

## PLANNING TRANSPORT NETWORKS AND IMPROVING TRANSPORT INFRASTRUCTURE IN HISTORICAL CITIES

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**Abstract:** This article describes the scientific and theoretical foundations for improving the transport-engineering infrastructure of Khiva, a city included in the UNESCO World Heritage list. Based on an urban planning-interventionist approach, the research analyzes the balance between traffic intensity, historical landscape stability, and environmental safety. Future growth in transport demand was predicted using GIS (geographic information systems) interpolation and econometric modeling methods, specifically Regression analysis and Durbin-Watson statistics. As a result of the study, a model was substantiated to reduce environmental pollution by 15% through administrative and infrastructural measures, including the introduction of small and large ring roads and an intermodal system..

**Keywords:** Khiva city, transport infrastructure, historical environment, Ichan-Kala, urban planning model, environmental sustainability, GIS modeling, intermodal system.

### Introduction

In the context of global urbanization, modernizing the functional-planning system of historical cities remains one of the most complex architectural and engineering challenges. Using Khiva as a case study, the rapid growth in motorization—where the number of vehicles in historical cities increased by 74% from 2013 to 2023—is exerting significant anthropogenic pressure on the "Ichan-Kala" UNESCO heritage site and its surrounding buffer zones.

**The Main Problem:** The primary issue is that increased traffic intensity not only releases harmful gases into the atmosphere but, most critically, generates powerful vibration waves. These micro-seismic vibrations undermine the physical integrity of the ancient foundations and brick structures of "Ichan-Kala". The objective of this research is to develop engineering solutions to preserve historical monuments and create an environmentally friendly urban environment by regulating traffic flow through urban planning and design methods in Khiva.

### Methodology

The study explored the following fundamental methods:

- **GIS ArcMap Interpolation:** Mapping environmental hazard levels of the area across 5 main groups.

- **Econometric Analysis:** Utilizing regression models that link transport growth with dynamics in GDP and nominal wages.
- **Durbin-Watson Statistics:** Confirming the reliability and absence of autocorrelation in the results, with an indicator ranging between 2.42 and 2.52.



**Figure 1. Historical part of Khiva city.**

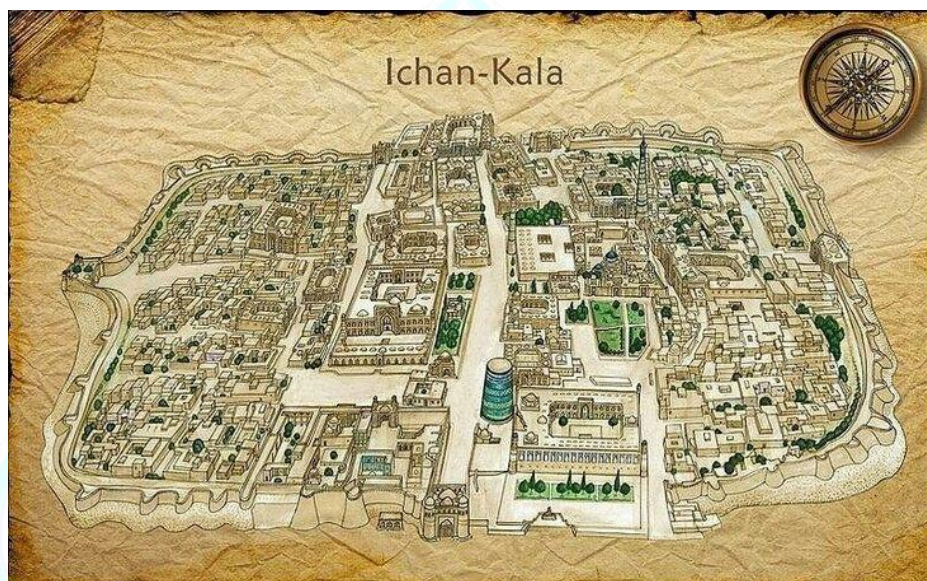
The literature review included the urban planning theories of figures like P. Hall and K. Lynch regarding city image and planning, as well as the scientific findings of local scholars A. Turaev and M. Joraev on the modernization of historic cities. Specifically, the transport flow optimization models developed by A.A. Kutliev (2024) served as the methodological foundation for this research.

On the Urgench-Khiva road of state importance, traffic intensity has reached 33,685 vehicles per day, which is 16 times higher than the established standard for Category IV roads.

**Environmental Risks:** Based on GIS analysis, the dispersion of NH<sub>3</sub> and H<sub>2</sub>S gases was categorized into five hazard zones. It was confirmed that in areas with high transport density, pollution levels significantly exceed sanitary norms. To preserve the historical and cultural identity of Khiva, the following comprehensive measures are proposed:

- **Hierarchical Ring Roads:** Implementing a Large Ring Road to reduce transit load by 35% and establishing a Small Ring Road.
- **Intermodal System and Transport Hubs:** Constructing multi-story and underground parking clusters on the city outskirts. Organizing transport transfer hubs and temporary storage areas at the entrances to the city center.
- **Ecological Transport Lines:** Launching a dedicated **trolleybus** line along the Small Ring Road. Within the intermodal system around Ichan-Kala, creating shuttle services (electric vehicles, e-scooters) and bicycle lanes.

- **Smart Management:** Digitally monitoring traffic flow using GIS technologies and a Smart-parking system.



**Figure 2. Ichan-Kala architectural monument.**

Based on the 1922 general plan of Khiva, the classification of the street and road network was analyzed across four road categories (International, Fortress-connecting, Central Entrance, and local dead-end streets) along with their technical dimensions.

Historically, before the invention of motor transport, horse and donkey carts were used. Analysis shows that the historical transport (horse and donkey carts) within "Ichan-Kala" had a width of 1.5 meters, with 30 cm of clearance allowed on each side for movement; the width of a single traffic lane was approximately 2.1 meters. Drawing on global urban planning experience, one of the primary indicators of transport infrastructure development is the density of the urban street-road network, characterized by the ratio of the network to the total city area.

The purpose of studying transport density is to identify when vehicles in a single lane can move at free-flow versus average speeds. Through speed and density models, the research determines when Khiva's street network reaches congestion-free, congested, or high-congestion states.

Taking into account the planned northern and southern hub designs, it is recommended to introduce e-scooters, small public electric vehicles, bicycles, traditional horse transport, and a trolleybus route on the small ring road for both residents and tourists. Improving urban planning methods—categorized as primary traffic planning measures—is recommended to transform the area into an eco-zone.

To reduce the transport load while preserving the historical and architectural image of Khiva, the following measures are being implemented and proposed:

1. **Organization of Ring Roads:** The "Large Ring Road" project is a key measure, potentially reducing transport load by 35%. A "Small Ring Road" is also planned to regulate local movement.
2. **Transport-Free Eco-Zones:** Plans are underway to turn "Ichan-Kala" and its immediate surroundings (the area inside the Small Ring Road) into transport-free eco-zones. Motor vehicle movement will be strictly prohibited through administrative measures to protect monuments from noise and toxic gases.
3. **Alternative Transport:** In these eco-zones, e-scooters, small electric public transport, bicycles, and traditional horse carriages are proposed for tourists and residents. A trolleybus route is also planned for the Small Ring Road.
4. **Improving the Parking System:** To reduce pressure in the city center, efforts are being made to establish multi-story and underground parking lots and transfer hubs in outer zones.

**Conclusion:** By applying a set of urban planning, design, and administrative measures, it is possible to optimize the transport load in Khiva. Implementing the proposed ring roads and intermodal system will lead to a 15% reduction in noise, vibration, and harmful gases. These solutions are fundamental factors in ensuring the longevity of "Ichan-Kala's" architectural monuments and enhancing the city's tourism appeal.

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