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How COVID-19 Lockdown Impacted on Mobility and Environmental data

Come il COVID-19 ha influito sulla mobilità e sull'ambiente

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Abstract. According to the COVID-19 lockdown and successive reopening a number of facts can be analysed. The main effects have been detected on: *mobility and environment, and specifically on traffic, environmental data and parking.* The mobility reduction has been assessed to be quite coherent with respect to what has been described by Google Global mobility report. On the other hand, in this paper a number of additional aspects have been put in evidence providing detailed aspects on mobility and parking that allowed us to better analyse the impact of the reopening on an eventual revamping of the infection, also taking into account of the Rt index. To this end, the collected data from the field have been compared from those of Google and some considerations with respect to the Imperial college Report 20 have been derived. For the pollutant aspects, a relevant reduction on most of them has been measured and rationales are reported. The solution has exploited the Snap4City IOT smart city infrastructure and data collector and Dashboard in place in Tuscany.

Keywords: Covid-19 lockdown, mobility and transport, environmental data, smart city.

Riassunto. Prendendo in considerazione alcuni dati relativi al periodo di *lockdown* dovuto al COVID-19 e alla successiva fase di riapertura è possibile analizzare una serie di fatti. Sono stati rilevati i principali effetti su: mobilità e ambiente, in particolare su traffico, dati ambientali e parcheggi. La riduzione della mobilità è stata valutata abbastanza coerente rispetto a quanto descritto dal rapporto sulla mobilità globale di Google. D'altra parte, in questo lavoro sono stati messi in evidenza una serie di ulteriori aspetti che forniscono elementi di dettaglio su mobilità e parcheggi che hanno permesso di analizzare meglio l'impatto della riapertura su un eventuale ripresa dell'epidemia, anche tenendo conto dell'indice Rt. A tal fine, i dati raccolti sul campo sono stati confrontati con quelli di Google e sono state ricavate alcune considerazioni rispetto all'Imperial College Report 20. Riguardo alla diffusione di inquinanti, è stata misurata una riduzione rilevante della maggior parte di essi; ne sono inoltre fornite le motivazioni. Il lavoro di ricerca e analisi si è basato sull'infrastruttura IOT smart city Snap4City e il relativo collettore di dati e il dashboard in funzione in Toscana.

Parole chiave: lockdown, Covid-19, mobilità e trasporti, dati ambientali, smart city.

1. Introduction

Italy has been one of the first countries in Europe to be invaded by the so-called COVID-19/coronavirus pandemic. Thus, the local and national governments implemented a number of Non-Pharmaceutical Intervention (NPIs), aiming at the lockdown. So that, such actions were introduced initially on specific regions and then in the whole country aiming at reducing social contact and propagation and thus at reducing: mobility and their motivations; creating a social distancing, banning social events, closing public events, services and restaurants, etc. In Tuscany, DISIT Lab with Snap4City infrastructure and service collects every day a large amount of data from several sources. The lockdown has progressively been performed from the 5^{th} to the 10^{th} of March. And it has been removed on the 4th of May, starting with a progressive reopening of production activities, while still leaving the social events, entertainments, restaurants, etc. closed. Also, research activity was resumed, but out DISIT lab never shut down. We remained in smart working modality for the whole duration of the lockdown, and we still are, continuously supporting the Snap4City infrastructure and services, and developing according to the large number of research projects we had put in place in the period.

Following from the above, in this paper we present an impact assessment of the effects of lockdown on data collected in the period with respect to previous weeks, months and years for the same variables and data collected. The main effects have been detected with regard to the following areas: *mobility, environment, social media and people flows, while this report is mainly focussed on mobility, transport and environmental aspects.* For these aspects, different data collected, and deductions can be provided. Therefore, for each of these domains and/or for each kind of data a separate discussion is presented in the following sections.

The paper is organized as follows: In section 2, an overview of Snap4City is reported. Section 3 describes the impact on mobility about the lockdown and possible deductions, also taking into account the data provided by the Civil protection for the area of Tuscany and the computation of the Rt. Section 4 describes the impact of lockdown on parking facilities and deductions. In Section 5, the impact of lockdown on environmental data and deductions are discussed. In Section 6, conclusions are drawn.

2. Snap4City overview

Snap4city (https://www.snap4city.org) has been developed to provide many online tools and guidelines involving different kinds of organizations (e.g., Research Centers and Universities, small business, large industries, public administrations, and local governments) and citizens (e.g., city operators, resource operators, companies, tech providers, category Associations, corporations, research groups, advertisers, city users, community builders) (Badii et al. 2018a; Bellini et al. 2018; Nesi, Paolucci 2018; Azzari et al. 2018; Badii et al. 2017; Badii et al. 2020). Full training on Snap4City is accessible from the website: https://www.snap4city.org/577. Snap4City improves city services, security and safety by offering a sustainable solution for smart city and Living Lab, thus attracting industries and stakeholders. Snap4City is able to keep under control the evolution of the city in real time, through reading sensors; computing and controlling key performance indicators, KPI; detecting unexpected evolutions; performing analytics; taking actions on strategies and alarms. Snap4City supports the city in the process of continuous innovation of services, infrastructures, with control and supervision, tools for business intelligence, predictions, anomaly detection, early warning, risk assessment, what-if analysis, also setting up strategies for increasing resilience in the city with respect to unexpected and/or unknown events.

Thanks to its knowledge base support, Snap4City provides flexible solutions to get immediate insights and deductions into the status of the city and its evolution, exploiting ultimate artificial intelligence, data analytics and big data technologies, activating sentient solutions collecting, and exploiting heterogeneous data of any kind, from any data source (open and private; static, real time, event driven, streams, certified and personal). Snap4City solution provides a flexible method and solution to create quickly a large range of smart city applications that exploit heterogeneous data and enable services for stakeholders by IOT/IOE, data analytics and big data technologies.

Snap4City applications may exploit multiple paradigms as data driven, stream and batch processing, putting co-creation tools in the hands of the following:

(i) Smart Living Lab users and developers, who have at their disposal a plethora of solutions to develop create applications without vendor lock-in nor technology lock-in,
(ii) final users customizable / flexible mobile Apps and tools,
(iii) city operators and decision makers specialized / sophisticated city dashboards and IOT/IOE applica-

tions for city status monitoring, control and decision support. Snap4City satisfies all the expected requirements of ENOL, EIP-CPP, Select4Cities challenge PCP and much more, and it is 100% open source, scalable, robust, respects the needs of users and their privacy; it provides MicroServices and easily replaceable tools; it is compliant with GDPR; it provides a set of tools for knowledge and living lab management, and it is compliant with more than 70 protocols, including end-to-end encrypted communication.

Snap4City is an official platform of FiWare, an official library of JS Foundation Node-RED, registered on E015, and it is also present on EOSC marketplace, and BeeSmartCity MarketPlace, etc. Snap4City obtained the 1st place award by Select4Cities partners and PCP (Antwerp, Copenhagen and Helsinki). Snap4City is also the platform of Herit-Data project (Sustainable Heritage Management towards Mass Tourism Impact thanks to a holistic use of Big and Open Data from Interreg MED program and co-financed by FESR).

Snap4City provides services and data of several cities/Organizations including: *Firenze, Helsinki, Antwerp, Lonato del Garda, Santiago de Compostela, Pisa, Prato, Pistoia, Lucca, Arezzo, Grosseto, Livorno, Siena, Massa, Modena, Cagliari, Valencia, Pont du Gard, Dubrovnik, Western Greece, Mostar; and from regions as Tuscany* (last 5 cities/organizations, including also Florence, are partner of Herit-data project and services have been provided within such project), *Garda Lake, Sardegna, Belgium, Finland, Emilia Romagna, Spain*, etc.

3. Impact of lockdown on traffic data

In the context of the mobility of people, the data sources that could provide the evidence of impact of the situation described above are *Traffic flow sensors* (which expresses the number of vehicles passing through the road, and thus the density of vehicles per time slot, for example: number of vehicles passing every 15 minutes). Those sensors are typically placed in the following areas:

- main roads of the city, monitoring inflow and outflow of the city.
- main entrance of the restricted traffic zone, RTZ.
- internal main roads of the city (which are not directly addressed in this report).
- high speed road of the region (which are not directly addressed in this report).

For cases (1) and (2), the flows inward and outward are computed on the basis of the traffic flow sensors, which are placed on the main roads connecting the city to the countryside (see Figure 1). In this way, those traffic sensors are describing the effective number of vehicles that enter or leave the city every 10/15 minutes, thus allowing to compute the total number of vehicles circulating during the day. In Florence, in normal conditions we have an average of 290.000 inbound and outbound vehicles every day, in both directions. The total flow is almost balanced at the end of the day and even hour by hour – where for *vehicles* we intend equivalent vehicles, which means that cars are counted 1, whereas bus are counted 2,5, motorbikes 0,5, etc. Note that, in taking into account traffic flow sensors, it is possible to reconstruct the traffic flow in the other road segments of the city in which the flow sensors are not present, as described in Bellini et al. 2018a; Bellini et al. 2018b. See also: https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTc5NQ== for public Dashboard with traffic flow reconstruction in real time. The traffic flow reconstruction allows to actually understand which one is the effective usage of the city roads without having to install a large number of sensors significantly reducing the overall costs.

As far as *traffic flows* are concerned, Figure 2 below shows how the lockdown impacted on the inflow and outflow of *vehicles* in Florence (which is the point 1 of the above list). The Dashboard reports the trend over H24 for in/out flows of the city and RTZ inflow, compared with the trend of the previous day. In the second half of the dashboard, the trend of vehicles entering (inflow) and exiting (outflow) daily from Florence city and its RTZ inflow over the last 12 months are reported, compared to the previous year data (in grey). The graphs present a weekly periodic trend (see also canyons due to the weekends), and some holes due to mistakes in the sensors network and communications.

In more detail, the trends of whole daily counting of vehicles entering (inflow) and exiting (outflow) from Florence in the period of January and May 2020 (in blue), compared to the corresponding values measured for 2019 on the same dates (in grey), can be analysed. The lockdown started effectively the 9th of March (a Monday), while in the first days of April the total flow traffic was reduced to 18% of the former […] (53.000 vec. per day with respect to the 284.000). On the other hand, on the 4th and 5th of May (the first and second days of the reopening) the reduction registered accounted for 52% (148.000 with respect to 284.000). Similarly, it can be stated that, for the RTZ, where the reduction in the first days of April has been at the 20%, and at the reopen in May of 46%. This reduction does not take into account the movements of people that are going to move by working or biking and neither in the flow internal to

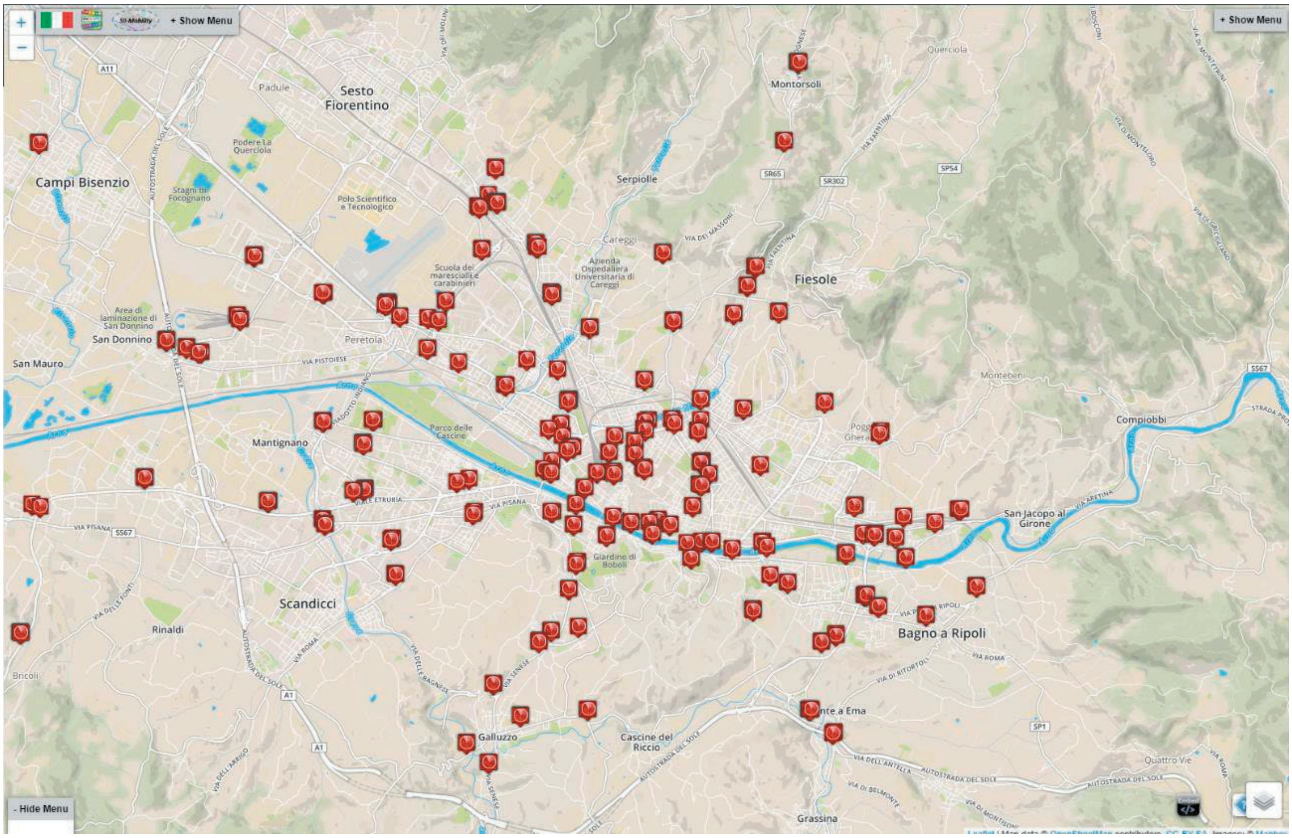

Figure 1. Placement of traffic flow sensors in the city, https://servicemap.snap4city.org/

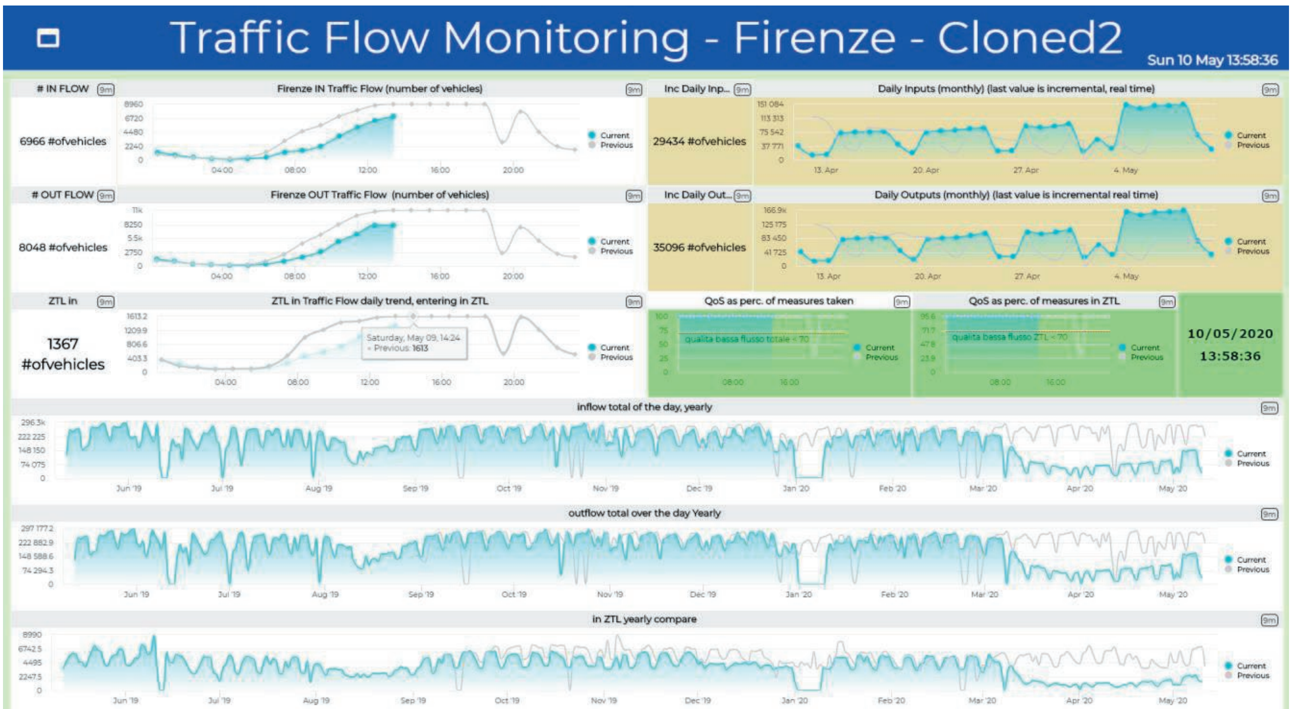

Figure 2. Traffic flow dashboard from Snap4City for Florence area, accessible from https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjY1MQ==

the city, a part for the flow into the RTZ. On the other hand, a similar reduction has been also recorded taking into account all other traffic flow sensors inside the city as in Figure 1, as well as along the high-speed road as FiPiLi in Tuscany.

Similarly, Google Global Mobility report (Google; Aktay et al. 2020), shows that people's mobility rate has decreased (in this case, this was measured through the Google mobile Apps) as reported in Figure 3. In this case, as reported by Google the reduction has been at the 30% regarding the baseline (so that -70%), at 75% for grocery & pharmacy, at 30% for Parking, at 33% for transit in stations, at 45% for working, while an increment of local residential movements has been recorded, with at a 128% with respect to the previous conditions. Comparing the data of Google with respect to those collected from the actual sensors, it seems evident that data collected by Google cannot be combined […], since the different trends indicate relative reductions or increment with respect to the corresponding baseline that is unknown. In this way, the actual reduction of mobility for working in terms of number of people is unknown. On the other hand, the reduction to the 30- 25% of mobility in confirmed for baseline, parking and transit stations, which is coherent with more precise values that were estimated by sensors across in Florence area.

The remaining 20% of traffic flows during lockdown has been mainly due to the mobility of mandatory services, including those activities that are needed to guarantee the functionalities of hospital, supermarkets, pharmacies, public transportation for those workers, etc. In the Report 20 of Imperial College (Vollmer et al. 2020), the effect of the recovery of traffic and mobility was estimated as +20% and +40% from the 4th of May with respect to the lockdown conditions have been analysed. In Vollmer et al. 2020, the proposed model puts the increment of traffic in connection with the R factor that should remain below 1 in order to control the pandemic. In Figure 4, the Simulation presented in Vollmer et al. (2020) regarding Tuscany for different cases in which a different rate of increment of mobility is supposed.

The effective impact of the registered increment of mobility in Florence is very difficult to assess, since the model is assuming that the return to standards of mobility would be performed with the same human behaviour which characterised the pre-COVID-19 times. On the other hand, most of the population has understood how to use the NPIs. Moreover, the model presented in Vollmer et al. 2020 does not clarify which amount of mobility they have supposed to have during lockdown. If they assumed the mobility very close to zero, the model in that sense has been optimistic. This means that the actual forecast of the number of deaths with respect to the increase in traffic and mobility is very hard to be produced even with large bounds of confidence. On the other hand, on 10 May, the traffic during the first week of restart after lockdown was recovered to the 52%, which is a relevant increase. The official Rt is produced by the Tuscany Region for the whole region has been estimated to be in decreasing trend and esti-

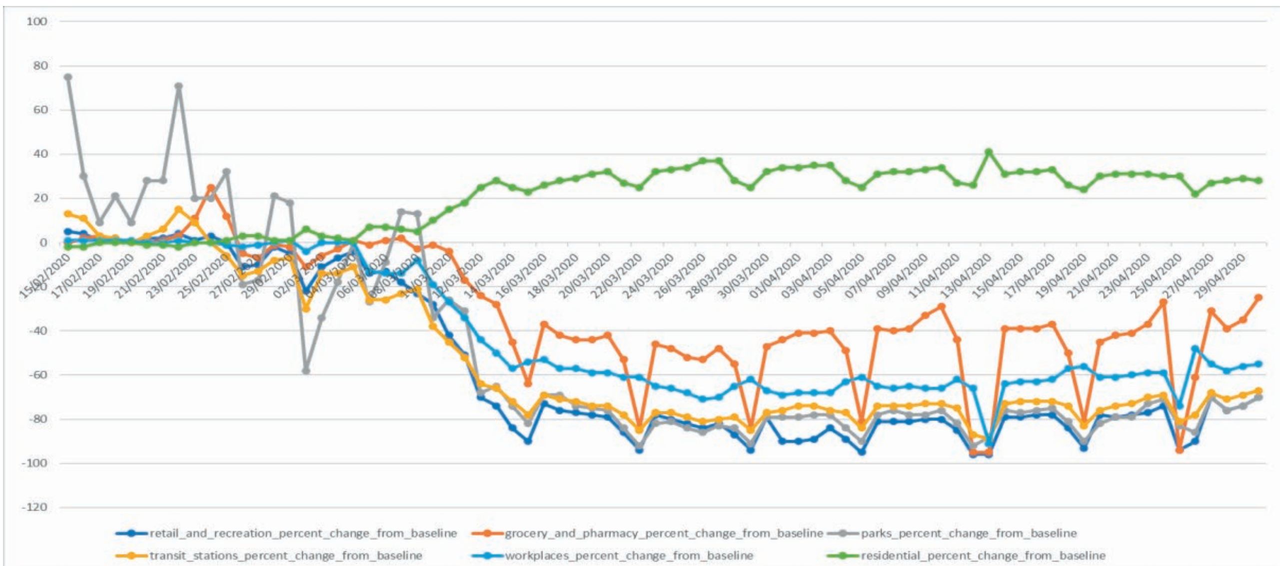

Figure 3. Reduction of mobility from Google Global mobility data (Google; Aktay et al. 2020). In the figure, red line marks the start of the lockdown.

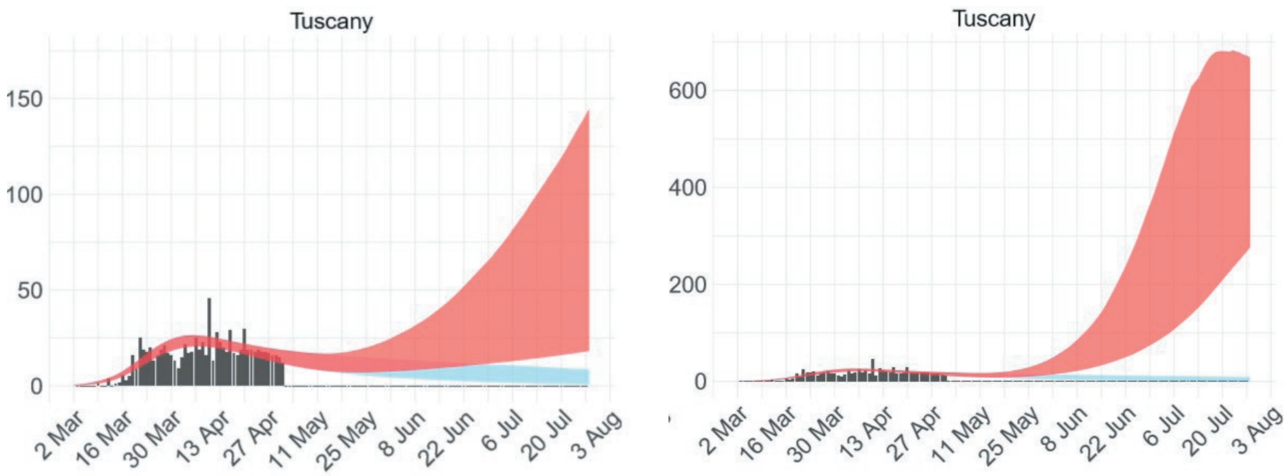

Figure 4. Simulation presented in Vollmer et al. 2020 regarding Tuscany: (i) in red the trend of the deaths as confidence intervals over time in the cases of +20 (on the left), +40 (on the right) of mobility, (ii) in cyan the trend of the confidence values over time of the possible deaths in the cases of lock down continuation, and (iii) in black the officially registered number of deaths.

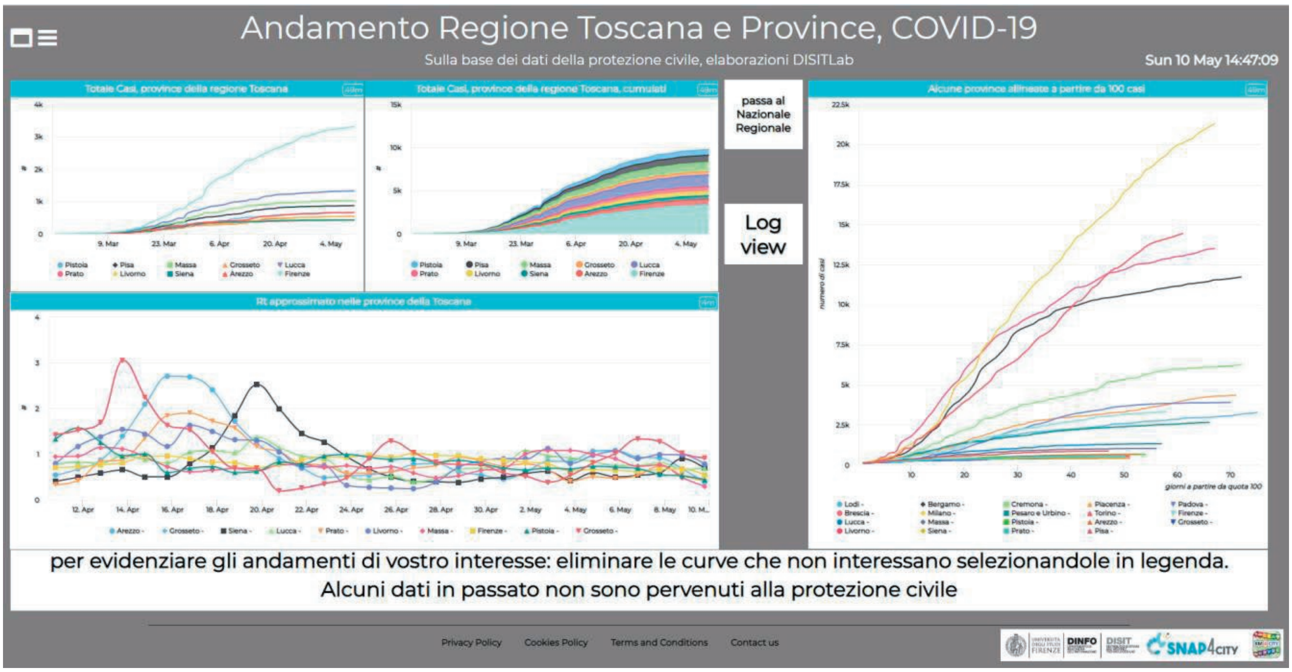

Figure 5. Data visual analytics on the basis of the COVID-19 data coming from Italian Civil Protection.
https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjU3NQ==

mated on the 9th of May as equal to 0.54 (https://www.ars.toscana.it/banche-dati/dati-sintesi-sintcovid-aggiornamenti-e-novita-sul-numero-dei-casi-deceduti-tamponi-per-provincia-e-per-asl-della-regione-toscana-e-confronto-con-italia-con-quanti-sono-i-decessi-per-comune?provenienza=home_ricerca&dettaglio=ric_geo_covid&par_top_geografia=090), while the computed value on our side has been confirmed as 0,54 for Florence (Rt has been always above 1 up to the 7th of April, and close to 1 for several days after, thus decreasing below 1 only in May. It was close to 3,5 the 9 March, when the lockdown started). These estimations are typically affected by relevant bounds of confidence. The Dashboard in Figure 5 reports the most relevant trends for the number of Cases in the provinces of Tuscany and the trends of Rt for all the provinces of Tuscany. From these data, it is clear that some of the provinces still have problems on Rt very close to 1. It should be noted that the computation of Rt is typically performed 4-5 days later than the actual value is recorded. The computed Rt values are an approximation with respect to https://www.datacamp.com/community/tutorials/replicating-in-r-covid19

The dashboard of Figure 5 is in Italian language and includes: the different trends at national level, on the left bottom corner the percentage of variation of daily cases, which is a consolidated index of the infection, the percentage of variation with regard to the number of deaths for major regions, etc. At the time of writing, most of the provinces in Tuscany have apparently reached a point close to maximum. It is even much more evident from the LOG view of the same graphs: https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjU4MA==

This Dashboard reports the trends of cases for the 10 provinces of Tuscany Region, and the aligned trends at 100 cases of the curves for the most infected provinces in Italy with respect to those of Tuscany (on the right side of the Dashboard). The last picture illustrates that most of the provinces in Tuscany have a much lower rate in the number of cases compared to the most infected provinces in Italy that are: Milano, Torino, Brescia and Bergamo.

4. Impact of lockdown on parking facilities and deductions

In the context of mobility and transport relevant data sources that could be affected by the situation described above are the Parking status sensors, which are placed close to the most relevant infrastructures (allowing one to count the number of free parking slots

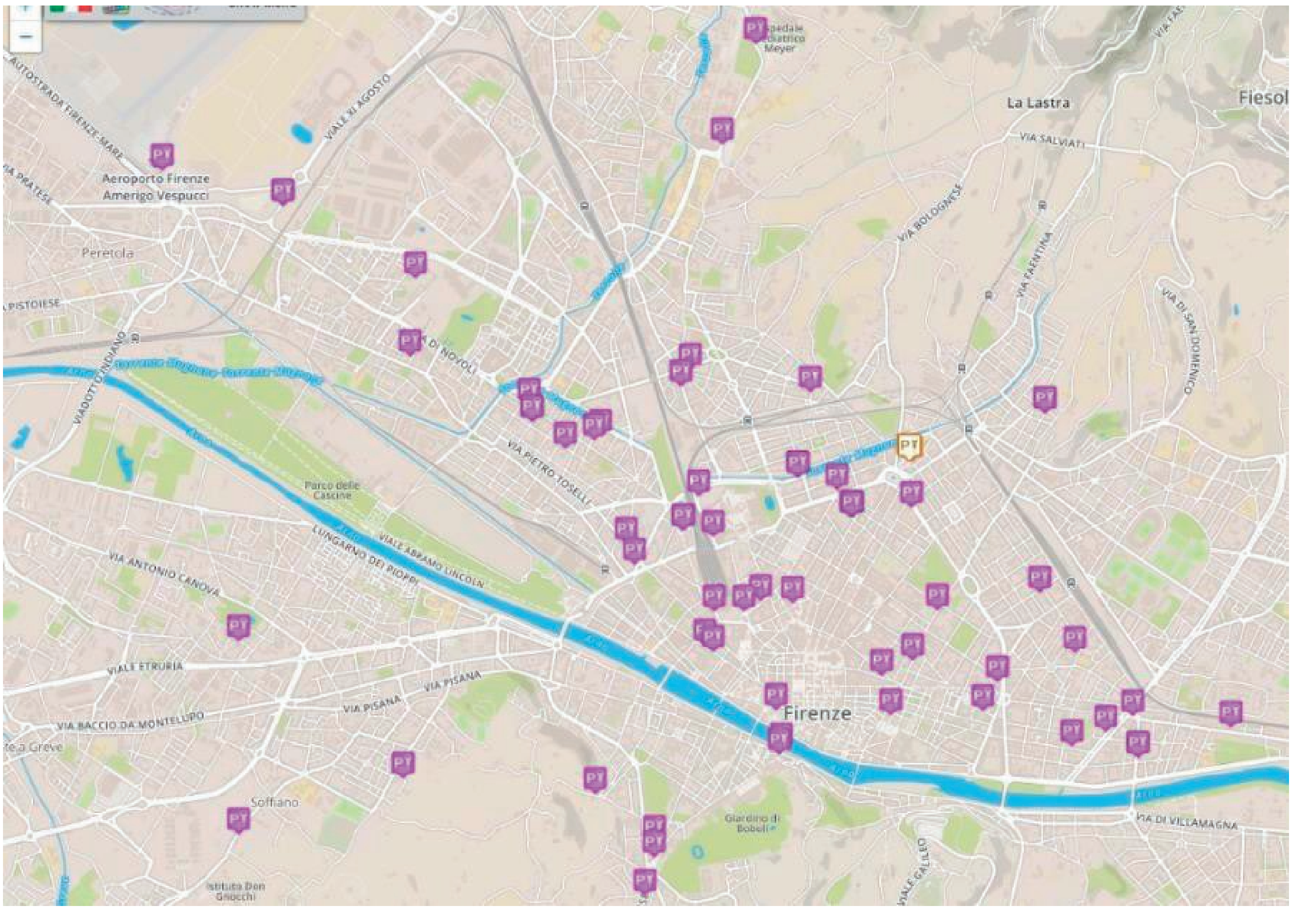

Figure 6. Main structures for parking facilities in Florence. Please note that only a part of them are monitored in terms of free parking lots in real time, https://servicemap.snap4city.org/

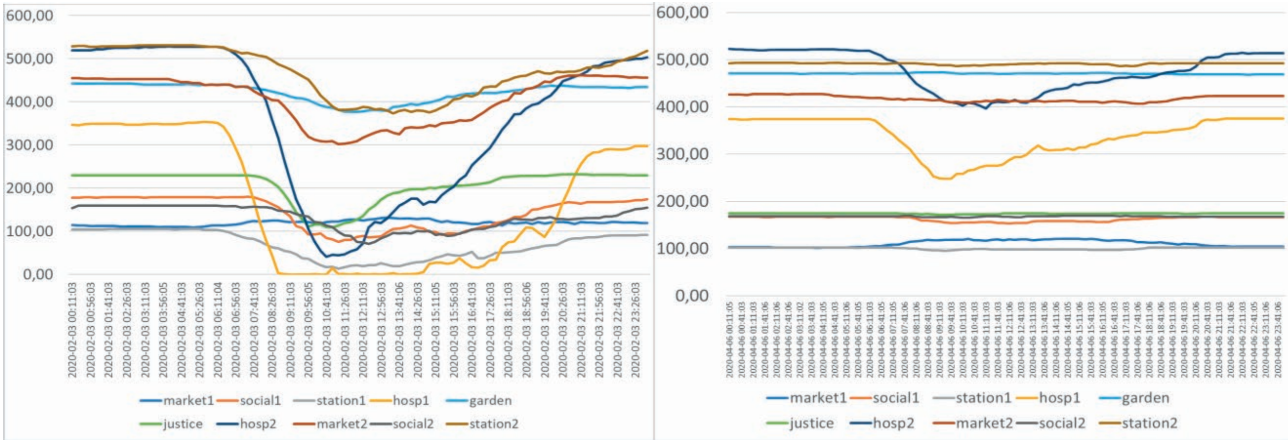

Figure 7. Typical Trends of the free parking lots on the first Monday of February (left) and April (right) for parking facilities in Florence.

over time). These include: hospitals, railways stations, palaces of justice, markets and shopping centers, social and entertainment areas. In Florence and in Tuscany there is a number of infrastructure parking lots, where free spaces are counted directly upon entrance/exit. On the other hand, in this paper we are focusing only on the major parking lots available, as depicted in Figure 6. Most of these are controlled, thereby they provide real-time data. For most of them, Snap4City mobile Apps also provide predictions and real time monitoring data.

The trends with regards to free parking lots have already been studied with the aim of providing short and long terms predictions Badii et al. 2018b. The typical trends for the days during working days and weekends were highly different, and they were also more critical in the working days when a number of parking infrastructures ran out of free parking lots. For example, in Figure 7, the comparison of the typical trends before the lockdown (left) and in the middle of the lockdown (right) is illustrated. Also, in this case, there is some information with respect to the Google global mobility report (Google; Aktay et al. 2020), which registered a global reduction at the 30%. Our data also confirmed that the global average reduction has been at the 31%, while the detailed data provide a better understanding of the composition of this 30%.

Table 1 reports the percentage of reduction in the exploitation of parking facilities in Florence. The reduction has been estimated by clustering them according to their main purpose and services: hospital, stations, social hubs, market, and justice. It is clear that the 20% reduction in mobility rates (as reported and discussed above) also impacted on the number of parking lots serving railway stations. Markets area obtained a lower reduction, due to their primary necessity of the services they provide. A significant reduction has been registered with regard to justice and social oriented parking – activities that were interrupted during the lockdown.

Table 1. Reduction of exploitation in parking facilities in Florence depending on their main utilization and purpose.

Main Purpose	% of reduction
Hospitals	55,9
railway stations	84,2
social hubs	85,8
markets	45,1
justice	96,1
AVERAGE REDUCTION OF the	69,8

5. Impact of lockdown on environmental data and deductions

Figure 8 reports air quality and pollution monitoring station in the Florence area. They are a small part of the air quality and pollution monitoring stations, with data collected by Snap4City. Their data come from sensors of CNR IBE, and ARPAT. Taken together, they are able to measure the following indicators: PM10, PM2.5, CO, CO2, NO, NO2, O3, temperature, humidity, and a few more indicators.

In the context of environmental monitoring relevant data sources that could be affected by the above-described situation are the values of the pollutants assessed by the above-mentioned sensors, which are located in the city. The most relevant parameters that could be affected by the lockdown are (some of these descriptions have been derived from those of Wikipedia):

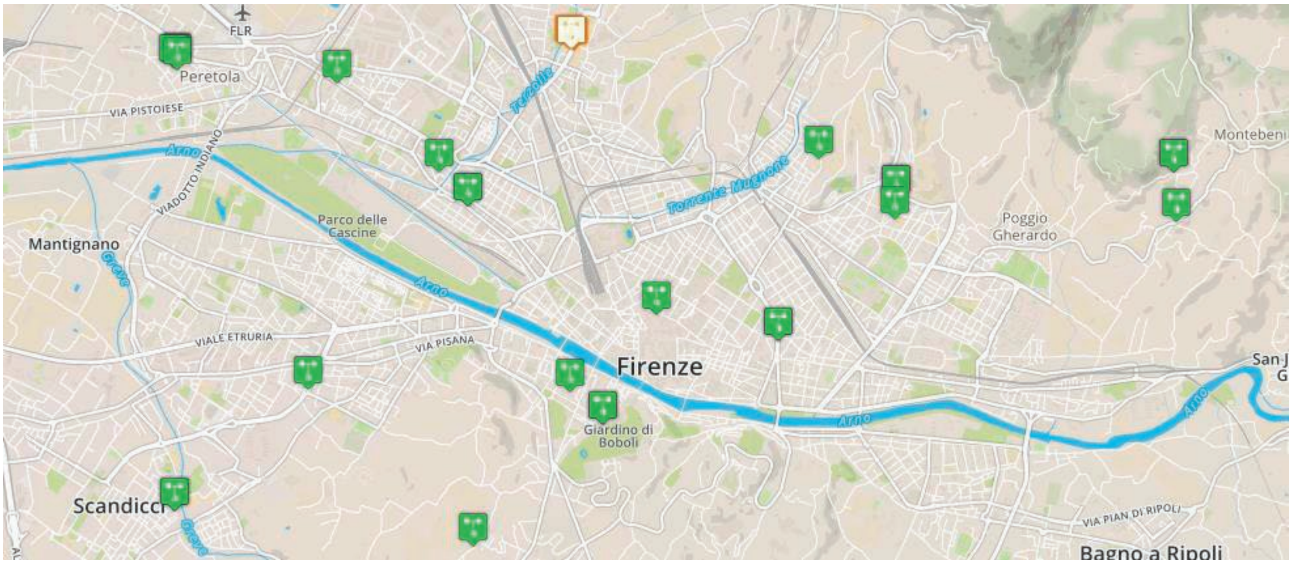

Figure 8. Air quality and pollution sensors in the area of Florence, as from https://www.snap4city.org

- **NO2, NO** as NOx Nitrogen Oxides. NOX is a generic term for the nitrogen oxides that are most relevant for air pollution, and they are produced from combustion, namely nitric oxide (NO) and nitrogen dioxide (NO2). NOx gases are also produced naturally by lightning. Other sources are house heating and industrial plants.
- **CO**: Carbon monoxide is a colourless, odourless, and tasteless gas that is slightly less dense than air. It is toxic to animals that use haemoglobin as oxygen carrier (both invertebrate and vertebrate) when encountered in concentrations above about 35 ppm, although it is also produced in normal animal metabolism in low quantities, and is thought to have some normal biological functions. In the atmosphere, it is spatially variable and short lived, having a role in the formation of ground-level ozone.
- **CO2:** Carbon dioxide (chemical formula CO2) is a colourless gas with a density of about 60% higher than dry air. It occurs naturally in Earth's atmosphere as a trace gas. The current concentration is about 0.04% (412 ppm) by volume, having risen from pre-industrial levels of 280 ppm. Natural sources include volcanoes, hot springs and geysers, freed from carbonate rocks by dissolution in water and acids. Because carbon dioxide is soluble in water, it occurs naturally in groundwater, rivers and lakes, ice caps, glaciers and seawater. It is present in deposits of petroleum and natural gas. CO2 is produced by all aerobic organisms when they metabolize carbohydrates and lipids to produce energy by respiration. It is returned to water via the gills of fish and to the air via the lungs of air-breathing land animals, including humans.
- **PM10, PM2,5:** Particulate Matter measures are expressed in microgram for cube meter of particles of 10/2,5 micrometres or less. PM2,5 are more critical due to the fact that the size of the particle is a determinant respiratory tract the particle will come to rest when inhaled. Larger particles are generally filtered in the nose, but particulate smaller than about 10 micrometres can settle in the bronchi, eventually leading to health problems. The 10-micrometer does not represent a strict boundary between respirable and non-respirable particles. The sources can be natural (soil erosion, marine spray, volcanoes, forest fires, pollen dispersion, etc.) or anthropogenic (industries, heating, vehicular traffic and combustion processes in general). The major components of atmospheric particulate matter are sulphate, nitrate, ammonia, sodium chloride, carbon, mineral dust. It is estimated that in some urban contexts more than 50% is of secondary origin.

An impact of lockdown can be observed by comparing between the February/March period and April in the most crowded areas of *Gramsci* and *Ponte alle Mosse* in Florence. The different trends allow to compare traffic flows (that has been strongly affected by the lockdown) with respect to the environmental variables such as: PM10, NO2, CO, etc. Among them, NO2 has been mostly influenced by the lockdown, due to its dependence on the traffic flow, heating and industrial activities. On the other hand, the other pollutants have also been influenced by the reduction in human activities. In order to assess the impact of the lockdown on those environmental and air quality indicators a comparison of the average values of the above-mentioned pollutant has been estimated to see the percentage of decrement with respect to the normal period, namely comparing February 2020 with respect to April (the central part of the lockdown). The results are reported in Table 2, which shows that the reduction of traffic at the 20% described above is one of the causes leading to the reduction of NO2 at the 39%. On the other hand, the reduction has not been proportional, since probably the heating of the houses has been increased in the same period, so that partially compensating the decrement of traffic and industry, which in Florence are not impacting very much in the city. It should be noted that the effects of traffic into cities and the estimation of predictions for the NOX on the basis of traffic, wind direction, and structured of the city are studies and produced by the TRAFAIR project, of which the results for Tuscany area are available on Snap4City Dashboards (Po et al. 2020).

Table 2. Reduction of the pollutant in the period of Lockdown with respect to February 2020.

	CO2	CO	NO2	PM10
Percentage at which the average value of the pollutant has been reduced (February wrt April, 2020)	41,06	47,54	38,84	61,99
Percentage at which the MAX value of the pollutant has been reduced (February wrt April 2020)	38,89	34,62	63,02	60,21

6. Conclusions

The analysis performed has identified a strong reduction in mobility rates and transport activities in line with what has been described by Google Global mobility reports. In addition, this also evidenced a number of detailed aspects that allowed us to better judge the impact of the lockdown and the potential effects of reopening on an eventual revamping of the infection computing and observing the Rt and its trend. To this end, the data collected from the field have been compared to those of Google and some considerations with respect to the Imperial college Report 20 have been derived. It is probably too early to draw conclusions, since this report was written on? the 10th of May, only 6 days after the formal reopening of the 4th. The resulting traffic volume has been repristinated to more than the 53%, which is a +33% with respect to the lockdown situations. This indicator and similar ones will be monitored and highlighted in view of the future return of tourists in Florence UNESCO site (as pilot of Herit-Data project). For parking, we still have to see an increase in their usage with respect to the lockdown conditions. As regard the environmental variables, and thus or air quality, the amount of pollutant has been strongly reduced by the lockdown. The largest reductions have been recorded with regards to NO2 (also due to the reduction of traffic), CO, PM10 and CO2 due to the reduction in the number of activities carried out by human activities.

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