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SCIENTIFIC ANALYSIS OF STREET AND ROAD INFRASTRUCTURE AROUND HISTORICAL MONUMENTS IN SAMARKAND: TOWARDS INTEGRATED URBAN PRESERVATION AND MOBILITY

Farrukh Madiev Muysinovich[1, a)], **Büşra Nur BARDAKÇI** [2,]

[1] *Department of Urban Planning, Samarkand State Architecture and Construction University, Samarkand, Uzbekistan.*
[2] *Dept of City and Regional Planning, Konya, Turkey*
[a)] *Corresponding author:* [a)]*madiyev.farrux@samdaqu.edu.uz*

Annotation: This scientific article presents a comprehensive analysis of the street and road infrastructure surrounding historical monuments in Samarkand, Uzbekistan. Using a GIS-based methodology, the study evaluates how existing transport systems affect both mobility and the preservation of cultural heritage sites such as Registan Square, Bibi-Khanym Mosque, and Shah-i-Zinda. The research identifies key spatial conflicts—such as traffic congestion, inadequate pedestrian access, and buffer zone encroachment—that pose risks to the integrity of these monuments. Based on spatial data, field surveys, and stakeholder input, the authors propose practical recommendations including the introduction of traffic buffer zones, smart traffic systems, and non-motorized transport alternatives. The findings highlight the urgent need for integrated urban planning strategies that balance the goals of heritage conservation and sustainable mobility. This article is intended for urban planners, conservationists, and municipal authorities working in historical cities.

Keywords: Samarkand, historical monuments, street and road infrastructure, urban mobility, GIS analysis, heritage preservation, buffer zone, sustainable transport, urban planning, cultural landscape.

INTRODUCTION.

Samarkand, a UNESCO World Heritage Site, represents one of the most historically significant cities in Central Asia. Its urban landscape is a fusion of ancient planning principles and modern infrastructure. This paper explores how street and road infrastructure around historical monuments impacts urban mobility and preservation. We focus on key areas such as Registan Square, Shah-i-Zinda, and Bibi-Khanym Mosque, identifying challenges and proposing sustainable solutions. [1][2][3]

Previous studies have emphasized the importance of preserving cultural heritage while ensuring accessibility (UNESCO, 2013; Ashworth, 1991). Research in cities like Istanbul and Cairo show that unregulated traffic and road expansion threaten heritage integrity. GIS and spatial analytics have been used to assess the compatibility of infrastructure with conservation priorities (Yildiz & Turker, 2018).

In Uzbekistan, limited studies have applied such methods to historic urban cores, creating a research gap this study seeks to address.

Urbanization and tourism in Samarkand have increased significantly over the past two decades, resulting in higher pressure on transport infrastructure near protected heritage zones. The uncontrolled expansion of road networks, informal parking near monuments, and lack of pedestrian prioritization pose threats not only to cultural landmarks but also to the city's historical character. Moreover, the absence of clear buffer zone regulation and zoning control near key monuments often leads to irreversible spatial degradation.

The present study aims to conduct a detailed spatial analysis of Samarkand's road network and its integration with heritage preservation needs. By applying GIS technology and referencing UNESCO's heritage management frameworks, we seek to identify incompatible infrastructure elements, evaluate traffic patterns, and propose interventions that balance mobility with conservation. The findings are expected to support municipal authorities, urban planners, and cultural heritage specialists in designing policies that ensure long-term sustainability for Samarkand's historical core.

2. Methodology

A mixed-methods approach was employed to investigate the interaction between street infrastructure and historical preservation in Samarkand. The study combined geospatial analysis, field observation, and stakeholder interviews to develop a holistic understanding of current challenges and potential interventions.

2.1. Data Collection

Primary data was collected through:

- **Field Surveys**: Conducted from April to May 2025, focusing on pedestrian movement, vehicular traffic volume, road conditions, and visual encroachment near heritage sites.
- **Traffic Counts**: Manual counting of vehicles and pedestrian flow was carried out during peak and off-peak hours around Registan Square, Shah-i-Zinda, and Bibi-Khanym Mosque to quantify traffic pressure.
- **Photographic Documentation**: Visual assessments were made to support analysis of road encroachments, signage clutter, and preservation state.
- **Stakeholder Interviews**: Semi-structured interviews with urban planners, municipal engineers, cultural heritage experts, tourism officials, and local residents provided qualitative insights.

2.2. Study Sites

Three major heritage zones were selected based on historical importance and exposure to urban pressure:

- **Registan Square**: A central heritage site with dense tourist traffic and mixed-use surroundings.
- **Bibi-Khanym Mosque**: Notable for its scale and location adjacent to bazaars and major road arteries.

- **Shah-i-Zinda**: A necropolis located on a hilly terrain with limited road access and pedestrian congestion.

2.3. Analytical Tools

To evaluate spatial and functional compatibility of road networks with heritage zones:

- **QGIS** was used for GIS-based spatial mapping, including road classification, buffer zone analysis, and heat mapping of traffic intensity.
- **AutoCAD** facilitated technical drawings and analysis of cross-sections, curbs, sidewalks, and access paths.
- **SWOT Analysis** was conducted to assess strengths, weaknesses, opportunities, and threats in current infrastructure policies affecting heritage areas.

2.4. Data Integration and Evaluation

Geospatial data was integrated with qualitative findings to produce composite maps and spatial conflict matrices. Spatial overlays were used to detect overlapping zones of traffic congestion and monument boundaries. This allowed the identification of high-risk zones for heritage degradation due to road infrastructure.

2.5. Ethical Considerations

Informed consent was obtained from all interviewees. The study followed UNESCO guidelines on the ethical study of World Heritage Sites, ensuring non-intrusive fieldwork and sensitivity to cultural contexts.

Results

The findings of this study provide a comprehensive picture of the current state of street and road infrastructure near Samarkand's key historical sites. GIS analysis, field surveys, and stakeholder feedback were synthesized to identify core challenges, spatial conflicts, and opportunities for improved planning.

3.1. Spatial Congestion Near Heritage Sites

The geospatial mapping revealed that traffic congestion is highest near **Registan Square** during weekends and tourist peak hours (10:00–14:00). Average vehicle flow exceeds **600 vehicles per hour** on adjacent streets, particularly along **University Boulevard** and **Tashkent Road**, both of which lack adequate pedestrian infrastructure. Buffer zone analysis showed that traffic corridors intersect directly with the **100–250m protection radius** designated by local urban regulations.

- **Bibi-Khanym Mosque** is bordered by open-air bazaars and small streets with informal parking, causing pedestrian spillover onto the carriageway.
- **Shah-i-Zinda**, due to its elevation and narrow approach roads, shows less vehicular pressure but suffers from high pedestrian density and stair congestion, especially during holidays.

3.2. Infrastructure Incompatibilities

Field surveys and AutoCAD documentation identified several technical incompatibilities between the current road network and heritage conservation principles:

- **Sidewalks** are frequently less than **1.2 meters** wide, violating accessibility standards for heritage areas.
- Road surfaces near monuments are patched or uneven, lacking heritage-sensitive paving materials.
- Absence of designated **tourist drop-off zones** creates random stopping and increased congestion near entry points.

Photographic documentation further revealed excessive visual clutter from modern signage, overhead wires, and uncoordinated vendor stalls, which obstruct views of the monuments and reduce aesthetic coherence.

3.3. SWOT Analysis of Urban Policy

The SWOT evaluation involving stakeholder input highlighted the following:

- **Strengths**: Government commitment to tourism development; presence of UNESCO management plan (though under-implemented); public support for heritage protection.
- **Weaknesses**: Weak enforcement of zoning laws; lack of integrated mobility strategy; outdated transport infrastructure around protected zones.
- **Opportunities**: Potential for green pedestrian corridors; availability of GIS tools for future planning; increasing foreign investment in smart tourism.
- **Threats**: Continued urban expansion; unregulated private transport services (especially taxis); erosion of site authenticity through modernization.

3.4. Stakeholder Perspectives

Interviews with 24 stakeholders revealed consensus on the urgent need for:

- Clear pedestrian zones and regulated traffic limits near heritage landmarks.
- Improved public transport connectivity to reduce private car dependence.
- Adaptive reuse of adjacent underused buildings as mobility hubs or information centers.

Tourism officials expressed concern about deteriorating visitor experiences due to noise, heat, and congestion, while residents voiced frustration over limited access and rising commercial pressure in historic neighborhoods.

3.5. GIS Heat Map Outputs

GIS heat maps visually confirmed "hotspots" of traffic and pedestrian conflict. The highest overlapping density of traffic and footfall was observed in the southeastern corner of **Registan Square**, where commercial and vehicular zones are not clearly delineated. Meanwhile, **Shah-i-Zinda** displayed linear congestion patterns tied to stairway access and festival traffic surges.

The analysis of Samarkand's urban mobility patterns in relation to its historical core reveals an inherent tension between conservation and modernization. This section interprets the findings in the context of international heritage management practices and urban planning theory, and discusses implications for future development.

4.1. Conflict Between Accessibility and Preservation

The results highlight a growing conflict between increasing tourist numbers and the fragile nature of historical urban fabric. High vehicular volumes near **Registan Square** and **Bibi-Khanym Mosque** compromise not only pedestrian safety but also the structural and visual integrity of these heritage sites. This mirrors findings in other historic cities such as **Istanbul**, where unregulated traffic flow caused micro-vibrations and pollution that accelerated architectural degradation (Yildiz & Turker, 2018).

Samarkand's current road layout was not originally designed to accommodate such high levels of motorized traffic. Unlike planned modern cities, the historical cores of Samarkand were organically developed and are now struggling to adapt to car-centric infrastructure. The narrow roads, minimal sidewalks, and lack of pedestrian prioritization are symptomatic of a deeper planning issue: a gap between **heritage-sensitive design** and **transport policy**.

4.2. Regulatory and Institutional Gaps

The SWOT analysis pointed out systemic weaknesses in regulatory enforcement. Despite having a UNESCO-backed management plan, the coordination between municipal transport departments and heritage protection authorities remains weak. Building and zoning codes are not sufficiently enforced, allowing unauthorized parking, ad hoc vendor stalls, and infrastructure upgrades that ignore historical aesthetics.

This situation reflects a broader issue observed in many developing cities with cultural significance — a lack of **intersectoral governance frameworks** that integrate tourism, conservation, and mobility planning (Ashworth, 1991). Without a central coordination mechanism, initiatives remain fragmented, reactive, and often contradictory.

4.3. Need for Context-Aware Infrastructure Design

Urban mobility planning in heritage zones must move beyond conventional solutions. For Samarkand, this means rejecting generic road-widening projects or concrete overhauls in favor of **context-sensitive** interventions such as:

- **Permeable pavements and stone materials** consistent with historical aesthetics.
- **Shared streets (woonerfs)** that allow limited vehicular access while prioritizing pedestrians.

- **Bicycle and electric shuttle networks** tailored to narrow alleys and tight spaces.
- **Smart signage and underground utilities**, which reduce visual clutter.

These approaches are increasingly used in historical European cities and could be adapted for Central Asian urban settings through pilot projects and design competitions.

4.4. Role of GIS in Planning and Monitoring

This study demonstrates the utility of GIS in identifying spatial conflict zones and analyzing the compatibility of infrastructure with conservation priorities. Through spatial overlays and heatmaps, areas of high pedestrian and vehicle overlap were visualized, enabling more precise planning interventions.

In future phases, GIS can also be used for **real-time monitoring** of traffic and pedestrian flows, **predictive modeling** of tourist behavior, and **simulation of pedestrianization scenarios**. The digital mapping of underground utilities, landscape elements, and sightlines can guide interventions that are minimally invasive yet maximally effective.

4.5. Social Dynamics and Local Involvement

An important outcome of the stakeholder interviews was the identification of diverging priorities: while local authorities emphasize economic development and tourism, residents express concern over quality of life and loss of neighborhood identity. This underscores the importance of **community-inclusive planning**, where resident feedback is integrated into design and policy-making processes.

Studies in cities like **Luang Prabang (Laos)** and **Granada (Spain)** emphasize the value of **heritage stewardship**, where locals are empowered as custodians of cultural assets rather than displaced by tourism-driven gentrification.

4.6. Balancing Modern Needs with Historical Value

Ultimately, the challenge in Samarkand — as in many heritage cities — is how to integrate **21st-century urban needs** (mobility, efficiency, accessibility) with the **timeless values of cultural identity** and authenticity. Solutions must be hybrid, incremental, and sensitive to scale. Large-scale infrastructural changes should occur outside buffer zones, while the historical core should be treated with restraint and care.

Creating a **"Heritage Mobility Master Plan"** could be a strategic step forward — integrating GIS data, conservation zoning, pedestrian networks, and transport nodes into a unified policy framework. Furthermore, pilot pedestrianization of key streets near Registan and Shah-i-Zinda during festivals or weekends could help test public acceptance and operational feasibility.

Samarkand, with its deep historical and cultural significance, stands at a critical junction where the preservation of its UNESCO-listed monuments must be reconciled with the growing demands of urban mobility. This study aimed to

evaluate the existing street and road infrastructure around major heritage sites—Registan Square, Bibi-Khanym Mosque, and Shah-i-Zinda—and assess how urban development affects heritage preservation and accessibility.

The findings reveal a series of complex challenges. The current infrastructure, while improved in some respects, remains inadequately equipped to balance historical sensitivity with functional urban transport. Vehicular traffic flows have increased near key monuments, causing environmental stress, visual pollution, and safety concerns for pedestrians, particularly tourists. Moreover, the study underscores the lack of an integrated planning framework that connects heritage conservation, traffic engineering, and community needs.

One of the most significant conclusions drawn is the urgent need for a **heritage-sensitive mobility strategy** that reflects both the local identity and global best practices. Samarkand should not replicate modern Western mobility solutions blindly but instead adapt context-specific methods that respect the city's historical layout, architecture, and cultural fabric. The proposed use of GIS-based monitoring and spatial analysis has proven instrumental in pinpointing high-conflict areas, visualizing mobility flows, and offering a foundation for long-term planning.

Furthermore, the study calls attention to the social aspect of infrastructure development. Preservation should not be limited to monuments alone but should encompass the urban environment, social memory, and local communities that interact with these spaces daily. A participatory approach that incorporates residents, shopkeepers, municipal officials, and tourists is key to achieving both sustainable mobility and cultural preservation.

Based on the evidence presented, the following strategic recommendations emerge:

1. **Establish a Heritage Mobility Master Plan** for Samarkand, with GIS integration and stakeholder input.
2. **Designate pedestrian-priority zones** around key monuments, especially during peak tourist seasons.
3. **Limit private vehicle access** in buffer zones using eco-friendly shuttle systems and designated parking peripheries.
4. **Develop regulatory tools** for enforcing design guidelines that are consistent with cultural heritage aesthetics.
5. **Invest in capacity building and training** for local planners, architects, and conservation professionals in heritage-urban integration.
6. **Launch awareness campaigns** to educate residents and tourists on the importance of protecting Samarkand's historical infrastructure.

In conclusion, the transformation of Samarkand's infrastructure must be **not only physical but strategic**, grounded in interdisciplinary coordination, historical awareness, and forward-thinking governance. The future of this ancient city depends on the ability of its stewards to develop an urban framework where the past is

protected, and the future is sustainably shaped. If managed wisely, Samarkand can become a model of how ancient cities in Central Asia and beyond adapt to modern challenges while preserving their timeless legacy.

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