The 30 km/h Speed Limit in Bologna: Effects on Mobility and Air Quality

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1 Introduction

In January 2024, Bologna implemented a city-wide urban mobility reform by establishing a 30 km/h speed limit on most of its streets, aligning with the principles of the "Vision Zero" and "Safe System" approaches. This measure aims to significantly enhance road safety, foster sustainable transport modes, and improve urban livability. It forms part of Bologna's Sustainable Urban Mobility Plan (SUMP), prioritizing pedestrians, cyclists, and public transit users over automobile traffic, a strategy consistent with broader European trends observed in cities such as Brussels, Paris, and Bilbao [4, 7].

The introduction of the 30 km/h limit triggered considerable public discourse and political debate. Advocates emphasize the proven safety benefits, such as reduced severity and frequency of road accidents, particularly benefiting vulnerable road users like pedestrians and cyclists [9]. Additionally, lower speeds are associated with improved air quality, reduced noise pollution, and a potential increase in active mobility behaviors, aligning closely with EU climate and sustainability targets [2].

Conversely, opponents of the policy cite concerns related to increased travel times, possible congestion, and economic implications, especially regarding commercial and logistical operations. Motorist associations and businesses have questioned the enforceability and practical effectiveness of the speed reduction without substantial parallel investments in transport infrastructure and public transit enhancement [6, 10]. This debate reflects broader tensions observed internationally between mobility reform advocates and groups prioritizing automobile-centric policies.

One year after implementation, the Bologna case presents an opportunity to empirically evaluate the policy's actual impacts. This paper specifically investigates changes in traffic patterns, bicycle usage, and air quality, employing available municipal data.

1.1 Background and Policy Context

The introduction of city-wide 30 km/h speed limits is increasingly prevalent across European urban environments, driven by initiatives such as "Vision Zero," which seeks to eliminate road fatalities and severe injuries through systemic urban redesign and regulatory measures [4, 8]. Prominent examples include Paris, which implemented a city-wide 30 km/h speed limit in 2021, and Bilbao, which adopted a similar measure in 2020. These policies have shown demonstrable reductions in vehicle speeds, accident rates, and improvements in perceived safety, encouraging increased pedestrian and cycling activity [5, 3, 1].

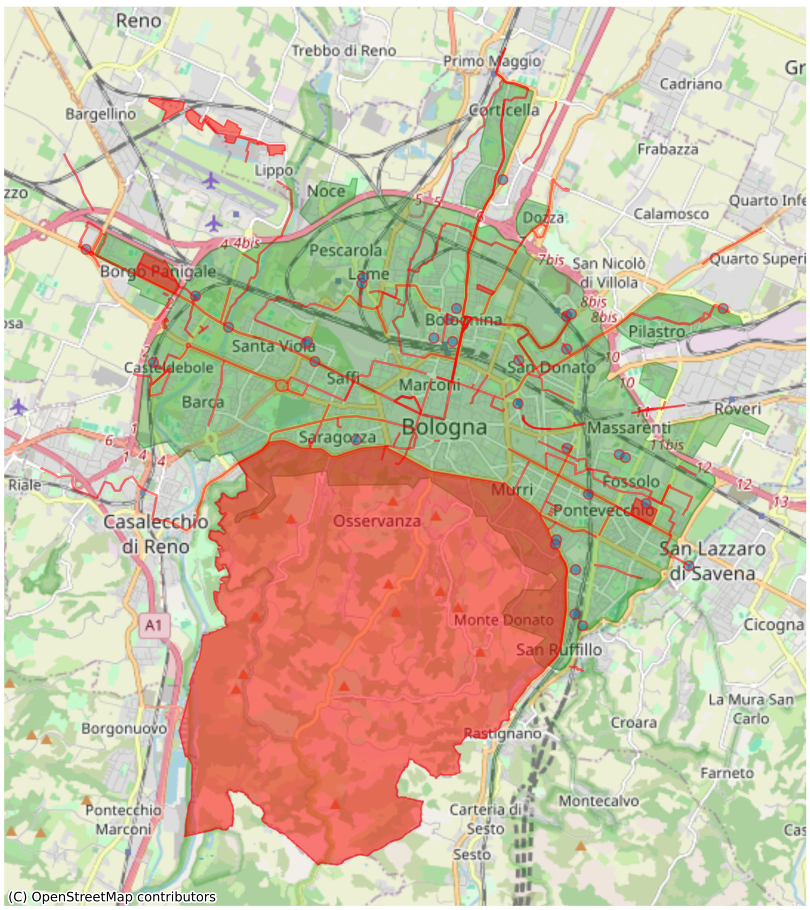


Figure 1: The extent of "Bologna Città 30" : 30 km/h zones (green), and collateral projects (red).

"Bologna Città 30", the initiative launched in January 2024, introduced a generalized 30 km/h speed limit covering most urban streets, while strategically exempting key arterial routes necessary for public transit and commercial traffic. The policy aligns explicitly with the objectives detailed in Bologna's SUMP, emphasizing improved pedestrian safety, promotion of active and micromobility solutions, and reduction in car dependency and associated emissions [7]. Integral to the implementation strategy were enhanced enforcement mechanisms, including extensive signage, speed control cameras, and public awareness campaigns designed to foster compliance and cultural acceptance of reduced speeds. In addition to the speed reduction and the enforcement, a series of collateral projects were included in the "Bologna Città 30" initiative, including realization of new bike paths, public transport improvements such as the introduction of trams, pedestrian safety measures and more.

1.2 Research Question

To what extent has Bologna's city-wide 30 km/h speed-limit reform (introduced January 2024) affected urban mobility and air quality—specifically in terms of (1) vehicular traffic volumes and their spatial redistribution, (2) alternativ mobility, as in public transport and bicycle traffic (including bike-sharing usage), and (3) ambient concentrations of key pollutants one year after implementation?

2 Used Datasets

To make the analysis possible, data coming from the Bologna open data project, a city-wide initiative that provides free, real-time access to high-quality datasets covering mobility, infrastructure, environment, culture, and social services, was used. Launched nearly a decade ago and recently upgraded to a unified platform, it ensures full compliance with European and national interoperability standards.

The datasets utilized in this study cover multiple dimensions of urban mobility and environmental monitoring, specifically including:

- **Vehicular Traffic**: Hourly data collected via underground inductive-loop sensors distributed across 314 road segments.
- **Air Quality Indexes**: Hourly pollutant measurements from three monitoring stations, tracking concentrations of $PM_{2.5}$, NO_2, PM_{10}, NO_x, benzene (C_6H_6), NO, ozone (O_3), and carbon monoxide (CO).
- **Bike Traffic**: Hourly bicycle counts from 20 automated bike counters located on key arteries connecting the city center to suburban areas.
- **Public Transportation**: Ticket validation records capturing usage patterns on the urban transit network.

While the present datasets allow for robust empirical analysis into the effects of Bologna's 30 km/h speed-limit reform, several limitations must be acknowledged.

First, a significant data constraint lies in the unavailability of 2024 road accident records at the time of writing. Given that road safety is a principal policy objective, the absence of granular crash data precludes a direct assessment of changes in accident frequency or severity. Although anecdotal reports suggest a decline in incidents, these cannot be rigorously verified.

Second, the analysis of air quality, while methodologically sound, is based on only three monitoring stations. This spatial limitation may obscure localized pollution dynamics, especially in areas with microclimatic variability or differing urban morphologies. Moreover, disentangling traffic-related emissions from other sources such as domestic heating, industrial activity, or long-range pollutant transport remains challenging, despite the use of weather controls and non-parametric testing.

Third, the data on alternative mobility—particularly cycling—are drawn from a limited sample of just four operational bike counters. Although the time-series depth compensates partially for this, the small number of spatial units restricts broader generalization and precludes the application of more sophisticated spatial models.

Fourth, the evaluation of public transportation usage is constrained by incomplete data availability. Specifically, the dataset ends in June 2024, allowing only a partial year-over-year comparison. This may fail to capture medium-term behavioral adaptations, especially in response to complementary infrastructure changes such as tramway expansion or service frequency adjustments.

Finally, while spatial analyses of traffic redistribution are supported by significant clustering patterns, the study does not incorporate direct survey or behavioral data. As a result, inferences about driver adaptation mechanisms (e.g., route substitution, mode shift, trip suppression) remain speculative.

These limitations underscore the need for future research to incorporate more comprehensive safety, mobility, and environmental data to fully evaluate the long-term impacts of urban speed-limit reforms.

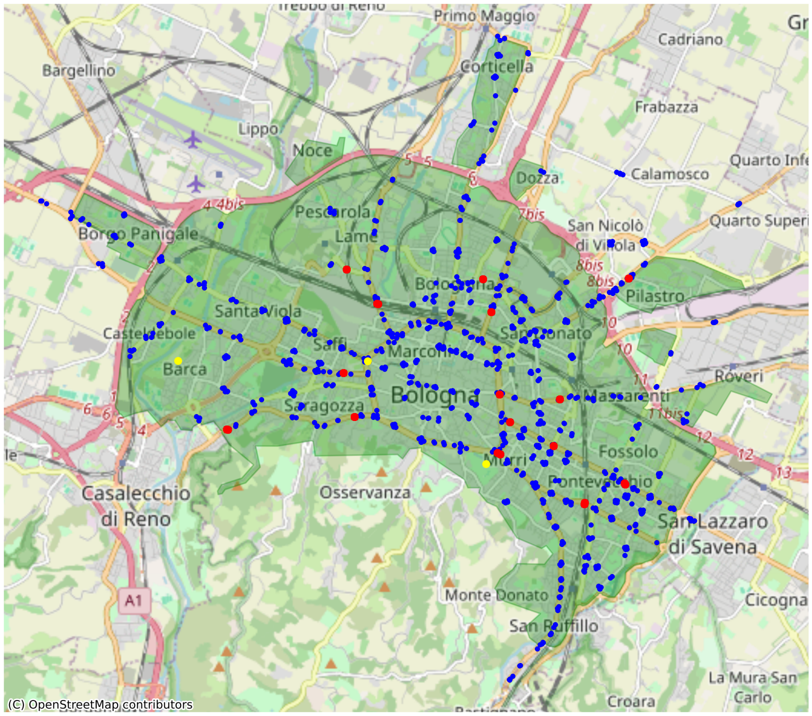


Figure 2: The location of the various sensors in the city of Bologna. In blue, car traffic sensors, in red bike counting sensors and in yellow air quality stations

3 Analysis

3.1 Car Traffic

As seen below, the highest concentrations of vehicular activity—indicated by red and orange hues—are centered around the historical core and central districts of Bologna, including areas such as Marconi, Irnerio, and San Donato. These zones are characterized by a dense urban fabric and constitute primary nodes for economic, administrative, and commercial activities, contributing to elevated traffic volumes. Similarly, significant congestion is evident along major arterial routes and ring roads, particularly those intersecting key neighborhoods such as Saragozza, Murri, and Mazzini.

Peripheral zones such as Borgo Panigale, Corticella, and San Ruffillo exhibit moderate traffic densities, marked by yellow and green gradients, suggesting transitional zones of vehicular flow. Conversely, outlying suburban and rural areas, including those extending toward Granarolo dell'Emilia and Casalecchio di Reno, display minimal traffic activity, as indicated by cooler blue tones.

The observed traffic distribution reflects typical urban mobility patterns, with central and arterial regions absorbing the bulk of vehicular movement.

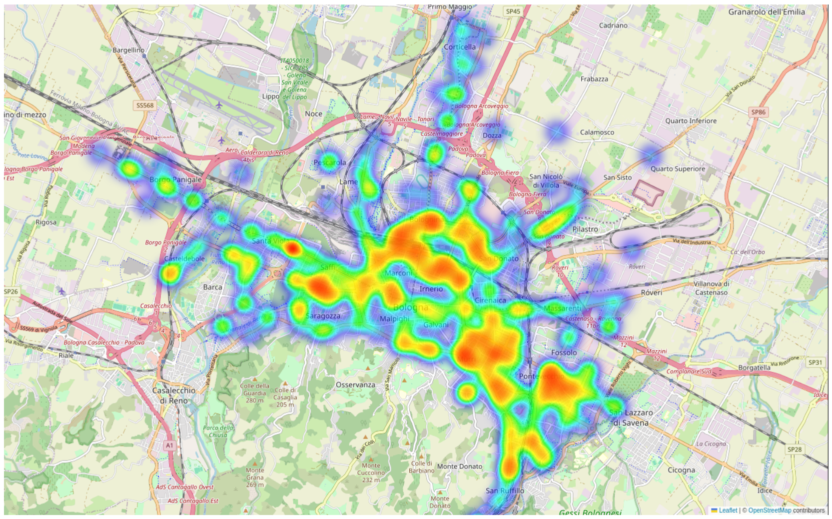


Figure 3: Heatmap of aggregated vehicular traffic across 2023-2025

Over the course of a year, vehicle volumes across Bologna decreased by 7.44% following the policy's implementation, indicating progress toward the goal of reducing road congestion. However, the impact was far from uniform across the city. As shown in Figure 4, which maps the difference in average vehicle counts before and after the policy for each traffic sensor, the effects varied widely by location.

In the historic center—particularly near Marconi Station and Giardini Margherita park—as well as in the south-eastern neighborhoods of Pontevecchio and San Ruffillo, red-tinted areas suggest that traffic levels remained stable or even increased slightly. Conversely, the north-western corridor, including districts like Borgo Panigale and Saragozza, is dominated by blue hues, indicating a significant decline in vehicle volumes.

This uneven spatial pattern implies that while the policy was effective in curbing through-traffic along the city's outer edges, it may have inadvertently redirected vehicles toward central and south-eastern routes. The result is a patchwork of traffic reduction and redistribution rather than a city-wide uniform decrease.

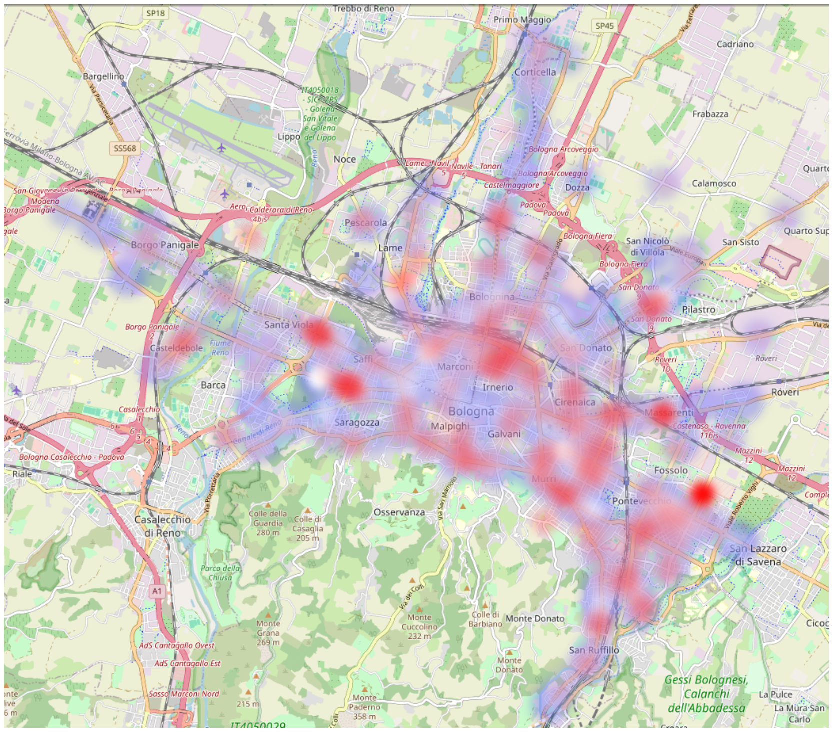


Figure 4: Difference in total vehicle traffic in pre and post policy period. Red is positive difference, blue is negative

A closer inspection of Figure 5 reveals that the sensors which lost the most traffic (blue markers, labels 11–20 in Table 1) are not randomly scattered but instead form a tight cluster in the eastern half of the pre–30 km/h zone, particularly around the San Donato–Cirenaica corridor and adjacent inner-ring collectors. Here, relative declines approach 90 % at several sites (e.g. label 15: –91.9 %, label 19: –85.4 %), signaling a concentrated "de-congestion" of the area that is one of the more important historic-centre approaches.

By contrast, the ten sensors registering the largest gains (orange markers, labels 1–10) lie almost exclusively on the outer ring roads and radial feeder routes. The strongest increases occur on the main eastern and western approaches (labels 1 and 2: +78 % and +64 %, respectively) and along the southern arc (label 9: +35 %), suggesting that motorists have redistributed their trips onto higher-capacity peripheral corridors to avoid the slower central sections.

Together, these patterns denote a clear spatial reallocation of traffic: volumes have been diverted away from the densely built, low-speed core toward the more elastic ring and access roads. Such a redistribution likely reflects drivers' route-choice adjustments in response to the new speed regime, with important implications for peripheral congestion, noise and emissions exposure, and the overall efficacy of the 30 km/h policy in reshaping urban mobility.

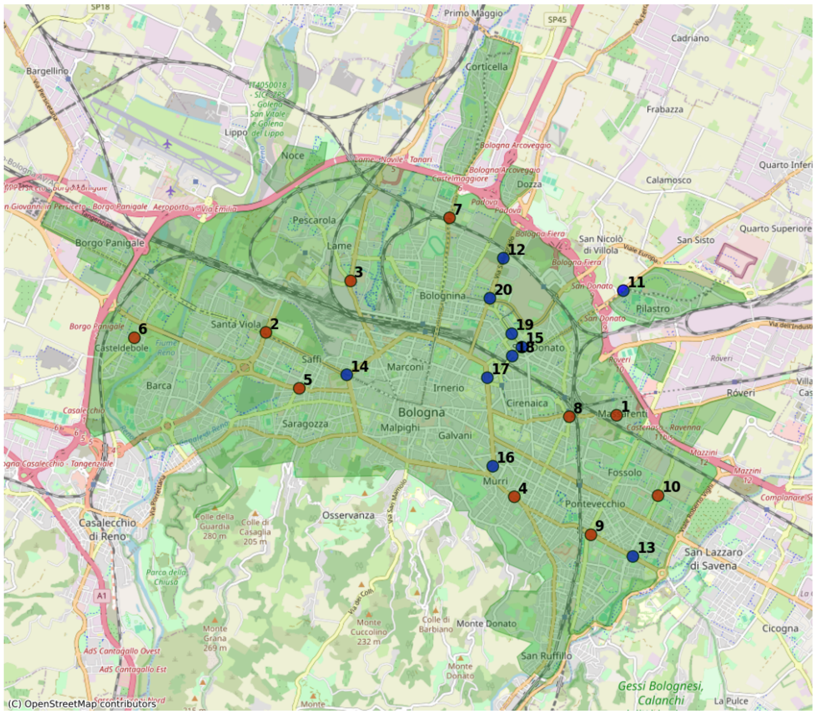


Figure 5: Map of Bologna showing the ten locations with the largest increases (red markers 1–10) and decreases (blue markers 11–20) in vehicular traffic following the policy intervention; numbered labels correspond to the values presented in Table 1.

The data reveal that, in absolute terms, the decreases in traffic volumes for individual sensors are significantly larger than the increases. This suggests that while some areas experienced slight upticks in traffic, the overall reduction was more substantial and widespread. It's likely that a high concentration of traffic from a few specific zones was redistributed across a broader area, diluting its impact and contributing to the general decline.

To quantify whether the observed clustering of gains and losses is statistically significant rather than a chance pattern we first computed a global Moran's I statistic of 0.062 (pseudo-$p = 0.009$), confirming statistically significant spatial autocorrelation in sensor-based traffic changes. A Local Moran's I (LISA) cluster analysis (Figure 6) then reveals a smooth gradient of traffic redistribution, with marked diversion away from the San Donato–Cirenaica corridor and the historic city centre toward surrounding sectors:

- **San Donato–Cirenaica de-congestion corridor.** The strongest Low–Low clustering appears along the San Donato–Cirenaica axis and its nearby collectors, where 14 of the 24 significant Low–Low sensors aggregate. At

Table 1: Top 10 Locations by Largest Positive and Negative Traffic Changes

Label	Pre-Policy	Post-Policy	Traffic Change	% Change
1	2 858 616	5 096 250	2 237 634	78.28
2	2 980 397	4 900 642	1 920 245	64.43
3	2 795 881	4 472 380	1 676 499	59.96
4	3 045 931	4 721 652	1 675 721	55.02
5	4 304 109	5 958 848	1 654 739	38.45
6	2 411 820	3 749 989	1 338 169	55.48
7	1 980 771	3 260 175	1 279 404	64.59
8	1 542 156	2 720 168	1 178 012	76.39
9	3 226 430	4 371 611	1 145 181	35.49
10	1 987 856	2 900 691	912 835	45.92
11	13 479 681	5 335 956	−8 143 725	−60.41
12	11 735 406	4 234 837	−7 500 569	−63.91
13	10 653 681	5 349 057	−5 304 624	−49.79
14	5 545 002	1 333 548	−4 211 454	−75.95
15	3 804 647	310 205	−3 494 442	−91.85
16	6 951 114	4 165 703	−2 785 411	−40.07
17	6 607 826	3 961 282	−2 646 544	−40.05
18	3 059 478	456 619	−2 602 859	−85.08
19	2 992 088	438 196	−2 553 892	−85.35
20	5 947 966	3 444 408	−2 503 558	−42.09

several nodes, volume reductions exceed 75 %, indicating a pronounced relief of one of the principal inbound approaches to the city centre.

- **Inner buffer area.** Encircling this de-congested corridor is a band of 31 Low–High and 15 High–Low outliers. Low–High sites lie just beyond the steepest drops—street segments that receive spill-inflows from the drained San Donato route—while High–Low points mark isolated local upticks, plausibly tied to park-and-ride nodes and commercial attractors within the semicentral streets.
- **Peripheral dispersal zone.** Beyond the inner buffer, 57 High–High clusters line the outer beltways and radial feeders. Motorists appear to systematically reroute onto these tangential and suburban corridors. A solitary High–High hotspot near the central station hints at a localized exception, perhaps reflecting multimodal interchange activity.

Together, these LISA clusters delineate a continuous shift in traffic: substantial de-loading of San Donato–Cirenaica and the historic core feeds gradual accretion of volume in adjacent collectors and dominant peripheral routes. This graded pattern underscores the importance of the inner buffer as a flow mediator. Tailored infrastructure enhancements or selective enforcement in this semicentral belt could thus sharpen the policy's de-congestion impact while preempting excessive spillovers onto the periphery.

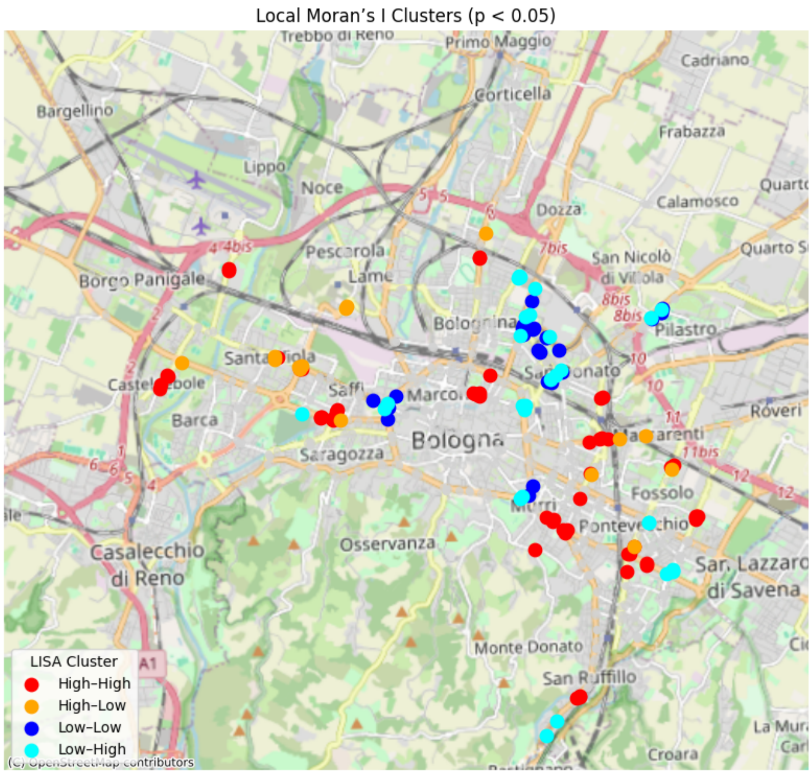


Figure 6: Local Moran's I cluster map ($p < 0.05$) showing hot- and cold-spots of traffic change.

3.2 Air Pollutants

A further indicator of the policy impact in the context of car usage is the value of air quality indicators before and after the policy.

Figures 3.2, 3.2 presents the 7-day rolling mean concentrations of the six pollutants at our three study stations, with the vertical dashed line marking the introduction of the 30 km/h limit.

NO_2 (biossido di azoto). Both Giardini Margherita (blue) and Via Chiarini (green) exhibit pronounced seasonal cycles, with winter peaks around 30–35 μg/m^3 and summer minima near 5–10 μg/m^3. Porta San Felice (orange) maintains a substantially higher baseline (40–55 μg/m^3 in winter), but after the policy date it shows a clear and sustained downward shift of 10–15 μg/m^3 relative to the pre-policy period, consistent with reduced traffic emissions on this peripheral corridor.

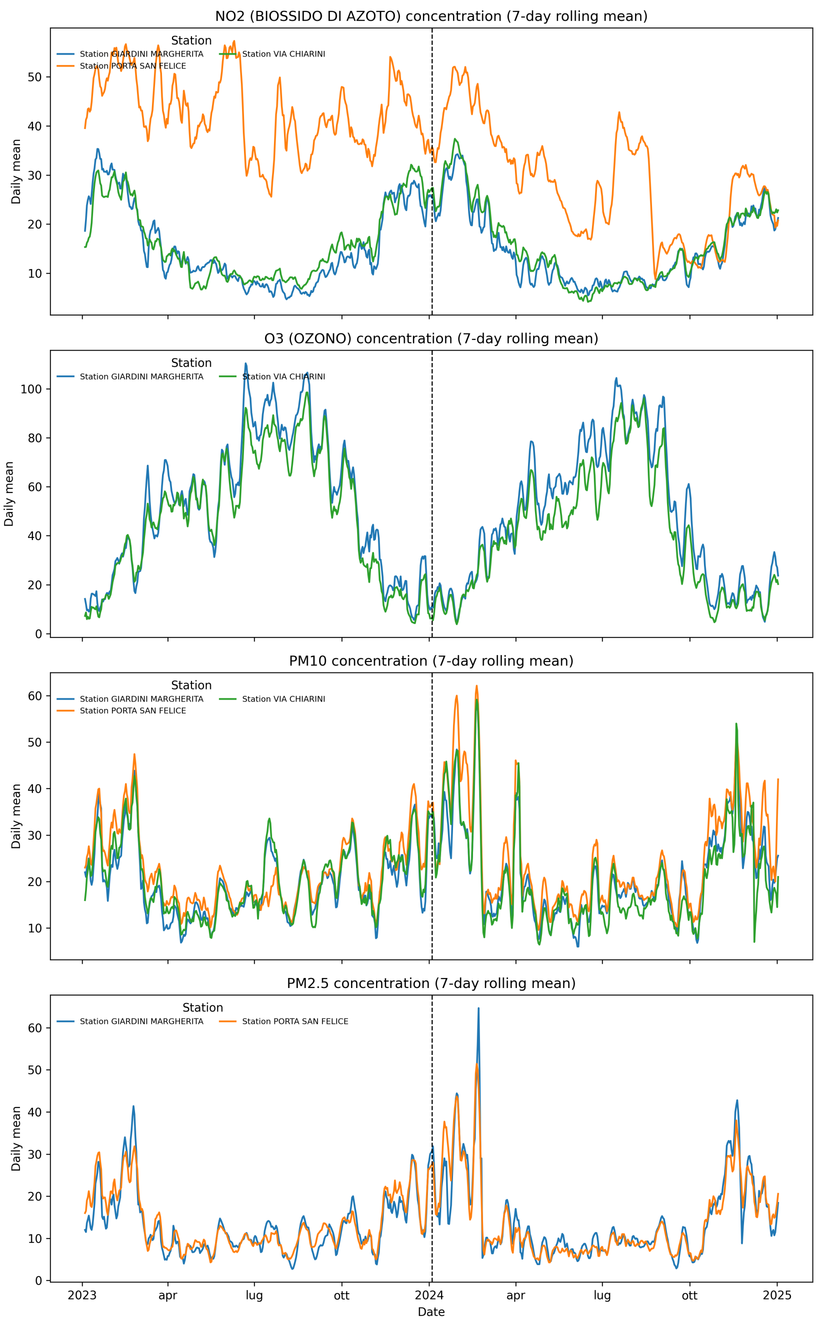
O_3 (ozono). All stations follow the well-known photochemical cycle, rising from spring troughs (10–20 μg/m^3) to midsummer peaks above 80–100 μg/m^3 before declining in autumn. Neither Giardini Margherita nor Via Chiarini shows an obvious level change at the policy date; if anything, the post-policy spring rebound is slightly muted at Via Chiarini, suggesting a marginal reduction in precursor emissions.

PM_{10} and $PM_{2.5}$. Coarse (PM_{10}) and fine ($PM_{2.5}$) particulate concentrations track each other closely at all sites, with episodic winter spikes (road salt, domestic heating) and summer lows near 5–10 μg/m^3. There is no pronounced, uniform level shift in $PM_{2.5}$. PM_{10} at Via Chiarini and Porta San Felice shows a modest decline in the months following the policy, but the effect is smaller than for NO_2.

C_6H_6 (benzene) and CO (monossido di carbonio) at Porta San Felice. Benzene and CO both decline gradually from early 2023 onward, but only CO exhibits a discernible drop immediately after the policy date (from 0.8–1.0 mg/m^3 down to 0.3–0.5 mg/m^3). Benzene remains relatively stable around 0.7–1.0 μg/m^3, indicating limited policy impact on volatile organic emissions at this site.

NO (monossido di azoto) and NO_x (ossidi di azoto) at Porta San Felice. Both NO and total NO_x display the strongest post-policy declines of all series: daily means fall from 40–60 μg/m^3 to 10–20 μg/m^3 for NO, and from 100–130 μg/m^3 to 30–60 μg/m^3 for NO_x. This sharp decrease underscores the substantial reduction in fresh tailpipe emissions on the peripheral ring road following implementation of the 30 km/h limit.

To rigorously assess whether observed changes in ambient pollutant concentrations can be attributed to the 30 km/h speed limit—rather than to coincident meteorological variation—we employed both regression-based and nonparametric testing strategies. First, for each station–pollutant pair we estimated an ordinary least-squares model of daily concentration as a function of policy period (pre vs. post), mean temperature, precipitation and seasonal dummies. The coefficient on the post-policy indicator thus represents the weather-adjusted policy effect. Second, we conducted independent-samples Mann–Whitney U tests on (a) the raw daily values stratified by wet vs. dry days and (b) the model residuals (i.e. observed minus weather-predicted concentrations). Together, these complementary methods allow us to isolate systematic shifts in NO_x, O_3, PM and other species while controlling for confounding by temperature and rainfall, and to confirm the robustness of any detected change in air quality.


NO2 (BIOSSIDO DI AZOTO) concentration (7-day rolling mean)
Station
Station GIARDINI MARGHERITA
Station PORTA SAN FELICE
Station VIA CHIARINI
Daily mean
O3 (OZONO) concentration (7-day rolling mean)
Station
Station GIARDINI MARGHERITA
Station VIA CHIARINI
Daily mean
PM10 concentration (7-day rolling mean)
Station
Station GIARDINI MARGHERITA
Station PORTA SAN FELICE
Station VIA CHIARINI
Daily mean
PM2.5 concentration (7-day rolling mean)
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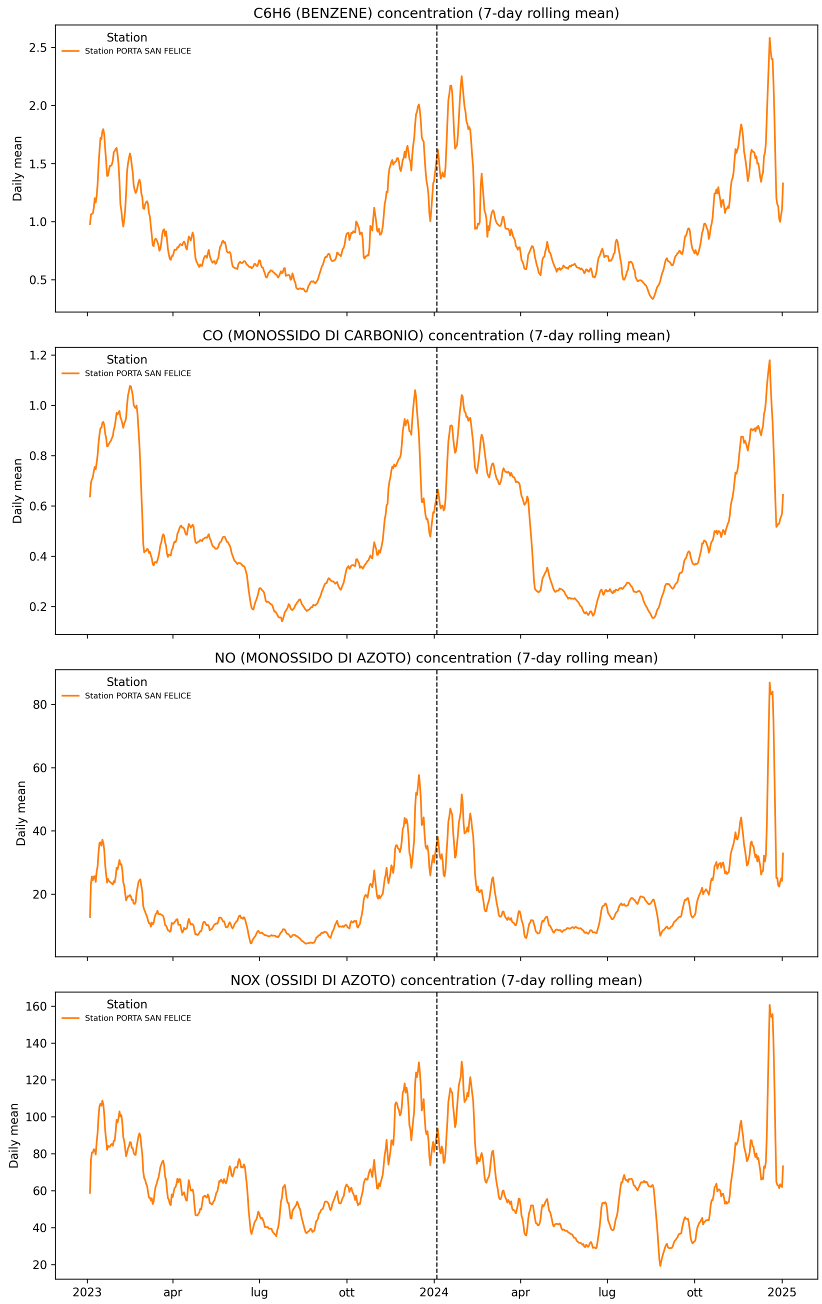

The results in Table 2 indicate that the 30 km/h policy produced its most robust air-quality benefits in nitrogen-oxide species and in ozone, with a modest impact on PM_{10}. At Porta San Felice, we observe highly significant declines in

Table 2: Significant Air-Quality Changes after 30 km/h Policy (Residual-Based Mann–Whitney U)

Station	**Pollutant**	$\mathbf{p}_{\mathrm{MW}}$	**Effect**
Giardini Margherita	O_3	0.027	Small but significant reduction in ozone.
Porta San Felice	NO	4.82×10^{-10}	Very strong decrease in nitric oxide.
Porta San Felice	NO_2	3.00×10^{-51}	Very strong decrease in nitrogen dioxide.
Porta San Felice	NO_x	7.88×10^{-7}	Significant reduction in total nitrogen oxides.
Via Chiarini	O_3	4.97×10^{-4}	Clear decrease in ozone at this semi-central collector.
Via Chiarini	PM_{10}	1.33×10^{-2}	Moderate but significant drop in coarse particulates.

NO, NO_2 and total NO_x, reflecting the strong reduction of tailpipe emissions on this peripheral corridor. At Via Chiarini, both O_3 and PM_{10} concentrations decrease significantly, suggesting that lower-speed traffic in the transition belt reduced both photochemical ozone formation and road-dust resuspension. In contrast, only ozone at Giardini Margherita shows a small but statistically significant drop, implying that central-park areas experienced weaker secondary-pollutant responses. These findings underscore how the reduction in max speed has likely resulted in decreased acceleations and decelerations, resulting in a clear decline in tailpipe emissions whose primary markers are Nitrous Oxides.

3.3 Alternative Mobility

The next step in assessing the impact of the policy would be to investigate the effect on alternative mobility solutions, such as bike and public transport. The municipality of Bologna has installed since 2019 a total of 20 bike counting sensors, of which only 4 were active at the start of the analysis period. Overall, across such sensors a 7.7% increase in bike flows was recorded after the introduction of the policy. As evident in 3, the routes that add the most percentage increase were indeed the ones where the traffic flow diminished the most, i.e. North-Eastern routes of access to the center(San Donato, Parri, Ercolani).

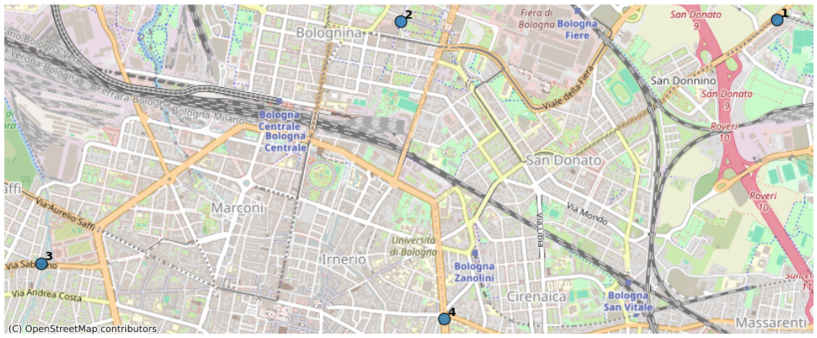

Figure 7: Bike counting stations taken into consideration

Table 3: Changes in Totale by Colonnina After 30 km/h Policy

Label	**Colonnina**	**Difference**	**Pct Change (%)**
1	San Donato	23448.00	11.95
2	Parri	32304.00	11.71
3	Sabotino	32478.00	3.33
4	Ercolani	96985.00	10.08

To better asses the policy effects on bike usage, we employ a *two-way fixed effects* (FE) panel regression model using ordinary least squares (OLS). This method is commonly used in econometrics to analyze panel data—data that varies across both space (e.g., different sensors or locations) and time (e.g., daily or monthly observations).

Fixed effects refer to accounting for all unobserved, time-invariant characteristics of observational units. In our case, this means adjusting for differences between bike-count stations (e.g., location, street design, land use) that do not change over time.

The OLS estimator in this context isolates the effect of key explanatory variables (e.g., nearby car traffic, weather conditions) by leveraging variation within each station over time, thus reducing bias from confounding factors that remain constant.

This approach is particularly well-suited to datasets with a small number of spatial units (e.g., four bike stations) but a long time series (e.g., daily data over two years), as it allows for credible inference even in the absence of large cross-sectional variation. The two-way fixed-effects panel regression at the daily level for each bike-count station i and date t is:

$$\mathrm{Bike}_{it} \;=\; \alpha_i \;+\; \lambda_t \;+\; \beta\,\mathrm{Car}_{it} \;+\; \gamma_1\,\mathrm{Rain}_t \;+\; \gamma_2\,\mathrm{Temp}_t \;+\; \varepsilon_{it}, \tag{1}$$

where:

- Bike_{it} is the total number of bicycle passages recorded at station i on day t.
- Car_{it} is the total count of motor vehicles within a 2000 m buffer around station i on day t.
- Rain_t and Temp_t are daily precipitation (mm) and average temperature (°C), respectively.
- α_i is a fixed effect, controls for all time-invariant station characteristics (e.g. street geometry, land use).
- λ_t is a fixed effect, captures common shocks and seasonality (e.g. weekday effects, holiday patterns).
- ε_{it} is an error term, clustered by station to allow for arbitrary within-station serial correlation.

To assess whether the policy intervention altered the car–bike relationship, we augment Equation 1 with a post-policy indicator $\mathbb{1}_{t \geq T_0}$ and its interaction:

$$\text{Bike}_{it} = \alpha_i + \lambda_t + \beta\, \text{Car}_{it} + \delta\, \mathbb{1}_{t \geq T_0} + \theta\, (\text{Car}_{it} \times \mathbb{1}_{t \geq T_0}) + \gamma_1\, \text{Rain}_t + \gamma_2\, \text{Temp}_t + \varepsilon_{it}.$$

This panel regression approach is necessary as a pure spatial autoregressive (SAR) model of the form

$$\text{Bike}_i \;=\; \rho \sum_j w_{ij}\, \text{Bike}_j \;+\; X_i \beta \;+\; \varepsilon_i$$

requires sufficient cross-sectional observations (N) to identify the spatial-lag parameter ρ and the covariate effects simultaneously. In our setting $N = 4$ bike stations, which is far too small to (i) estimate a non-singular 4×4 spatial-weights matrix W, and (ii) recover precise standard errors on ρ and β. By contrast, the panel framework leverages the rich time series dimension ($T \approx 730$ days) to:

1. Sweep out unobserved, time-invariant station heterogeneity via α_i.
2. Capture common temporal shocks via λ_t.
3. Retain identification of the car-bike slope β and weather effects γ_1, γ_2 from within-station, across-time variation.

Thus, with only four spatial units but two years of daily data, the panel regression delivers much more credible inference than a cross-sectional SAR could.

Table 4 presents our preferred specifications. Column (1) reports the baseline two-way fixed-effects model with explicit weather controls, and Column (2) adds the interaction between daily car counts and the post-policy indicator.

Table 4: Daily Panel Regressions of Bike Counts on Car Counts and Weather

	(1) Baseline FE + Weather	(2) + Car × Post
car_count	0.0063*** (0.0020)	0.0075*** (0.0021)
car_count×post		0.0016*** (0.0004)
rain_mm	−15.89*** (4.88)	−18.42*** (5.71)
temp (°C)	30.28*** (9.28)	32.71*** (9.87)
Within R^2	0.2955	0.4516

Standard errors clustered by station in parentheses.

$^{***}p < 0.01$.

In Column (1), an additional car in the 2000 m buffer is associated with approximately 0.0063 more bike counts per day ($p < 0.01$).As expected, rainfall depresses cycling by about 16 rides per millimeter ($p < 0.01$), while each 1 °C increase in average temperature raises ridership by roughly 30 bikes per day ($p < 0.01$).

Column (2) shows that the slope of the car–bike relationship becomes even steeper after the policy: the interaction term implies an additional 0.0016 bikes per car post-policy ($p < 0.01$), for a combined post-policy slope of 0.0091. The weather effects remain stable and highly significant. Taken together, the bike-traffic regressions show that the 30 km/h reform didn't just modestly boost cycling; it actually strengthened the link between motorized and active mobility, suggesting complementary, rather than substitutive, dynamics in the city's transport mix.

To analyze the efficiency of Bologna's public transport system before and after the implementation of the 30 km/h policy a passengers-per-vehicle-kilometer (load factor) metric was used. The load factor is calculated as:

$$\text{Load Factor} = \frac{\text{Monthly Ticket Validations}}{\text{Total Vehicle-Kilometers Operated}}$$

A regression model controlling for monthly seasonality indicates a positive but statistically insignificant increase of 0.0194 in load factor post-policy (p = 0.946). While the visual trend (see figure 8 post-January 2024 suggests a slight improvement, this effect is not robust to statistical testing. These results imply that, within the available timeframe and data granularity, the policy's impact on public transport efficiency cannot be conclusively determined. Further monitoring over a longer horizon may be required to capture behavioral and system-level adaptations more clearly.

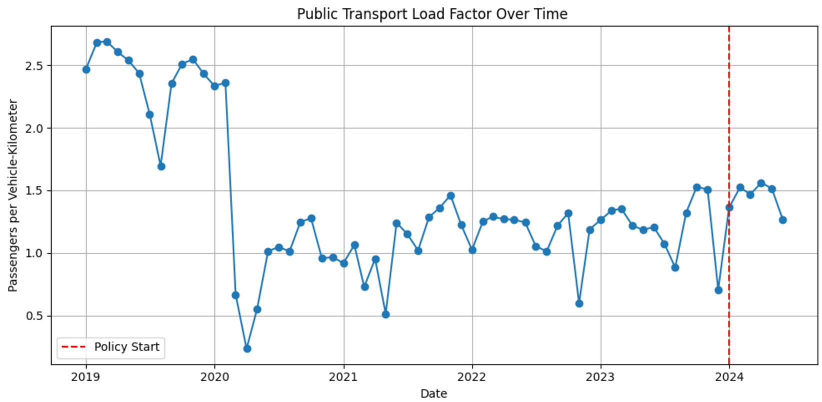

Figure 8: Monthly evolution of the public transport *load factor* in urban Bologna from 2019 to mid-2024. The vertical dashed line marks the introduction of the 30 km/h city-wide speed limit in January 2024.

4 Conclusions

One year after the implementation of Bologna's city-wide 30 km/h speed limit, the empirical evidence reveals a multifaceted transformation of the urban mobility and environmental landscape. The policy's effects are complex and spatially heterogeneous, yet its overarching impacts suggest meaningful strides toward the goals of Bologna's Sustainable Urban Mobility Plan and the broader Vision Zero agenda.

First, the analysis of vehicular traffic indicates a statistically significant 7.44% reduction in overall traffic volumes, with marked spatial reallocation rather than uniform decline. Central and historically congested corridors, particularly in the San Donato–Cirenaica axis, experienced pronounced decongestion, while peripheral arterial routes absorbed much of the diverted traffic. The clustering analysis confirms that this redistribution is not random, but structured, with implications for peripheral air quality and congestion dynamics. This shift underscores the importance of strategically managing secondary effects through coordinated planning and infrastructure enhancement in transitional zones.

Second, the air quality assessment demonstrates that the 30 km/h policy contributed to measurable environmental benefits. The most significant reductions were observed in nitrogen oxides, particularly along the Porta San Felice corridor, suggesting a substantial decline in tailpipe emissions attributable to smoother traffic flow and reduced acceleration-deceleration cycles. Moderate declines in PM10 and ozone levels at select locations further corroborate this trend, though the absence of uniform improvement across all pollutants and monitoring sites indicates that ambient air quality remains influenced by additional factors such as meteorological variability and non-traffic-related sources.

Third, the findings on alternative mobility patterns provide preliminary evidence of a modal shift. A 7.7% increase in bicycle usage—most pronounced along corridors where vehicular traffic declined—suggests a behavioral adaptation in response to improved cycling conditions. The panel regression analysis reinforces this link, revealing a strengthened positive relationship between decreased car usage and increased bike traffic post-policy. These results suggest that the speed limit reform may act synergistically with other pro-cycling infrastructure investments to promote sustainable transport modes.

Overall, Bologna's 30 km/h initiative illustrates the potential and challenges of urban speed management as a lever for sustainable mobility and environmental improvement. While the reform achieved tangible gains in traffic calming and emissions reduction, its uneven spatial impacts call for targeted secondary interventions. Future research should incorporate accident data when released and longitudinal behavioral indicators to fully capture the safety and modal shift outcomes. Nonetheless, the Bologna case contributes valuable empirical support to the evolving narrative of European urban transport reform, highlighting the efficacy of integrated, data-driven policy approaches in reconfiguring urban mobility systems.

References

[1] L. Cavalli, J. Pérez, and A. Rossi. Urban speed limits and their impacts on mobility: Lessons from european cities. *Journal of Urban Transport Studies*, 15(2):101–120, 2023.

[2] European Commission. Eu urban mobility framework, 2022.

[3] Bilbao City Council. Urban mobility report 2021, 2021.

[4] European Transport Safety Council. Vision zero and safe system approaches in european cities, 2022.

[5] Ville de Paris. Rapport d'évaluation des zones à 30 km/h, 2022.

[6] Il Resto del Carlino. Bologna, polemica sui limiti a 30 km/h: commercianti preoccupati. `https://www.ilrestodelcarlino.it/`, 2023.

[7] Comune di Bologna. Piano urbano della mobilità sostenibile (pums). `https://www.comune.bologna.it/`, 2023.

[8] International Transport Forum. Vision zero: A global road safety initiative, 2021.

[9] World Health Organization. Speed management: A road safety manual for decision-makers and practitioners, 2022.

[10] La Repubblica. Limiti a 30 km/h, bilancio dopo un anno di polemiche e consensi, 2024. Published: 10 January 2024.