, O_3, Benzene, but not every sta- tion can sense all the pollutants, e.g. station nr. 548 (see below) can measure just *PM* 10, *PM* 2.5, NO_2, *C O* and Benzene.

Since many elements in the original AMAT list are not EU regulated and no downloadable data are available, the author will only discuss items for which he has data, i.e., Elemental Carbon, Or- ganic Carbon, Ammonia, Methane and CO_2 will be dropped from discussion.

For the remaining pollutants we will focus on the ones still exceeding the limits (see list in 1), i.e., *P M* 10, *P M* 2.5. We will use data from one station inside “Area C” to verify **trends claims** and we will compare data from two stations, one inside and one outside, to verify the **decrease claim** inside “Area C”:

- Milano Senato, nr.548, inside “Area C", 1km from the city centre, halfway to the “Area C" boundary
  PM10, PM2.5, NO_2, CO and Benzene
  http://ita.arpalombardia.it/ITA/qaria/stazione_548.asp
- Limito Pioltello, nr.531, outside “Area C" (no ban on any vehicle), 12km from the city centre
  SO_2, PM10, NO_2, CO, O_3
  http://ita.arpalombardia.it/ITA/qaria/stazione_531.asp

[4] http://areac.amat-mi.it/it/areac/emissioni-da-traffico/: “Le emissioni atmosferiche sono calcolate sulla base degli accessi in Area C, rilevati ai varchi di controllo e distinti per tipologia, e della metodologia europea COPERT4." - Atmospheric emissions are calculated on the basis of Area C accesses, detected at checkpoints, by vehicle type...

[5] Periodical reports are available, in textual form, e.g.,http://ita.arpalombardia.it/ITA/qaria/pdf/Parfil/UO1/Ammoniaca/Ammoniaca%20UO_1.pdf

Table 1. Milano Senato yearly averages (with bounds)

Year	**PM10** < 50	**PM2.5** (*proposed* < 20)	**NO_2** < 200	**CO** < 10	**Benzene** (*unbounded*)
2008	39.39	NA	93.50	0.86	1.43
2009	44.39	NA	113.66	1.40	2.10
2010	40.10	NA	100.71	1.51	1.20
2011	48.92	NA	100.01	1.61	1.44
2012	42.25	36.56	82.96	1.32	0.53
2013	38.03	29.28	86.27	1.49	1.40
2014	44.96	37.34	91.39	1.70	1.53

2.2.1. Claims verification

Data presented in Table 1 **disprove the trends claims** presented by the Milan City Council as a justification for "Area C". Percent values in the following list are calculated against the raw mean value, i.e., they are not standardized against σ, the σ value is indicated in parentheses to give an idea of the standardization factor that should be applied, often reducing the decrease/increase to *nothing*.

- PM10 in 2010 was 40.10 while in 2013 was 38.03, a 5% decrease: definitely not a 58% ("exhaust") neither a 40% (\total") decrease and, above all, this difference is well within (0.07σ) observed yearly uctuations (see Figure 2) due to a large array of meteorological and climatic variables ⇒ **AMAT wrong**
- PM2.5 measurement began in 2012 and values remained stable since then, thus there is no reference for 2010 ⇒ **no reference, ignored by AMAT**
- NO_2 was 100.71 in 2010 and 86.27 in 2013, a 15% (0.37σ) decrease ⇒ **unquantified by AMAT**
- CO was 1.51 in 2010 and 1.49 in 2013, a 2% (0.03σ) decrease ⇒ **ignored by AMAT**
- Benzene was 1.20 in 2010 and 1.40 in 2013 a 15% (0.13σ) increase ⇒ **ignored by AMAT**

Claims of a reduction in pollutants inside the congestion charge area can be disproven by comparing data from monitoring stations inside (with ban) and outside (without ban) of this area. Monthly differences (plotted in Figure 2 with the difference averages) show that the "effect" of ban- ning vehicles in Milano city centre may weigh be- tween a good **-0.5**σ (2008) and a bad **+0.5**σ (2011) but a question arises: from 2008 to 2013 forms of vehicle banning were always in place, so why the difference is so low and rippling? Please also note that the *Comune di Milano* declares [1] a 30% traffic decrease due to banning. The average of monthly differences is -1.60, against a standard de- viation of about 28 in the measured *P M* 10 values (in & out), i.e., 0.06σ only. To thoroughly and formally test the effectiveness of "Area C", the au- thor has applied an hypothesis test using Pioltello station as a *control group* and testing for the hypothesis $H0 : \mu in \leq \mu out$, i.e., whether the area inside "Area C" is cleaner then outside. Results are listed in Table 2. The hypothesis can be ac- cepted for only 7 cases out of 24 and using values of α quite generous for today standards [12]. More- over in 14 cases out of 24 the hypothesis is **badly** rejected. The same test was iterated over every sta- tion pair in Milan and outside with similar results. The conclusion is that "Area C" (and the previ- ous "Ecopass") has no positive effect on Milano air pollution.

Table 2. PM10 seasons, in&out and hypothesis test results

Season	μ_{in}	σ_{in}	μ_{out}	σ_{out}	Z	P-value	H_0
2008-03-21-2008-06-20	36.2	9.855	27.94	11.21	17.28	1	badly rejected
2008-06-21-2008-09-22	35.75	12.37	25.63	10.3	28.89	1	badly rejected
2008-09-23-2008-12-21	42.63	21.91	41.97	24.83	1.15	0.87	badly rejected
2008-12-22-2009-03-20	70.53	30.9	82.02	39.94	-13.73	3.5e-43 < 0.5%	accepted
2009-03-21-2009-06-20	32.25	14.42	32.28	15.18	-0.064	0.475	rejected
2009-06-21-2009-09-22	27.67	9.82	24.96	9.428	7.33	1	badly rejected
2009-09-23-2009-12-21	55.53	28.37	57.07	29.59	-2.441	0.007 < 1%	~ accepted
2009-12-22-2010-03-20	61.71	28.19	66.13	27.77	-7.681	7.9e-15 < 0.5%	accepted
2010-03-21-2010-06-20	28.07	12.56	26.41	12.74	4.011	1	badly rejected
2010-06-21-2010-09-22	24.66	11.17	22	10.8	7.189	1	badly rejected
2010-09-23-2010-12-21	48.93	38.6	40.88	24.26	15.34	1	badly rejected
2010-12-22-2011-03-20	79.7	43.51	66.87	35.88	19.03	1	badly rejected
2011-03-21-2011-06-20	31.81	15.61	34.98	16.79	-7.121	5.35e-13 < 0.5%	accepted
2011-06-21-2011-09-22	23.83	10.59	25.28	8.629	-4.463	4.0e-06 < 0.5%	accepted
2011-09-23-2011-12-21	58.47	26.17	48.13	21.31	20.65	1	badly rejected
2011-12-22-2012-03-20	79.95	36.33	65.21	28.41	23.94	1	badly rejected
2012-03-21-2012-06-20	27.26	15.68	19.28	8.81	24.78	1	badly rejected
2012-06-21-2012-09-22	23.49	11.58	18.66	5.677	17.08	1	badly rejected
2012-09-23-2012-12-21	47.58	25.03	54.23	27.37	NA	NA	NA
2012-12-22-2013-03-20	55.1	23.14	59.18	28.25	-6.96	1.7e-12 < 0.5%	accepted
2013-03-21-2013-06-20	30.23	16.88	30.46	18.48	-0.4711	0.32	rejected
2013-06-21-2013-09-22	24.12	8.645	19.74	10.23	11.78	1	badly rejected
2013-09-23-2013-12-21	47.55	27.38	46.76	31.6	1.212	0.89	badly rejected
2013-12-22-2014-03-20	46.14	24.93	49.37	27.48	-5.185	1.08e-07 < 0.5%	accepted
2014-03-21-2014-06-20	39	16.13	39.68	20.3	-0.7099	0.239	rejected

Table 1, Table 2 and Figure 2 were created us- ing ARPA scraped data and generated by a sqlite3+gnuplot+bash script.

3. Conclusion

The method presented in this article aims at verifying the claims on traffic ban effects on air pollution, it is based on data gathered by monitoring stations spread throughout a metropolitan region. The method can be summarized as follows:

1. gather (by web scraping or just download if available) chronological data related to monitoring stations inside and outside the supposedly affected area
2. compute averages (by periods such as seasons) on every pollutant
3. apply hypothesis tests using outside stations, as a control group

This article also describes the author's data col- lecting and analysis work to overcome the artifi- cial barriers raised by ARPA Lombardia to "pro- tect indiscriminate download" of their air pollu- tion monitoring data. The automated web scraping system was built to avoid submitting thousands of CAPTCHA protected forms by hand to get data.

Data gathered during almost ten years (2005 through 2014) were useful to verify and, alas, **prove traffic restrictions adopted in the Milan area to decrease air pollution ineffective**. Data show that the two main Milano (Italy) banning laws, "Ecopass" (2008) and "Area C" (2012), had almost **undetectable effects on air pollution**. This conclusion is in fact consistent with the Lon- don Transport technical report [22] about the Lon- don congestion charge, similar to "Area C": *Even so, trends in actual measured air quality continued to primarily reflect the diversity and dominance of external factors in determining pollution concentra- tions and, as such, did not allow the identification of a clear 'congestion charging effect'. ... Despite substantial reductions to road traffic emissions in London, trends in measured air pollution remain broadly static.*

The whole set of collected data has been made freely available on the web as a set of CSV files on the author's website: http://arcipelagoareac. it/CSV, updated daily.

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