



IMPACT OF ROAD INFRASTRUCTURE ON TRAFFIC SAFETY IN KASHKADARYA REGION

Karimov Akbar Akbarovich

Associate Professor at Karshi State Technical University

Narzullayev Abror Ahror ogli

Master's student at Karshi State Technical University

Email: abornarzullayev9902@gmail.com

Abstract: Road traffic safety is a critical issue in urban areas, where increasing traffic volumes and complex road network structures contribute to a higher risk of traffic accidents. This study investigates the impact of road infrastructure conditions on traffic safety in the Kashkadarya region, using Karshi city as a case study. The research focuses on street intersection density as a key infrastructural indicator influencing traffic safety outcomes. Open-source road network data were extracted from OpenStreetMap and analyzed using Geographic Information System tools. A grid-based spatial approach was applied to calculate intersection density across the study area, and traffic accident statistics were integrated to assess safety performance. A relative risk index was used to quantify the relationship between intersection density and traffic accident occurrence. The results reveal a clear spatial association between high intersection density and elevated traffic risk levels, particularly in central and highly trafficked zones. The findings highlight the importance of incorporating spatial infrastructure indicators into traffic safety assessment and urban transport planning to support data-driven decision-making and targeted safety interventions.

Keywords: Road infrastructure, traffic safety, intersection density, geographic information system, urban road network, spatial analysis, Karshi city



Introduction

Road traffic safety remains one of the most critical challenges in urban environments, particularly in rapidly developing regions where increasing motorization places significant pressure on existing road infrastructure. The growth of urban populations and traffic volumes intensifies the complexity of traffic systems, making the identification of infrastructure-related risk factors an essential task for improving road safety outcomes. Among various infrastructural elements, the structure and density of street intersections play a significant role in shaping traffic flow patterns and influencing the likelihood of road traffic accidents.

Recent advances in geospatial technologies and the availability of open-source spatial data have created new opportunities for analyzing urban road networks with greater accuracy and efficiency. OpenStreetMap has emerged as a valuable data source for extracting detailed road network information, enabling researchers to assess infrastructural characteristics such as intersection distribution and network connectivity. When combined with Geographic Information System tools, these datasets allow for spatial visualization and quantitative analysis of road infrastructure parameters within clearly defined urban boundaries.

In the context of Uzbekistan, and particularly in the Kashkadarya region, comprehensive studies examining the relationship between road infrastructure conditions and traffic safety remain limited. Karshi, as a major urban center of the region, exhibits diverse traffic patterns influenced by rapid urban development and varying road network configurations. The density and spatial distribution of street intersections within the city represent an important infrastructural indicator that may significantly affect traffic safety performance.

This study aims to conduct a scientific analysis of the impact of road infrastructure conditions on traffic safety in the Kashkadarya region, using Karshi city as a case study. By integrating open-source road network data with traffic safety statistics and applying spatial analysis techniques, the research seeks to identify



patterns linking intersection density to traffic risk levels. The findings are expected to contribute empirical evidence to the understanding of how infrastructural characteristics influence traffic safety and to support data-driven decision-making in urban transport planning and road safety management.

Materials and Methods

This study adopts a spatial–analytical approach to examine the relationship between road infrastructure characteristics and traffic safety, with a particular focus on street intersection density. The methodological framework is based on the integration of open-source geospatial data, traffic safety statistics, and Geographic Information System techniques to ensure transparency, reproducibility, and regional relevance.

The study area is Karshi city, located in the Kashkadarya region of Uzbekistan. City boundaries were delineated using open spatial data to ensure consistency in spatial analysis. Road network data were obtained from the OpenStreetMap platform, which provides comprehensive and regularly updated information on urban street layouts. To ensure regional applicability, the extracted road network data were filtered and processed according to characteristics specific to urban road infrastructure in Uzbekistan.

Spatial analysis and visualization were conducted using QGIS software. Street intersections were identified as nodes within the road network where two or more street segments intersect. The extraction of intersection points was performed systematically to avoid duplication and to ensure accurate representation of network connectivity. Intersection density was selected as the primary infrastructural indicator due to its strong association with traffic flow complexity and potential conflict points within urban transport systems.

To quantify intersection density, the study area was overlaid with a uniform grid system, where each grid cell covered an area of one square kilometer. The number of street intersections within each cell was calculated, allowing for the



spatial distribution of intersection density to be assessed across the city. This grid-based approach enabled a standardized comparison of different urban zones and facilitated the identification of areas with high concentrations of intersections.

Traffic safety assessment was conducted by integrating spatial intersection data with available traffic accident statistics for Karshi city. A relative risk coefficient was calculated by correlating intersection density values with observed traffic safety indicators. This approach allowed for the evaluation of how variations in infrastructural density influence traffic risk levels within different parts of the urban area.

The results were visualized using thematic maps, where intersection density levels were classified into distinct categories and represented by graduated color scales. This visualization technique supported the identification of high-risk zones and enhanced the interpretability of spatial patterns. The methodological framework provides a systematic and scalable approach for analyzing road infrastructure impacts on traffic safety and can be applied to other urban areas with similar data availability.

Results

The spatial analysis enabled the identification of specific urban zones characterized by high concentrations of street intersections within Karshi city. Areas exhibiting the highest intersection density were delineated through grid-based classification, allowing focal zones of infrastructural complexity to be clearly distinguished. These zones represent critical points within the urban road network where traffic interactions are most intensive.

In the identified high-density zones, a detailed count of street intersections was conducted. The analysis revealed that within the selected urban sector, 92 street intersections were recorded in proximity to Mustaqillik Street. In addition, 71 intersections were identified along the perimeter formed by Nasaf and Istiqlol streets. A notably high concentration of intersections, totaling 65, was observed at



the junction of Nasaf Street and Amir Temur Avenue within the same analytical boundary. These findings demonstrate a pronounced spatial clustering of intersections in central and highly trafficked areas of the city.

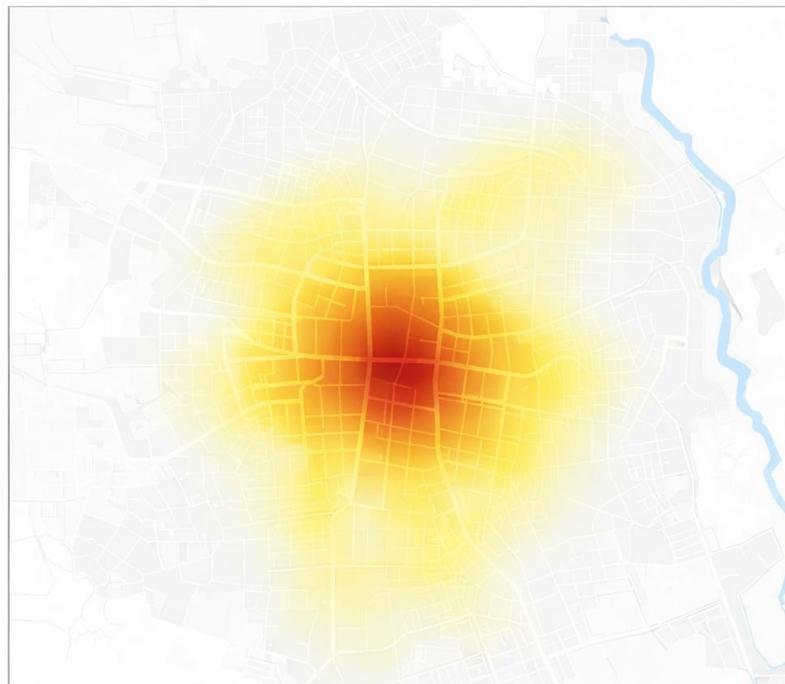


Fig. 1. Spatial distribution of street intersection density in Karshi city.

The results highlight the significant influence of street network configuration on traffic safety outcomes. Although the individual contributing factors to accident occurrence vary, the observed patterns indicate a clear association between street intersection density and traffic safety performance. Areas with elevated intersection density tend to experience increased traffic complexity, which may elevate the probability of conflict points and accident risk. At the same time, international empirical evidence suggests that well-designed high-density networks can also support improved safety outcomes when supported by appropriate traffic management measures.

To further quantify this relationship, a risk coefficient was calculated by correlating intersection density values with traffic accident data across the study area. The spatial distribution of the calculated risk coefficient demonstrates that



zones with higher intersection density generally correspond to higher traffic risk levels. These results emphasize the importance of considering intersection density as a key indicator in traffic safety assessment and urban road infrastructure planning.

The findings provide empirical support for the role of road infrastructure structure in shaping traffic safety conditions in Karshi city. The identified high-density zones represent priority areas for targeted safety interventions, including traffic regulation improvements, intersection redesign, and enhanced pedestrian safety measures.

To evaluate the relationship between traffic accident occurrence and street intersection density, a relative risk index was introduced. This index reflects the concentration of traffic accidents within areas characterized by different levels of intersection density and is defined as:

$$R_d = \frac{A_d}{G_d} \quad (1)$$

where R_d denotes the relative traffic risk associated with a specific intersection density class; A_d represents the total number of recorded traffic accidents within grid cells belonging to the given density class; and G_d indicates the total number of grid cells corresponding to that density class. Each grid cell covers an area of 1 km².

Using Equation (1), the relative risk index was calculated for all identified intersection density categories. This approach enables a standardized comparison of traffic risk levels across urban zones with varying road network structures. The calculated risk values reveal a clear spatial pattern, where areas with higher intersection density exhibit elevated relative risk levels, while zones with lower intersection density tend to show minimal traffic risk.

The results demonstrate that intersection density serves as a meaningful indicator for assessing traffic safety conditions. By linking spatial infrastructure characteristics with accident data, the proposed index provides a robust analytical framework for understanding how road network design influences traffic safety



outcomes. This methodological approach supports evidence-based urban transport planning and facilitates the identification of priority areas for targeted safety interventions.

Table 1. Relationship between intersection density classes, traffic accidents, and spatial grid distribution in Karshi city

No.	Intersection density range (per km ²)	Number of traffic accidents	Number of 1 km ² grid cells
1	80–96	9	1
2	64–80	13	2
3	48–64	39	9
4	32–48	44	28
5	16–32	52	46
6	1–16	25	81

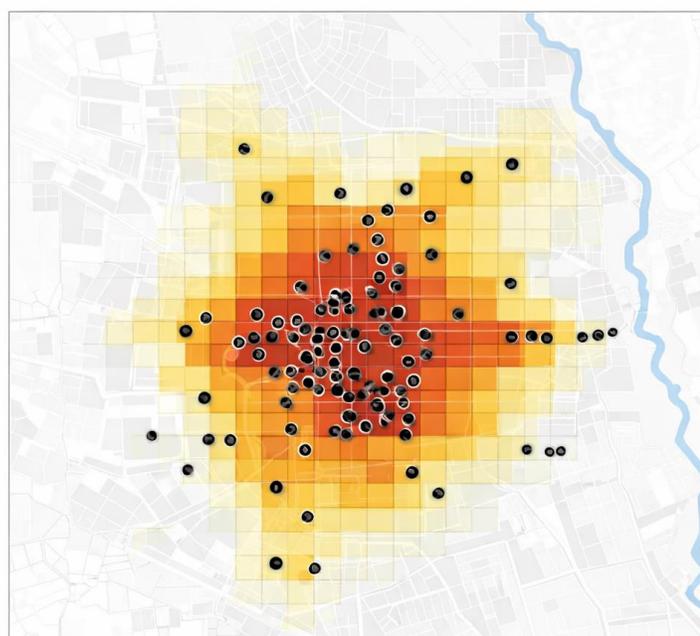


Fig. 2. Spatial relationship between traffic accident distribution and street intersection density in Karshi city.



Conclusion

This study examined the impact of road infrastructure characteristics on traffic safety in the Kashkadarya region, using Karshi city as a case study. The results confirm that street intersection density is a significant factor influencing traffic safety in urban areas. Spatial analysis revealed that zones with higher intersection density are associated with increased traffic complexity and elevated accident risk.

The application of a grid-based approach and a relative risk index enabled a clear comparison of traffic risk levels across different urban zones. Areas characterized by dense intersection networks consistently demonstrated higher relative risk values, while zones with lower density showed reduced traffic risk. These findings highlight the importance of incorporating intersection density as a key indicator in traffic safety assessments.

The outcomes of this research emphasize the need for targeted safety measures in high-density intersection areas, including improved traffic regulation, intersection design optimization, and pedestrian safety enhancements. The proposed methodological framework, based on open-source geospatial data and GIS analysis, can be applied to other urban contexts and supports evidence-based urban transport planning.

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