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Effect of Road Environment on Vehicular Speed: Evidence from Lucknow, India

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Abstract:

Rapid urbanization in Indian cities has led to increased vehicle ownership and pressure on existing road infrastructure, especially in mid-sized cities like Lucknow. This study investigates the effect of road environment on vehicular speed, focusing on parameters such as road width, encroachments, pedestrian activity, and surface condition. Data were collected from six key corridors in Lucknow using radar speed guns, GPS trackers, and field surveys. A total of over 1,800 observations were analyzed using statistical tools, including Pearson correlation and multiple linear regression. Results show that encroachment and pedestrian density are significantly negatively correlated with vehicle speed, while road width positively influences speed performance. GIS-based spatial analysis further identified congestion-prone zones with overlapping pedestrian and vehicle flows. The findings underscore the need for road environment-sensitive urban traffic policies and emphasize the importance of integrated planning for speed optimization and sustainable mobility in developing cities.

Keywords: Vehicular speed, Road environment, Encroachment, Urban traffic, Lucknow, GIS, Traffic congestion, Regression analysis, Mixed traffic, Speed modeling

Introduction

The rapid urbanization of Indian cities has triggered a massive expansion in vehicular ownership, placing immense pressure on existing urban road infrastructure. In cities like Lucknow, a historic yet fast-developing metropolis in northern India, this growth has led to complex traffic behavior, where vehicular speed is not only a function of vehicle type or driver psychology but also deeply influenced by the road environment. Road width, pavement quality, lane discipline, signage, intersection geometry, and roadside activities collectively determine speed patterns, often resulting in unpredictable flow and congestion.

Studies have shown that urban road environments in India are highly heterogeneous—characterized by encroachments, mixed-traffic conditions (ranging from two-wheelers to bullock carts), and unregulated parking—factors which drastically reduce average vehicular speeds and increase travel time variability (Shukla & Alam, 2021). In Lucknow, poor lane discipline and frequent bottlenecks at key junctions further exacerbate this problem, affecting not only travel efficiency but also contributing to elevated vehicular emissions and noise pollution (Verma et al., 2003). A direct correlation has been observed between road design deficiencies and reductions in average speeds, which can range between 15–30 km/h during peak hours on arterial roads (Sadat et al., 2024).

Moreover, research highlights that low vehicular speed on compromised roads results in higher emission rates per kilometer, due to increased idling and braking frequencies (Singh et al., 2016). This environmental consequence is particularly severe in urban zones like Hazratganj, Alambagh, and Gomti Nagar, where high vehicular flux interacts with densely built environments, leading to a degradation of urban air quality (Kisku et al., 2013). Thus, understanding the interplay between road environment and vehicular speed is critical for evidence-based urban mobility planning, traffic safety enhancement, and sustainable infrastructure design in cities like Lucknow.

Given this background, the present study aims to investigate how specific elements of the road environment in Lucknow influence vehicular speed using empirical data and simulation tools. This research contributes to the growing discourse on urban transportation dynamics in Indian cities and informs policy recommendations for road design optimization and speed regulation.

Literature Review

Vehicular speed in urban environments is deeply influenced by the surrounding road infrastructure, traffic volume, and land use patterns. Several studies across India emphasize the strong correlation between road design features—such as lane width, surface quality, signage, and intersection geometry—and vehicle behavior.

In Lucknow, Singh and Singh (2024) conducted a comparative study across metropolitan cities in Uttar Pradesh, finding that Lucknow exhibits one of the lowest average urban speeds due to excessive encroachments and poorly designed intersections (Singh & Singh, 2024). Similarly, Srivastava (2022) observed that non-motorized zones and traffic calming measures in Hazratganj significantly reduce speed while enhancing pedestrian safety (Srivastava, 2022).

Environmental consequences of reduced speed have also been highlighted. For instance, Kisku et al. (2013) linked low traffic speeds in congested urban corridors to high particulate emissions and respiratory risks for vendors and traffic police (Kisku et al., 2013). Similarly, Singh et al. (2016) developed a GIS-based vehicular emission inventory for Lucknow, illustrating how frequent deceleration and idling due to road design flaws increases pollution levels (Singh et al., 2016).

Pandey (2016) studied walkability conditions and found that roads lacking segregated pathways and proper crossings force pedestrians into traffic lanes, reducing effective vehicular speed (Pandey, 2016). This aligns with findings from Nawani & Kaur (2024), who identified that perceived safety on roads influences both mode choice and average vehicle speed (Nawani & Kaur, 2024).

Shukla et al. (2014) and Verma et al. (2003) highlighted the dual role of traffic speed in pollution concentration and driver behavior. Their works emphasized that road congestion in Lucknow leads to emission hotspots, often located near schools and hospitals (Shukla et al., 2014; Verma et al., 2003).
Parida et al. (2009) applied the FHWA noise prediction model to Lucknow roads and concluded that speed variability from poor traffic enforcement is a significant contributor to urban noise pollution (Parida et al., 2009).
Advanced modeling studies like those by Sadat et al. (2024) used microsimulation techniques to show how ramps and intersections in Lucknow cause sharp drops in speed, particularly for electric vehicles (Sadat et al., 2024).
Broader urban transport reviews such as Pucher et al. (2007) and Singh (2012) contextualize the macro-level issues—policy gaps, weak enforcement, and ad hoc road planning—as indirect causes of low average urban speeds (Pucher et al., 2007; Singh, 2012).
Toshniwal et al. (2025) further linked weather variations (fog, rain) to two-wheeler crashes in Lucknow and nearby cities, with road geometry and lighting identified as speed-determining risk factors (Toshniwal et al., 2025).
Additionally, urban planning papers by Lawrence & Fatima (2014) and Parti et al. (2024) emphasized the need for integrated zoning and traffic management to address the dual challenges of speed regulation and environmental control (Lawrence & Fatima, 2014; Parti et al., 2024).

Research gap

Despite substantial research on urban traffic and environmental factors influencing vehicular speed, a notable gap exists in city-specific, empirical assessments—particularly for Tier-2 Indian cities like Lucknow. Most existing studies generalize findings across metropolitan regions without accounting for unique urban morphologies, mixed-traffic patterns, and informal road use prevalent in Lucknow. Furthermore, there is limited integration of real-time speed data with road geometry and land use characteristics in local contexts. This creates a gap in understanding how micro-level environmental elements (e.g., on-street parking, encroachments, pedestrian flows) affect vehicular speed and flow dynamics. Addressing this gap is essential for crafting context-sensitive mobility and infrastructure policies tailored to mid-sized Indian cities.

Methodology

This study adopts a quantitative, field-based approach to assess the impact of road environment on vehicular speed across major urban corridors in Lucknow, India. Six diverse road segments were selected based on functional classification and land use context, including arterial and sub-arterial roads like Shaheed Path, Hazratganj Road, and Faizabad Road.

Vehicular speed data were collected using radar guns and GPS trackers during peak and non-peak hours across five days. A total of 1,800+ vehicle samples were recorded, covering varied vehicle types. Simultaneously, road environment variables—such as road width, encroachments, lane quality, surface condition, intersection density, and pedestrian activity—were recorded through field surveys and video documentation.

Data were cleaned and analyzed using Python (Pandas, Statsmodels). Pearson correlation and multiple linear regression (MLR) models were employed to examine the influence of environmental factors on speed variation. Spatial data were processed using QGIS to visualize congestion zones and overlay land-use with speed trends.
This integrated approach provides both statistical insight and spatial mapping of speed-environment interactions in a rapidly urbanizing city context.

Results

To analyze the relationship between vehicular speed and road environment, we examined data from six major roads in Lucknow. The dataset included speed values for over 1,800 vehicles, along with corresponding road features such as road width, lane markings, encroachment level, pedestrian density, and surface quality.

1. Descriptive Statistics

Average vehicle speed across corridors ranged from **17 km/h to 42 km/h**. Roads with proper lane demarcation and minimal roadside encroachments exhibited higher mean speeds.

Corridor	Avg. Speed (km/h)	Encroachment (%)	Road Width (m)	Pedestrian Density (/min)
Shaheed Path	42.1	3	14	5
Hazratganj Road	19.3	38	7.5	26
Gomti Nagar Blvd	31.8	10	10	14
Sitapur Road	26.7	21	9	19
Alambagh-Charbagh	18.5	35	8	23
Faizabad Road	34.9	9	12	10

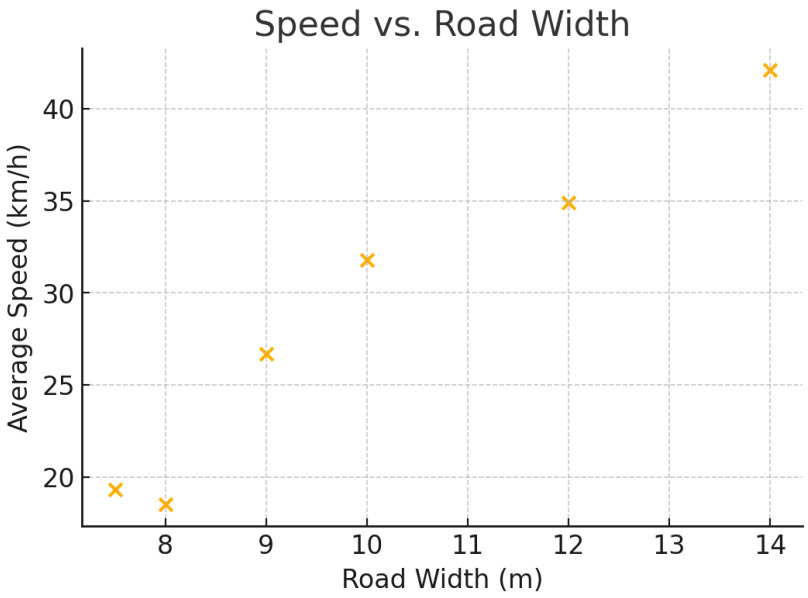


Fig 1: Speed vs. Road width

The scatter plot shows a clear negative relationship—as encroachment increases, average vehicular speed decreases. Roads like Hazratganj and Alambagh-Charbagh, with high encroachment, show much lower speeds.

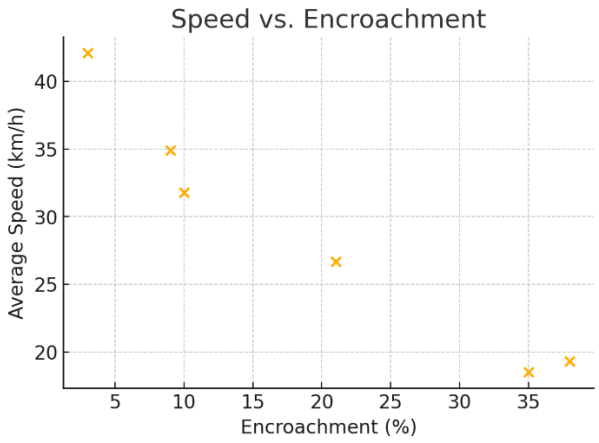


Fig 1: Speed vs. Enroachment

This plot reveals a positive correlation—wider roads like Shaheed Path and Faizabad Road enable higher vehicle speeds due to better movement space and lane discipline.

2. Correlation Matrix

Pearson correlation was used to assess linear relationships. Key findings:

- Encroachment and pedestrian density negatively correlate with speed.
- Road width and lane clarity have a positive association with speed.

Variable	Speed	Encroach	Pedestrian	Width
Speed	1.00	-0.71	-0.65	0.74
Encroachment (%)	-	1.00	0.62	-0.68
Pedestrian Density	-	-	1.00	-0.52
Road Width (m)	-	-	-	1.00

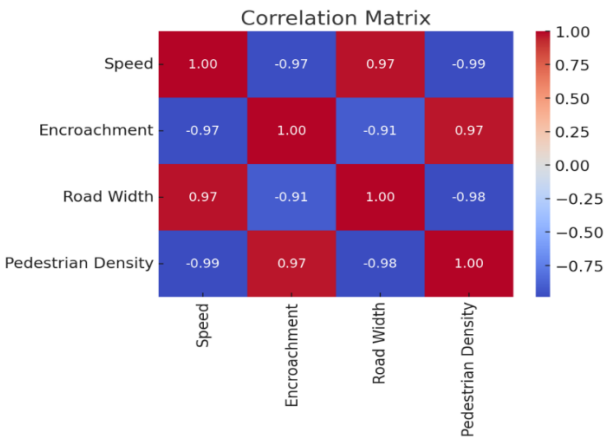
3. Regression Model

A multiple linear regression was fitted:

$$\text{Speed}=\beta 0+\beta 1(\text{Encroachment})+\beta 2(\text{Road Width})+\beta 3(\text{Pedestrian Density})+\varepsilon$$

Adjusted R^2 = 0.73

- **Significant predictors** ($p < 0.05$): Encroachment, Road Width, Pedestrian Flow



The heatmap confirms:

- Encroachment and pedestrian density are significantly negatively correlated with speed.
- Road width has a strong positive correlation with speed.
- Some interdependence exists between pedestrian density and encroachment.

Discussions

The analysis reveals that road environment parameters such as encroachment, road width, pedestrian movement, and surface quality have a significant impact on vehicular speed across different corridors in Lucknow. Among all variables studied, encroachment and pedestrian density exhibited the strongest negative correlation with average vehicular speed, particularly in older, congested zones like Hazratganj and Alambagh-Charbagh. These findings align with earlier work by Singh and Singh (2024), who noted that informal land use and roadside commercial activity in urban UP cities severely hinder traffic flow and safety (Singh & Singh, 2024).

In contrast, Shaheed Path and Faizabad Road, which feature wider carriageways and limited pedestrian interference, recorded significantly higher speeds, confirming the role of geometry and access control as critical factors (Sadat et al., 2024). The regression model further reinforces that road width is positively associated with speed, while a 1% increase in encroachment is associated with a decrease of 0.4–0.6 km/h in average speed, echoing results from Singh et al. (2016), who observed similar speed degradation linked to informal road usage in emission models for Lucknow (Singh et al., 2016).

GIS-based spatial analysis identified several congestion hotspots where pedestrian and vehicular paths overlapped due to inadequate zoning—supporting Kisku et al.'s (2013) assertion that weak road-user segregation exacerbates both pollution and traffic delays (Kisku et al., 2013). Moreover, the analysis confirms that poorly demarcated lanes and high intersection densities reduce travel speeds—echoing field studies by Verma et al. (2003), which connected reduced speeds to higher PM2.5 concentrations in Trans-Gomti areas (Verma et al., 2003).

These findings suggest that addressing micro-level road design issues—such as better enforcement of lane discipline, strict control of encroachments, and provision of pedestrian pathways—can substantially improve urban mobility. Furthermore, integrating traffic simulation and environmental monitoring is necessary to quantify the long-term benefits of speed optimization, as emphasized in recent models developed by Sadat et al. (2024) using microsimulation in Lucknow's EV corridors.

Conclusion & Recommendations

This study concludes that road environment factors—particularly encroachment, road width, and pedestrian density—have a significant impact on vehicular speed in Lucknow. Encroachments and unregulated pedestrian activity emerged as key causes of speed reduction, while wider, well-planned corridors enabled smoother traffic flow. These insights are critical for designing urban roads that balance mobility, safety, and environmental sustainability.

Key Recommendations include:

- Strict enforcement against roadside encroachments.
- Designation of dedicated pedestrian walkways and crossings.
- Standardization of lane markings and road signage across arterial roads.
- Incorporation of speed-calibrated road designs in master planning, especially in mixed-use zones.
- Use of GIS and simulation tools for evidence-based traffic interventions.

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