**Influence of Lane-Based Traffic Flow and Speed on Urban Air Pollution Levels: A Case Study from Tashkent**

Kudratulla Azizov1, a) and Amir Beketov1, b)

1*Tashkent State Transport University, 1 Temiryulchilar St., Tashkent 100167, Uzbekistan*

*a) azizov\_q@tstu.uz   
b) Corresponding author:beketovamir@tstu.uz*

**Abstract.** This study explores the influence of traffic lane position and average vehicular speed on the concentrations of key air pollutants (CO, NO, NO₂, SO₂) within an urban street environment. Empirical data were obtained during the spring of 2025 through field measurements carried out on smooth, defect-free sections of 4-, 6-, and 8-lane urban roads in Tashkent under favorable weather conditions. The analysis focuses on how pollutant levels vary across different traffic lanes—from the outermost right to the innermost left—relative to their average speed. Results indicate a clear gradient: the highest pollution levels occur in the right-most lanes, where traffic tends to be slower and less consistent, particularly due to public transport stops and vehicle loading/unloading. Pollutant concentrations decline progressively in the central and left lanes, where speed and flow are more stable. This effect was most pronounced for nitrogen oxides (NO and NO₂), which frequently surpassed the allowed limits, whereas CO and SO₂ typically remained within acceptable thresholds. The findings point to the significant role of interrupted traffic flow in exacerbating local air pollution. Policy recommendations include minimizing heavy-duty vehicle presence in curbside lanes during peak hours and optimizing traffic fluidity to reduce localized emissions. These insights support the development of more environmentally informed street planning and urban traffic control strategies.

**Keywords:** urban air quality, traffic speed, lane configuration, emission patterns, nitrogen oxides, carbon monoxide, sulfur dioxide, field measurement, traffic control, Tashkent

**INTRODUCTION**

Air pollution stemming from vehicle emissions remains a critical environmental concern in densely populated urban areas with high traffic intensity. A substantial share of harmful pollutants—such as carbon monoxide (CO), nitrogen oxides (NO and NO₂), and sulfur dioxide (SO₂)—is emitted at street level, directly affecting the environment in which city residents live and move.

Numerous research efforts have emphasized that traffic parameters—particularly vehicle speed and lane usage—exert a notable influence on the concentration of airborne pollutants. Variations in speed and lane distribution shape the emission rates of nitrogen oxides, fine particulate matter (PM2.5), and other pollutants prevalent in the urban atmosphere [1, 2]. For instance, elevated speeds may contribute to increased emissions due to greater fuel consumption, whereas uneven lane distribution can exacerbate congestion, thereby intensifying pollutant accumulation [3, 4]. Additionally, meteorological conditions such as wind direction and speed significantly affect the dispersion patterns of pollutants, altering local exposure levels [1, 5]. Some studies have also pointed out that traffic-generated micropollutants like polycyclic aromatic hydrocarbons (PAHs) are prone to accumulating in heavily congested areas, reinforcing the importance of lane allocation in pollutant dispersion dynamics [6].

It is therefore evident that factors beyond traffic volume and vehicle type—such as the spatial distribution of lanes and the prevailing travel speeds—are crucial determinants of air quality along urban streets. Notably, edge lanes, particularly the rightmost lanes, often experience reduced speeds, more frequent acceleration and deceleration, and a higher presence of heavy-duty and public transport vehicles. In contrast, central and left-hand lanes tend to support smoother and faster traffic flow.

In light of these considerations, the present study investigates how lane positioning and average vehicle speeds influence the distribution of air pollutants along urban road sections with different lane configurations (4, 6, and 8 lanes). The fieldwork was conducted in spring 2025 under meteorologically favorable conditions, specifically on straight and well-maintained road segments, to minimize external variables and isolate the effects of traffic flow characteristics.

**METHODOLOGY**

This research was carried out in Tashkent on level, straight urban street segments with differing lane configurations, specifically those featuring 4, 6, and 8 traffic lanes. The selected study sites included: Sarikul Street, Eski-Sarikul Street, Beruniy Street, Nurafshon Street, Nukus Street, Amir Temur Avenue, Shakhrisabz Street, Makhtumkuli Street, Alisher Navoi Street, Mukimiy Street, Shota Rustaveli Street, Fargona Yuli Street, and Mirzo Ulugbek Street.

Each location was chosen based on a consistent set of selection criteria designed to reduce external influencing factors and ensure uniform measurement conditions:

* absence of road surface defects such as potholes, cracks, or deformations;
* smooth pavement quality to support uninterrupted vehicle flow;
* lack of intersections, bus stops, and traffic signals within the measured segment;
* favorable meteorological conditions, with ambient temperatures ranging from +15 °C to +25 °C, no precipitation, and light wind;
* all measurements were conducted in April 2025 during the spring season.

The objective of these criteria was to establish comparable baseline conditions across all lanes and street types.

Pollutant concentrations and traffic characteristics were recorded separately for each traffic lane, with specific attention to average speed and lane location:

* Lane 1 (outer/rightmost): typically, the most congested and slow-moving;
* Lane 2: moderate flow with increased average speed;
* Lanes 3 and 4 (where applicable): highest speeds and minimal interruptions.

For each lane, the following parameters were collected:

* levels of air pollutants (CO, NO, NO₂, SO₂), measured using a portable gas analyzer (Harwest E4000 model);
* average traffic speed, calculated using stopwatch timing in combination with video analysis;
* time of day and observation duration, with measurements primarily occurring during peak traffic periods (morning and daytime hours).

The resulting dataset was categorized by road type (based on the number of lanes), individual lane number, and pollutant type. Graphical analysis was used to illustrate the correlation between pollutant concentrations and vehicle speeds for each lane, with linear trend lines applied to support both qualitative observation and quantitative evaluation.

This methodological approach made it possible to identify intra-road variations in pollution levels depending on traffic lane characteristics and vehicle speed, enabling deeper insights into localized emission patterns within urban traffic flows.

**RESULTS AND DISCUSSION**

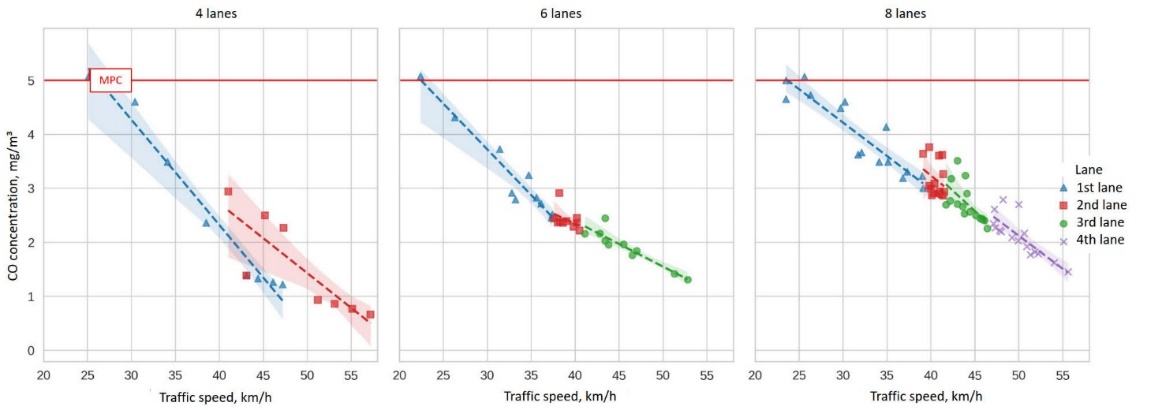
The analysis demonstrated that pollutant levels are influenced not only by the overall volume of traffic but also by the specific lane position and the average travel speed within each lane. Across all studied street types, a consistent pattern emerged: lower average speeds—typically recorded in the outermost (first) lane—correspond with elevated pollutant concentrations.

As shown in Figure 1, which depicts the relationship between CO concentration and average vehicle speed across lanes for streets with 4, 6, and 8 lanes, the following trends were observed:

* Lane 1 (rightmost) exhibited the highest levels of carbon monoxide, corresponding to the slowest traffic speeds, generally within the 25–40 km/h range;
* Lane 2 displayed moderate CO concentrations;
* Lanes 3 and 4, where applicable, registered the lowest CO levels, with traffic moving at higher speeds between 45–60 km/h.

Although a noticeable rise in CO concentration was identified in the right-hand lanes, the measured values in most instances did not exceed the Maximum Permissible Concentration (MPC) limit of 5.0 mg/m³. This finding may be attributed to the relatively efficient combustion of fuel at moderate engine loads and smoother vehicle operation at consistent speeds.

These results highlight the significance of lane-specific traffic dynamics in shaping localized air quality conditions. Slower speeds and frequent decelerations—characteristic of curbside lanes—contribute to pollutant buildup, while higher and more stable speeds in central lanes help reduce emission intensity. This underscores the need for targeted traffic management measures that consider intra-road variations in speed and flow to mitigate urban air pollution more effectively.

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**FIGURE 1.** Relationship between carbon monoxide (CO) concentration and average vehicle speed across traffic lanes on urban streets with 4, 6, and 8 lanes

Figures 2 through 4 reveal patterns similar to those observed for CO, further emphasizing the impact of lane-specific vehicle speeds on pollutant accumulation.

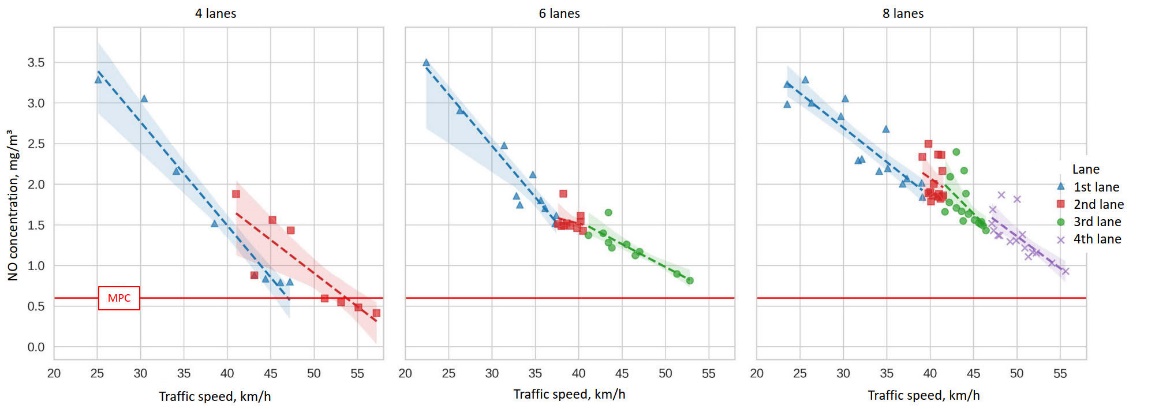
For nitric oxide (NO) and nitrogen dioxide (NO₂), the data show frequent and substantial exceedances of their respective Maximum Permissible Concentration (MPC) limits across nearly all measured segments.

* NO consistently surpasses the 0.6 mg/m³ threshold, especially in right-hand lanes where speeds are lower and traffic interruptions are frequent.
* NO₂, with a stricter MPC of 0.085 mg/m³, demonstrates even more widespread exceedances, highlighting its greater toxicity and the sensitivity of urban environments to this pollutant, even under moderate emission rates.

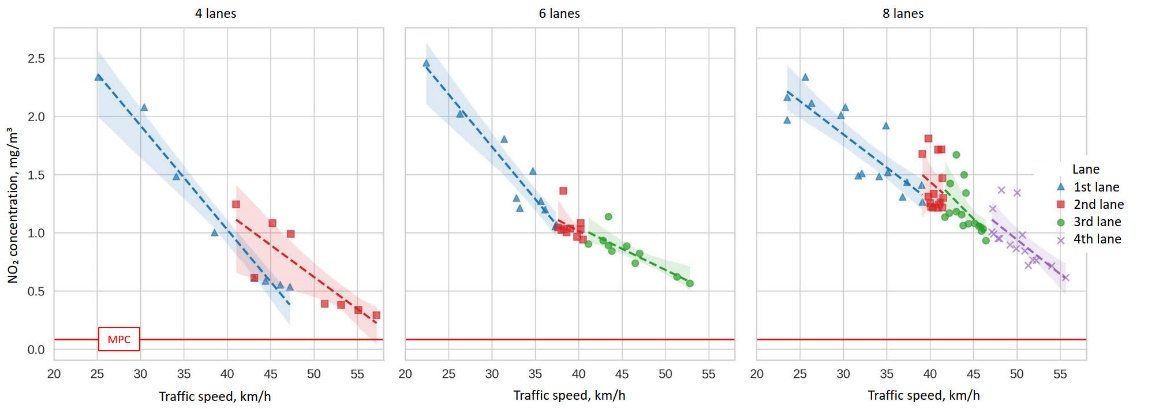
In contrast, the distribution pattern for sulfur dioxide (SO₂) is more variable. Elevated concentrations primarily occur in first-lane segments, where the presence of heavy vehicles is more pronounced.

* While the outer lanes occasionally record values above the permissible limit, left and center lanes generally maintain SO₂ concentrations within regulatory standards.
* Overall, the data suggest a balanced distribution for SO₂, with exceedances noted in approximately half of the observed cases.

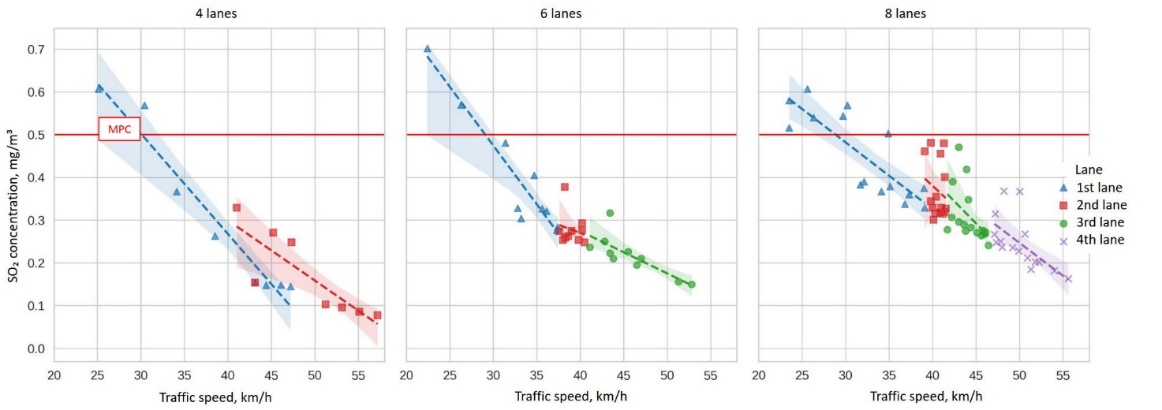
These findings reinforce the importance of lane-specific traffic characteristics in shaping the spatial distribution of air pollutants. They also emphasize the need for targeted emission mitigation strategies, particularly in rightmost lanes where pollutant buildup is most acute.

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**FIGURE 2.** Relationship between NO concentration and average traffic speed by lane (4-, 6-, and 8-lane roads)

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**FIGURE 3.** NO₂ concentration trends versus vehicle speed and lane position across urban street types

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**FIGURE 4.** SO₂ concentration by lane and speed, highlighting heavy vehicle influence in outer lanes

**TABLE 1.** Mean concentrations of major air pollutants (CO, NO, NO₂, SO₂) recorded by lane number across streets with 4-, 6-, and 8-lane configurations in Tashkent.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Number of lanes | Lane Number | Speed, km/h | CO, mg/m³ | NO, mg/m³ | NO₂, mg/m³ | SO₂, mg/m³ |
| 4 | 1 | 45.2 | 1.301 | **0.828** | **0.574** | 0.149 |
| 4 | 2 | 54.2 | 0.807 | 0.510 | **0.351** | 0.091 |
| 6 | 1 | 32.7 | 3.130 | **2.126** | **1.380** | 0.400 |
| 6 | 2 | 39.0 | 2.940 | **1.542** | **1.053** | 0.277 |
| 6 | 3 | 45.8 | 1.570 | **1.219** | **0.836** | 0.217 |
| 8 | 1 | 31.9 | 3.940 | **2.532** | **1.735** | 0.452 |
| 8 | 2 | 40.6 | 3.156 | **2.027** | **1.398** | 0.369 |
| 8 | 3 | 44.2 | 2.702 | **1.725** | **1.181** | 0.309 |
| 8 | 4 | 50.1 | 2.113 | **1.353** | **0.938** | 0.246 |
| etc. | — | — | — | — | — | — |

*Note: The table displays average pollutant concentrations calculated per lane across different street types. While simplified for clarity, the full dataset comprises more than 20 unique combinations of lane positions and corresponding average vehicle speeds, providing a comprehensive foundation for statistical and graphical analysis.*

The findings confirm that both lane position and average vehicle speed exert a significant influence on the distribution of urban air pollutants.

Across all road types—4, 6, and 8 lanes—the first (rightmost) lane consistently recorded the highest concentrations of measured pollutants. Several contributing factors likely explain this pattern:

* lower average travel speeds observed in curbside lanes;
* increased frequency of stop-and-go conditions, braking, and lane-changing maneuvers;
* a higher proportion of heavy-duty and public transport vehicles, which are known to emit larger volumes of pollutants compared to light-duty vehicles.

As traffic speed increases progressively toward the center and leftmost lanes, a notable reduction in pollutant concentrations is observed. This supports two key conclusions:

* slower, inconsistent traffic flow contributes to elevated emission levels;
* faster and more uniform movement in inner lanes (2nd, 3rd, and 4th) corresponds to improved air quality, assuming other conditions are held constant.

The contrast is most pronounced on 8-lane roadways, where, for instance, CO concentrations differ by up to 0.45 mg/m³ between the 1st and 3rd lanes. This may be attributed to:

* greater overall traffic density and complexity of lane usage;
* higher volumes of freight and transit vehicles in outer lanes;
* reduced pollutant dispersion capacity in areas with dense urban infrastructure—an effect commonly known as the "urban canyon" phenomenon.

These results reinforce the necessity of accounting for lane-specific traffic patterns when designing urban air quality mitigation strategies.

**CONCLUSION**

The analysis confirmed that the highest concentrations of air pollutants—including CO, NO, NO₂, and SO₂—are consistently observed in the first (rightmost) traffic lane, irrespective of whether the road consists of 4, 6, or 8 lanes.

Core observations:

1. An inverse relationship was found between average vehicle speed and pollutant levels: when speeds decline from approximately 55–60 km/h to 25–30 km/h, the measured pollutant concentrations increase by a factor of 1.5 to 2, indicating the sensitivity of emissions to traffic flow efficiency.
2. Inner lanes (particularly the 2nd, 3rd, and 4th lanes) offer more stable traffic conditions, with fewer stops and higher, more uniform speeds, thereby contributing to lower emission levels under similar external conditions.

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