Herança – History, Heritage and Culture Journal
2025, 8(3)
ISSN: 2184-3090
https://revistaheranca.com

Research Article

Analyze Sustainable Urban Planning in Conservation of a Heritage City through GIS: Taking Xi'an as an Example

Zhaodong Zhong [1,2] Khai Ern Lee [3] Lei Wang [4] Nurfashareena Muhamad [5*]

[1] Ph.D. Candidate, Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, Selangor, Malaysia
[2] Assistant Professor, College of Landscape Architecture and Art, Xinyang Agriculture and Forestry University, Xinyang, China
[3] Prof. Ts. Dr., Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, Selangor, Malaysia
[4] Associate Professor, International Research Center of Big Data for Sustainable Development Goals, BeiJing, China
[5] Gs. Dr., Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, Selangor, Malaysia
* **Corresponding Author:** fasha@ukm.edu.my

Citation: Zhong, Z. D., Lee, K. E., Wang, L., & Muhamad, N. (2025). Analyze sustainable urban planning in conservation of a heritage city through GIS: Taking Xi'an as an example. *Herança, 8*(3).

ARTICLE INFO

Received: 14 Mar 2025
Accepted: 02 Apr 2025

ABSTRACT

The study here is on the use of Geographic Information Systems (GIS) in sustainable urban planning in heritage cities, with a case study of Xi'an. The study is a search for ways through which GIS can be used to conserve heritage in the face of constraints of urban development, particularly road network development and accessibility of cultural heritage sites. The study also investigates challenges in the application of GIS in sustainable urban planning, such as constraints in data and policy. A qualitative approach is utilized that uses secondary sources of evidence such as government records, satellite images, and GIS databases. GIS software such as ArcGIS and QGIS are used to analyze the spatial correlation of Xi'an's road network and cultural heritage sites, assess urban sustainability indicators, and identify conflicts and opportunities in balancing urbanization and heritage conservation. The research indicates that although Xi'an's road network offers greater connectivity, some of the expansions are threatening the conservation of heritage. GIS analysis indicates locations where accessibility can be improved without jeopardizing cultural landmarks. Pedestrianization in the area close to heritage sites, traffic control optimized to decongest sensitive areas, and buffer zones to safeguard historical areas from encroachment by urbanization are the most important recommendations. The study contributes to the mounting literature on heritage conservation and sustainable urban planning using GIS applications. It demonstrates the use of GIS as a helpful tool for planners, offering fact-based advice for optimizing infrastructure planning, enhancing urban access to heritage sites, and guiding future policy planning. Not only is the study relevant for Xi'an but can be generalized to other similar heritage cities worldwide with urbanization problems, establishing the usefulness of GIS in urban sustainable development everywhere.

Keywords: GIS; Heritage Conservation; Urban Sustainability; Road Networks; Xi'an; China.

INTRODUCTION

The introduction of Geographic Information Systems (GIS) has transformed modern urban planning, providing more advanced spatial analysis tools to assess, visualize, and manage urban growth. In heritage-rich areas, the integration of GIS in planning processes is essential in balancing development with sustainability as cities expand (Z. Wang, J. Liu, T. Li, J. Chao, & X. Gao, 2021). GIS helps urban planners analyze spatial relationships between infrastructure, cultural heritage sites, and environmental factors, thus enabling informed decision-making (Yuan, R. Liu, & T. Huang, 2024). Preserving cultural heritage is one of the most important concerns in the contemporary world, where cities are experiencing rapid growth and urbanization. Heritage cities, therefore, often face the dilemma of modern development and cultural preservation due to the invaluable cultural, historical, and architectural assets found within them (Frangedaki et al., 2020). The tension between these two forces is especially evident in cities like Xi'an, China, which have a rich historical significance but are also

undergoing rapid urban expansion. Xi'an, historically known as Chang'an, was the starting point of the ancient Silk Road and is home to several UNESCO World Heritage Sites, such as the Terracotta Army and the ancient city wall (Yuan et al., 2024). Despite its deep cultural roots, Xi'an faces significant challenges in balancing its urban growth with the protection of these priceless heritage assets. This will also place pressure on heritage conservation efforts with urban sprawl, increased traffic congestion, and infrastructure development. Now, more than ever, is the time when sustainable urban planning that can ensure modern development along with heritage preservation is a crying need.

One of the main challenges in heritage cities is the conflict that arises between urbanization and heritage conservation (Imtiaz, Arif, Nawaz, & Shah, 2024). As cities expand, the growing demand for space leads to the construction of roads, buildings, and other infrastructure that often encroach upon or disrupt historical sites (Khavarian-Garmsir, Sharifi, & Sadeghi, 2023). In Xi'an, for instance, the rapid development of its road networks has led to the encroachment on historical sites, affecting both their accessibility and preservation. It should be balanced, therefore, to meet the requirements of urban growth and the need to protect the heritage site with its cultural value and the requirement for modern infrastructure (F. Wang & Gu, 2023). Hence, such balance is, not only culturally and historically but also an environmental and economic issue since sustainable urban planning can be very essential to allow future generations to access and appreciate these sites with minimal negative impacts of urban growth. Furthermore, the problems associated with traffic congestion, pollution, and degradation of heritage sites give this region a clue that solutions to these problems must integrate 'sustainable' practice with heritage conservation (Moyano, Carreno, Nieto-Julián, Gil-Arizón, & Bruno, 2022).

Today, urban sustainability stands as the center of modern city planning, mainly in culturally diversified cities. Urban sustainability is considered a city's capability to be able to resist upcoming challenges, for example, global warming, loss of resources, and socio-economic inequities but at the same time to function efficiently and comfortably (Cheshmehzangi, Butters, Xie, & Dawodu, 2021). Sustainable urban planning emphasizes the integration of environmental, social, and economic factors into the decision-making process so that development does not occur at the expense of the environment or cultural heritage (Gilman, 2022). The planning and development of road networks is an important aspect of urban sustainability (Shah et al., 2024). Roads connect people to essential services, heritage sites, and economic activities. However, poorly designed road networks can contribute to traffic congestion, pollution, and other negative environmental impacts that affect both urban residents and cultural landmarks (Jarzebski et al., 2021). In cities like Xi'an, where heritage sites and modern infrastructure coexist, the challenge lies in creating road networks that enhance accessibility to these sites without compromising their preservation. Sustainability in urban planning is a balance of functionality in the transportation system with the need to protect cultural and historical landmarks such that the development of infrastructure does not undermine the cultural identity of the city (Pretorius, 2024).

Geographic Information Systems (GIS) have emerged as the powerful tool in the field of urban planning, especially for heritage conservation (Höhl, 2020). GIS is the collective term applied to the set of tools and technologies that enable users to collect, manage, analyze, and present spatial data. GIS in the urban planning can help to better understand the spatial relations between infrastructure, heritage sites, and green spaces (Nawaz, Su, & Nasir, 2021). Urban planning benefits in GIS are achieved by visualizing the impact that has been incurred upon heritage sites (Ni & Wei, 2024). It becomes an analysis of how a specific urban development process affects such a site; decision-making could therefore be informed. One of the key applications in GIS would involve spatial analyses; overlay, proximity, and buffering would help pinpoint a potential clash between urban growth and heritage preservation (Agustina, 2021). In the context of Xi'an, GIS can be used to analyze the impact of urban development on heritage sites, assess the accessibility of these sites via road networks, and evaluate the effectiveness of urban sustainability indicators, such as air quality, green spaces, and traffic flow (L. Shen, Q. Yang, & H. Yan, 2023). Further, GIS can support the design process for a sustainable urban plan by depicting the prohibition and re-direction zones for urbanization so that heritage sites are retained in their integrity. GIS-based applications offer enhanced decision making, increase participation to greater degree of the people and also presents an integrated insight of the complexity of how sustainability and sustaining heritage can occur, (Stroscio et al., 2021).

Urbanization presents both opportunities and challenges to the preservation of heritage, particularly in historically rich cities like Xi'an. When cities expand so quickly, pressure on heritage sites is increasing, which has the tendency to create conflicts between preservation and development. Geographic Information Systems (GIS) have been demonstrated to be a valuable tool in addressing such conflicts by providing spatial analysis and decision-making assistance to sustainable urban planning. In a city like Xi'an with such a deep history, the use of GIS in urban planning has the ability to balance the requirement for modern infrastructure and the necessity to preserve cultural heritage.

One of the essential aspects of this balance relates to the influence of road networks on accessibility to heritage sites. Although increased road connectivity can foster tourism and public engagement with heritage sites, poorly planned urban sprawl can possibly result in the deterioration of such cultural heritage sites. This study will seek to explore the application of GIS in heritage conservation management and sustainable urban planning in Xi'an. In particular, it will seek to explore how GIS can be applied to analyze the spatial relationships between road networks, heritage sites, and other urban features to identify any probable conflicts and opportunities for sustainable integration. The study will seek to evaluate how the road infrastructure in Xi'an can be planned to enhance the accessibility of heritage sites as well as mitigate the negative impacts of urban sprawl. The study will also identify the contribution of road networks towards sustainability through the enhancement of sustainable urban development. Drawing on GIS-based analysis, the study will offer recommendations to urban planners and policymakers on how environmental and infrastructure planning can be optimized within the city walls of Xi'an. Through these objectives, the study will add to the body of literature on the application of GIS to heritage conservation and sustainable urban planning.

This study is critical because it allows for actionable findings for urban planners, conservationists, and policy makers who deal with the complex issue of ensuring heritage conservation through urban growth. Using GIS technology provides a new, data-driven means of analyzing the spatial dynamics of urban growth in heritage cities by offering a new evidence-based framework. The study's findings could help inform future urban planning strategies in Xi'an, as well as in other heritage cities with similar urbanization challenges (X. Liu, S. Shao, & S. Shao, 2024). Such integration with GIS technology will facilitate more efficient means of achieving improvement in heritage city resilience: these cities ensure cultural artifacts are saved and passed down for many generations into the future as more sustainable ways are achieved within them. Since these recommendations aim at improving the networks of roads to get better access to heritage places along with an inclusion aspect of sustainability, the recommendations by the author will prove important for academics alike but equally interesting for field-practitioners (Cugurullo, Acheampong, Gueriau, & Dusparic, 2021). The results of this study can also feed into wider debates about the role of technology in the conversation and preservation of urban heritage, demonstrating how GIS can be involved in bridging the gap between modern development and cultural preservation. More importantly, this study can be replicated and extended to other cities in China and other parts of the world, so significant lessons can be drawn for sustainable urban planning in heritage-rich areas.

LITERATURE REVIEW

Urban Sustainability in Heritage Conservation

Urban sustainability is the integration of social, economic, and environmental development to achieve sustainable urban development, a concept that has become an essential part of heritage conservation today (Haldorai & Ramu, 2021). According to researchers, there are specific issues related to heritage cities that call for specific approaches toward sustainability. For example, conservation practice blended with urban development always creates disputes in terms of resource distribution, land use, and community involvement (Alp, 2024). This pressure is coupled with issues such as increasing urbanization and globalization, forcing cities to uphold their cultural heritage despite accelerated economic development (L. Shen et al., 2022). More so, urban heritage requires that there be critical analysis of policies regarding heritage preservation and ensuring that sustainable objectives do not infringe upon the history and integrity, at the same time, meet the demands of rapidly growing populations (Heshmati, Gheitury, & Shadfar, 2022). These complexities necessitate a shift towards adaptive and innovative planning mechanisms, which leverage both traditional and modern practices.

Geographic Information Systems have been very instrumental in tackling the problems described above as it offers a very robust framework in analyzing, visualizing, and managing urban space (Adeyelure, 2022). It will enable scholars to map the history of any historical site and observe environmental changes. The effect of urban sprawl can also be seen, thereby providing better informed decision-making skills (Y. Li et al., 2023). Studies have focused on the fact that GIS can combine various datasets, such as demographic trends and land-use changes, into actionable insights that support urban sustainability initiatives in heritage cities (Wierzbicka & Arno, 2022). However, the application of GIS is not without limitations, particularly in data accuracy and stakeholder accessibility, which can hinder its effectiveness in under-resourced regions (Matrone et al., 2023). These challenges are, therefore, pointers to further need for advancement and capacity building in the technological aspect of utilization in GIS-based processes of urban planning, particularly heritage preservation. In heritage conservation, GIS assists in the spatial analysis of the relationship between heritage sites, road networks, and urban growth. GIS can be employed to map out vulnerable heritage areas, maximize access to cultural sites, and suggest sustainable land-use policies that reduce the threats to historical resources. Nonetheless, GIS is challenged by factors such as accuracy problems with data, high costs of implementation, and poor accessibility

for stakeholders in underdeveloped areas.

It is at this juncture when principles of urban sustainability are integrated with advanced GIS tools, which in itself underlines the importance of greater community participation and more extensive interdisciplinary collaboration. Researchers argue that participatory approaches in planning permits local communities to become involved in heritage conservation work, making schemes more culturally sensitive and socially equitable (W. Li et al., 2022). More than that, the cross-sector collaboration between governments, private organizations, and academic organizations is necessary for innovation and resource sharing in sustainable urban planning (Son et al., 2023). In this respect, partnership can create synergies through which the preservation of cultural heritage can merge with a broader objective of urban development. Lastly, such integration underscores the transformational role GIS and principles of urban sustainability can take in understanding the intricate dynamics of heritage city conservation. The limitation of this area points toward increased development and strengthening of efforts that will focus more on heritage preservation and urban planning through sustainable principles.

Finally, urban sustainability of heritage relies fundamentally on efficient policies of land utilization and on pressures from globalization. Although all of these make big impacts in managing heritage, assessing them would always have to refer to applications with GIS for proper data-referenced action by conservation professionals. GIS can be used as an evaluative tool when assessing the impacts of globalization upon heritage sites to map trends in changes and measures the success of urban policies aimed at maintaining cultural heritage. Combining GIS within these conversations will allow urban planners to formulate strategic plans balancing development with culture and creating a sustainable urban future.

GIS Applications in Urban Planning

GIS has revolutionized the face of urban planning since it provides planners with mapping, spatial analysis, and data visualization tools to inform decision-making. GIS allows planners to integrate diverse datasets, including topographic maps, land use patterns, and demographic distributions, into coherent frameworks that help analyze urban dynamics (Luo et al., 2023). Advanced spatial analysis enables planners to assess the suitability of sites, evaluate environmental impacts, and determine patterns of urban sprawl. Therefore, GIS is a critical tool in the management of complex urban issues. For instance, applications of GIS in urban road networks have enhanced the management of traffic flow, optimized route planning, and supported the design of more efficient transportation systems (Sukwai, Mishima, & Srinurak, 2022). Also, since GIS organizes data into layer formats, stakeholders better understand issues facing the urban interface and cooperate on sustainable development solutions. Further expanding its role into developing strong designs for urban infrastructure, the prediction of future trends, which includes resource demands and population change, is possible (Pang, Dong, & Y. Liu, 2021). With heritage conservation, GIS provides helpful support since it documents and tracks historical sites ensuring that processes of urban development protect these sites. This technology identifies at risk heritage and analyses how the identified heritage will be impacted by the planned urban development proposals (Hsiao & S. Shen, 2023). Using software, for example, spatial overlay and 3D mapping, geographers can produce virtual data storages on the cultural features to assess their temporal meaning in more complex urban scenarios. For example, in heritage city preservation projects, GIS has been used to assess the impact of urban infrastructure, such as road networks and zoning changes, on the sustainability of cultural sites (Ni & Wei, 2024). This application not only mitigates risks but also supports proactive measures in urban planning. GIS integrates modern urban requirements with cultural heritage conservation through such integrative approaches. It promotes sustainable development while giving respect to the integrity of the past.

GIS Road Network

Geographic Information Systems (GIS) play an important role in urban planning, especially in road network planning in cultural heritage cities towards sustainable development. Through combining data acquisition, spatial analysis, and mapping, GIS facilitates the rationalization of road infrastructures and tackles problems in sustainable urban environments (Sánchez-Aparicio et al., 2020). The technology supports easier identification of traffic congestion patterns, road access limitations, and land-use conflict—planning factors in planning efficient transport systems without destroying historical sites (Ghasemi, Behzadfar, & Borhani, 2023). In historical cities, GIS harmonizes increased expansion of the road network with cultural heritage conservation through evaluating transport infrastructure and cultural sites' spatial interactions (W. Li et al., 2022). Buffer analysis and heat mapping are among GIS-based spatial modeling methods, and they have been applied well to Cairo and Tehran cities for coordination of road networks with heritage preservation areas. In Cairo, buffer analysis was employed to identify the safe area surrounding historical locations in a manner that new roads will not be connected to heritage locations (Elghazouly, Elnaggar, Ayaad, & Nassar, 2024). In the same way, Tehran utilized heat maps to map traffic jams around cultural areas so that traffic diversion plans would be created to reduce vehicular pressure on sensitive heritage areas (Nasiri et al., 2022). GIS technologies not only improve access but also reduce

environmental and structural deterioration brought about by excessive use and urban sprawl. For Xi'an, a city with a profound historical legacy, GIS applications in road network management can provide strategic insights into sustainable urban development without compromising cultural assets (X. Liu et al., 2024). By adopting buffer analysis, Xi'an can delineate protective perimeters around its ancient city walls and heritage districts, preventing inappropriate infrastructural encroachments. Additionally, heat maps can be utilized to analyze traffic patterns near historical sites, facilitating the implementation of sustainable mobility solutions such as pedestrianized zones and controlled traffic flows (Luo et al., 2023). Lessons from Cairo and Tehran underscore the transformative potential of GIS in heritage conservation, offering Xi'an a data-driven approach to preserving its urban history while improving road accessibility.

Case Studies and Best Practices

This study uses case studies of cities, such as Tehran and Cairo, and some in Spain that demonstrate the use of heritage conservation combined with urban planning while providing a mix of success and failure stories to seek sustainability. In Tehran, GIS was used for overlaying historic sites on city development plans so that areas could be identified in which modern infrastructure was threatening cultural landmarks (Nasiri et al., 2022). This approach enabled planners to develop interventions with heritage site preservation yet still allow for urban growth. Similarly, Cairo made use of GIS to manage its sprawling landscape but planned and plotted the historical zones with the contemporary city with balance tourism needs against the communities' interests (Elghazouly et al., 2024). Such efforts explicitly highlight the importance of GIS in reconciling heritage preservation with urbanization. The case of Spain, as usual, adopted an approach for the sustainable development of a city like Barcelona, thus reinstating the concept of the usability of GIS as heritage conservation activities merged into community participation would create an integrated urban regeneration practice (Sánchez-Aparicio et al., 2020). Therefore, to recap, the previous case studies managed to identify how GIS could become the transformative factor of heritage city planning. The chosen case studies of Tehran, Cairo, and Spain present varied uses of GIS in heritage preservation and urban planning, with both successes and challenges. Tehran successfully utilized GIS to map conflicts between historic sites and modern infrastructure, allowing for targeted interventions. Cairo maintained tourism growth while balancing local people's interests with GIS-based zoning approaches, and Spain, notably Barcelona, incorporated GIS with the involvement of citizens for sustainable city renewal. The constraints such as inconsistency in data, governance, and accessibility of stakeholders differed across cases. These cities were selected for their contrasting strategies and regional diversity and generated rich insights into the flexibility of GIS across various urban and cultural settings.

With these successes, however, significant inequalities are still felt most especially in stakeholder participation and GIS scalability. As indicated from the examples of Tehran and Cairo, public awareness was insufficient while funding was an issue in proper implementation of GIS applications (Ghasemi et al., 2023). For example, Spain has achieved much in terms of incorporating heritage preservation within a greater system of urban planning; however, the integration of the flow of tourism with the cultural identity at local levels is pretty weak (Sánchez-Aparicio et al., 2020). All of these indicate the requirement for more vigorous policies and technologies in the support of a more balanced application of GIS across the varied settings. The lessons from these cities emphasize the importance of combining technological tools with participatory governance to address the unique challenges posed by heritage conservation. Applying these findings to Xi'an highlights the importance of tailoring GIS applications to its distinct historical and cultural landscape (X. Liu et al., 2024). As a heritage city with deep historical roots, Xi'an can benefit from the integration of GIS tools used in previous case studies while addressing challenges specific to its context, such as managing tourist footfall and protecting fragile archaeological sites. Lessons from Cairo and Tehran underscore the need for comprehensive stakeholder engagement to ensure the successful implementation of GIS in Xi'an's urban planning initiatives (W. Li et al., 2022). Meanwhile, Spain's experiences point to the value of community-driven approaches in balancing cultural preservation with urban growth. By adapting these best practices and addressing identified gaps, Xi'an has the potential to emerge as a model for sustainable urban planning that seamlessly integrates heritage conservation and modern development.

METHODOLOGY

Research Design

The current research utilizes a mixed-methods design, integrating qualitative and quantitative analysis techniques to examine the interlinkages between heritage conservation and sustainable urban planning in Xi'an. A GIS-based case study is utilized to examine how historic preservation activities, infrastructure development, and urban expansion interact within the city's spatial system. Xi'an, which is a historically important city under rapid

modernization, is a special challenge whose urban growth needs to be kept in check to maintain its compact cultural heritage. It relies on geospatial analysis methods for quantifying urban growth patterns, evaluating their effects on heritage zones, and locating areas where conservation needs to be prioritized. GIS applications enable a comprehensive spatial analysis, with overlay analysis, spatial clustering, and buffer analysis capabilities to measure the accessibility, encroachment, and sustainability of heritage conservation in an evolving city environment. The qualitative aspect of the study supports this spatial analysis by examining urban planning policy, government reports, and conservation measures, which provide evidence of the regulatory framework for heritage preservation in Xi'an. By embracing such methodologies, the research offers an evidence-based but policy-informed examination of urban sustainability within the historic districts of the city.

Data Collection

The research gathers data from various secondary sources, providing a solid GIS-based evaluation of Xi'an's urban planning environment. Spatial data are compiled from sources like OpenStreetMap, government geospatial databases, and Google Earth's satellite images, providing accurate information regarding Xi'an's road networks, land use patterns, and locations of heritage sites. These data enable a spatial and temporal analysis of urban expansion and its impact on the conservation of historical sites. Remote sensing information also supports the identification of land-use alterations across time, facilitating the identification of locations where urban sprawl can encroach on protected heritage areas. Urban analysis remote sensing information was typically obtained on a regular basis, with high-resolution satellite imagery updated every 6 to 12 months, depending on the satellite system (e.g., Sentinel-2, Landsat, or commercial satellites like Maxar). The data collection process focuses on acquiring records from the most recent available sources, with a time frame covering data from 2020 to 2024. To complement these spatial data, the research also gathers qualitative information from urban planning and sustainability reports published by Xi'an's municipal government and heritage conservation bodies. Such reports present necessary policy information and regulatory frameworks, which facilitate the contextualization of the spatial information within the governance structure of urban preservation. GIS software like ArcGIS and QGIS are used to process and visualize these data, providing an accurate and high-resolution analysis of the spatial dynamics between contemporary infrastructure and historical areas. By combining both spatial and textual information, the research offers an integrated approach to sustainable urban planning in heritage cities.

Data Analysis

For data analysis, the research employs spatial analytical methods to analyze patterns of urban growth and their impacts on heritage preservation efforts in Xi'an. Overlay analysis is performed to analyze spatial overlaps between modern infrastructure and heritage areas, defining areas where pressures of development can threaten cultural monuments. This process enables a simple visual identification of areas that need more stringent conservation policies. Spatial clustering methods are also employed to identify high-density urban development areas around historical locations, showing focal points of concentrated urbanization that could hasten threats to cultural preservation. This method enables identification of areas where interventions in urban planning policies can be made to balance modernization with preservation. Buffer analysis is also employed to analyze the road network accessibility of heritage sites, determining whether urban expansion is enhancing or restricting access to cultural monuments. These quantitative spatial results are further analyzed based on qualitative policy analyses to ensure that both geospatial data and governance issues are considered when drawing conclusions in the study. By combining these approaches, the research offers a holistic spatial approach to sustainable urban planning in Xi'an, with insights that can inform policy, infrastructure planning, and preservation measures in other historic cities with comparable urbanization challenges. Table 1 outlines various data sources essential for analyzing urban sustainability and heritage conservation. GIS databases provide spatial data for mapping heritage zones and urban infrastructure, while satellite imagery aids in verifying and identifying unrecorded features. Local government reports offer insights into urban planning frameworks and conservation strategies. Academic studies contribute case studies and best practices for comparative analysis, and sustainability reports help evaluate the environmental and infrastructural impact of urban development. Together, these data sources provide a holistic approach to understanding the interplay between urban growth and heritage preservation.

Table 1. Summary of Data Sources and Attributes

Data Source	Type of Data	Attributes	Purpose
GIS Databases (e.g., OpenStreetMap, Local Government GIS Portals)	Spatial Data	Heritage site locations, road network layouts, land use patterns	Mapping and overlay analysis of heritage zones and urban infrastructure
Satellite Imagery (e.g., Google Earth)	High-resolution Visual Data	Visual representation of urban landscapes and heritage zones	Verification of spatial data and identification of unrecorded

Data Source	Type of Data	Attributes	Purpose
			urban features
Local Government Urban Planning Reports	Textual and Statistical Data	Urban sustainability indicators, zoning regulations, development policies	Contextual understanding of planning frameworks and heritage conservation strategies
Academic Studies and Literature	Secondary Data (Qualitative and Quantitative)	Case studies, best practices, and policy evaluations	Comparative analysis and identification of gaps and lessons relevant to Xi'an
Sustainability and Infrastructure Reports	Statistical and Analytical Data	Indicators of urban development, environmental impact metrics, and public infrastructure data	Evaluation of urban planning practices and their implications for sustainable development

Case Study: Xi'an

Historical and Urban Context of Xi'an

The very ancient city in China, that starts the Silk Road, is actually a treasure-trove of all kind of cultural and historical heritage; the city also has an incredible number of heritage sites, the Terracotta Army of Emperor Qin Shi Huang, the Giant Wild Goose Pagoda, as well as an ancient City Wall, all a testament to this city's age, over 3,000 years. These landmarks symbolize the city's cultural significance and attract millions of tourists every year, hence contributing to its economic vitality (X. Liu et al., 2024). However, Xi'an's unique position as a historical and modern urban center presents significant challenges for urban planning. With a population exceeding 13 million, the city has experienced rapid urbanization, leading to expanding road networks, high-density developments, and increasing pressure on its heritage sites. These dynamics therefore demand a fine balance between retention of historical characteristics and requirements that modern cities bring (K. Yuan, Abe, Yasufuku, & Takahashi, 2022).

The rapid growth of the city brings along many issues, including heritage zone encroachment, failing to incorporate the preservation of cultures into the designs of cities, and environmental degradation (D. Li, J. Wang, & Shi, 2023). For instance, the expansion of roads and high-rise developments often clash with the preservation of traditional architectural landscapes, thereby putting the integrity of heritage sites in conflict. Moreover, the rising influx of tourists has put additional strain on these historical areas, highlighting the need for sustainable urban planning approaches. Despite these challenges, Xi'an has made strides in incorporating heritage conservation into its urban policies, leveraging modern technologies like GIS to inform planning decisions. Thus, understanding the interplay between historical and urban contexts will provide sustainable strategies for the protection of the city's cultural legacy and for growth in the urban (Ni & Wei, 2024).

GIS Analysis of Xi'an's Road Networks

The GIS analysis of Xi'an's road networks reveals the spatial relationships between modern infrastructure and its heritage sites, offering insights into the city's urban planning dynamics. The road network plays a crucial role in connecting heritage sites with other parts of the city, ensuring accessibility for residents and tourists (Luo et al., 2024). Overlay analysis of GIS data depicts that some of the road development projects are advancing into heritage zones, especially at the ancient City Wall and in historical districts such as the Muslim Quarter. It is liable to damage the integrity of those places physically and aesthetically, hence in need of meticulous planning so as not to inflict irreparable harm.

Spatial clustering and buffer analyses highlight areas of road network expansion where potential conflicts may have been created toward heritage conservation goals. Spatial clustering was carried out using the Getis-Ord Gi statistic (hot spot analysis)* to identify areas of significant road network expansion. This method checks for spatial autocorrelation by measuring the clustering of high or low values within a dataset. Hot spots of statistically significant high values are regions of high growth, and cold spots of low values are regions of low growth. The test was performed in a GIS environment to map and visualize the clusters against heritage conservation sites. Clusters of extremely close-knit nodes of road intersection in Giant Wild Goose Pagoda and Bell Tower regions may be areas that are affected by possible conflicts in infrastructure expansion across cultural and aesthetic value of heritage sites (Agustina, 2021). In addition, buffer analysis shows that some heritage sites cannot be accessed evenly with some being well-linked within the road network and others being rather isolated. This uneven accessibility affects tourist experiences and limits the engagement of local communities with their cultural heritage. By identifying these patterns, GIS analysis provides a valuable framework for addressing conflicts and

improving the integration of heritage conservation into Xi'an's urban planning initiatives. These findings present both the supporting and undermining roles of road networks in the achievement of urban mobility and heritage conservation (L. Shen et al., 2023). Therefore, context-sensitive planning policies need to be adopted, such as rerouting traffic away from heritage sites and focusing on public transport services that will have minimal effects on the environment. Additionally, the inclusion of buffer zones and pedestrianized paths will improve heritage site access and conservation. Through these GIS-informed strategies, Xi'an can better reconcile its urban development goals with the imperative of cultural preservation, ensuring a sustainable future for its historical and modern urban landscapes. Figure 1 presents a map of Xi'an, showcasing its rich cultural and historical heritage through key landmarks such as the Terracotta Warriors Museum, Daming Palace, and the Great Mosque. The map highlights road networks connecting these sites, offering insights into the city's layout and accessibility, and supports urban planning efforts by identifying how cultural preservation and modern development coexist, enabling better tourism management and improved accessibility for visitors. This visual representation emphasizes Xi'an's significance as a hub of ancient Chinese history and a center for tourism and cultural preservation.

Figure 1. Map of Xi'an Highlighting Key Heritage Sites and Road Networks

Urban Sustainability Indicators in Xi'an

Looking at the assessment of the city's urban sustainability indicators, there are different metrics that would say much about the development trajectory of the city, such as the green spaces within which the quality of urban life is determined and hence the environmental sustainability of the city. GIS analysis reveals that although much was achieved in integrating parks and green belts into the urban structure of the city. The explosive growth of sprawl and construction of infrastructure had resulted in green areas being reduced, mainly around historical areas (P. Zhao, Md Ali, Nik Hashim, Ahmad, & H. Wang, 2024). The removal of these green lands threatens not only the ecological balance but also the aesthetic and cultural outlook of the city. Additionally, traffic flow and pollution levels are critical indicators of urban sustainability in Xi'an, where increasing vehicular traffic has contributed to air pollution and congestion, particularly around heritage areas. Traffic congestion in central urban districts like the Muslim Quarter and near the City Wall exacerbates pollution levels, affecting both the environment and the health of residents and visitors (Yi, W. Li, & D. Zhang, 2021). This thematic map, as shown in Figure 2, provides a visual overview of the spatial distribution and interrelationships between different sustainability indicators in Xi'an, enabling a better understanding of environmental, social, and economic

conditions across the city. The map illustrates the spatial distribution of geological features and their relationship with landslides in Xi'an. Zones A, B, C, and D represent specific geological formations: A (Proterozoic and Mesozoic granite gneiss), B (Precambrian metamorphic rocks with Quaternary loess), C (Malan and Lishi loess), and D (Quaternary fluvial sediment deposits). The red triangles indicate landslide-prone areas. This GIS-based analysis helps in urban development by identifying hazard zones, suitable construction areas, and optimizing road networks to avoid high-risk regions.

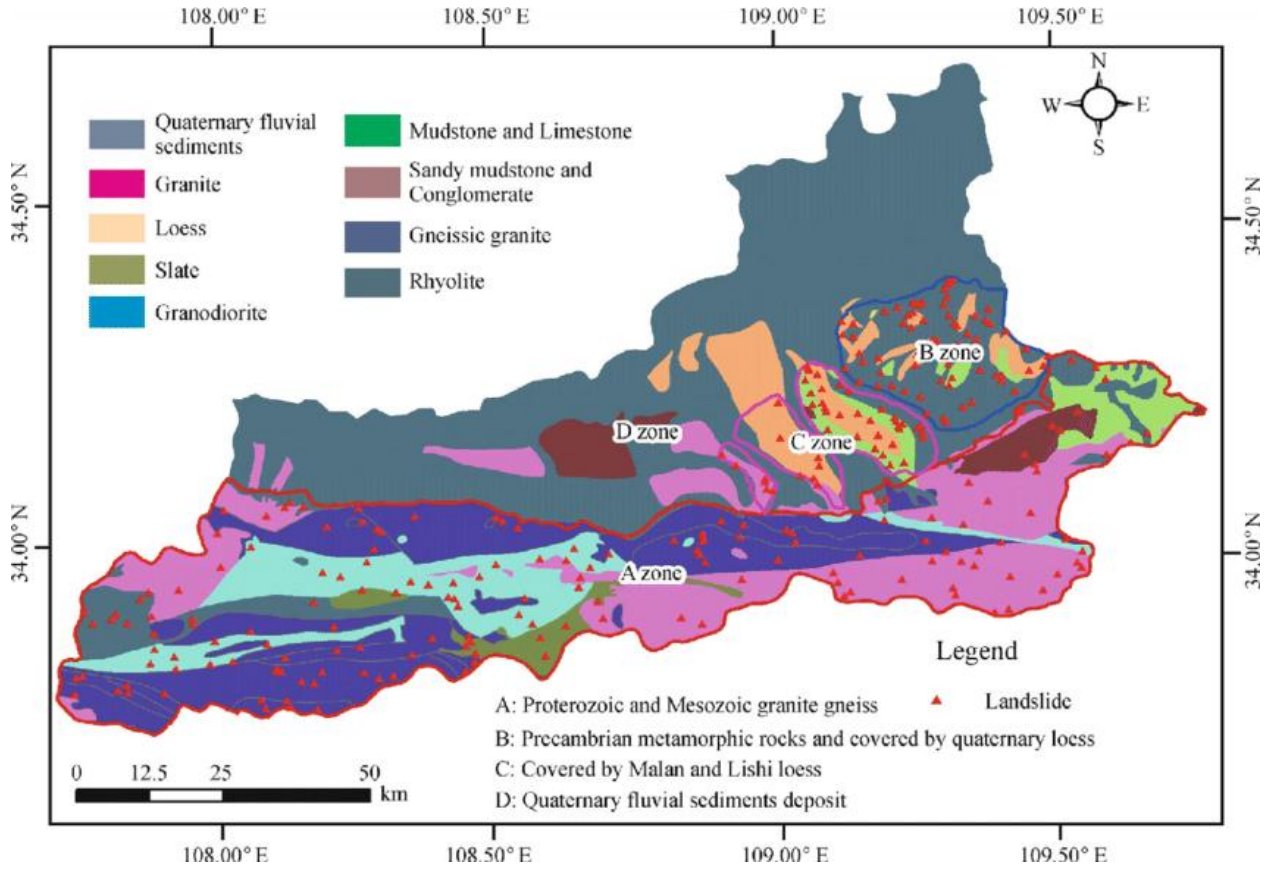

Figure 2. GIS-generated Thematic Map of Sustainability Indicators in Xi'an

Probably due to the contrast between urban movement and environmental suitability, traffic flow management in ancient districts of Xi'an is found to be much challenging. Geographically supported analyses of traffic volumes and patterns illustrate that in such congested localities, typically narrow roads are responsible for blocking the traffic through the heritage region and the number of vehicular-pedestrian-tourism traffic (J. Liu et al., 2023). These conditions contribute to high air and noise pollution, which defeats the whole point of the campaign to reduce the carbon footprint of the city while simultaneously improving the air quality. Waste management in these crowded areas, for instance, is another parameter of urban sustainability, which gets worse during the peak tourist season when most of the visitors inflate the volume of waste, therefore overstressing the infrastructure of the city (Dai, Tang, Y. Li, & Lu, 2025). In response to these challenges, Xi'an's urban planners have focused on developing sustainable transportation networks, improving waste management systems, and incorporating green infrastructure, such as vertical gardens and urban parks, to mitigate environmental degradation. The integration of these sustainability indicators with GIS tools allows for data-driven decision-making to address the city's environmental challenges.

Challenges and Opportunities

The urbanization of Xi'an presents several challenges, as shown in Table 2, in terms of balancing heritage conservation with modern infrastructure development. One of the primary conflicts arises from the expansion of urban areas into regions rich in cultural heritage (Dang & J. Li, 2021). In particular, the push for road network expansion, new housing developments, and commercial centers often encroaches upon historically significant districts, such as the area surrounding the Terracotta Army and other key archaeological sites. This expansion fosters economic growth while also promoting urbanization, but at most of these locations, it endangers historical integrity. In many ways, the preservation process for these cultural heritages has sometimes been compromised

due to the desire for urban expansion, which gives rise to this conflict between development and conservation interests (Kan et al., 2021). The lack of coordination between the heritage conservation agencies and the predominantly fragmented decision-making processes of bodies involved in the urban planning systems may further depreciate the condition of management concerning the preservation state in the near future.

Another challenge arises from the growing pressure of tourism on Xi'an's heritage sites. The city's historical landmarks attract millions of visitors each year, creating an imbalance between tourism-driven economic benefits and the conservation of these fragile sites (Anser, Adeleye, Tabash, & Tiwari, 2022). Overcrowding, wear and tear on infrastructure, and the strain on public services are some of the consequences of uncontrolled tourism in Xi'an. These challenges show a need for the development of sustainable tourism strategies by factoring heritage protection, crowd management, and best practices for sustainable development. In this respect, there is scope for innovative ways to capitalize on GIS technology for conflict resolution in these regards (Luo et al., 2023). By mapping with GIS for an analysis of patterns of urban growth and location of heritage sites, planners can identify areas of conflict potential, and provide recommendations that integrate the conservation effort into sustainable development plans. For instance, planners can use buffer zone analysis to determine clear boundaries around heritage sites so that further urban encroachment is restricted while accessibility to the surrounding areas is retained for locals and tourists alike (P. Zhang, Gao, & Ma, 2024).

GIS can offer solutions to a number of problems related to environment in Xi'an, starting from air pollution and problems of waste. Analyzing GIS tools will develop alternative transportation networks that will increase accessibility to heritage sites while reducing the pressure on the transportation system, creating a healthier natural environment (Khavarian-Garmsir et al., 2023). Furthermore, it assists in quantifying the outcome of green infrastructural initiatives, including parks and walking paths, that ensure the enhancement of the city's livability. Not to mention the fact that their establishment positively contributes to cultural heritage as historic neighborhoods become more photogenic and their ecological value boosts. Sustainability Indicators incorporated within GIS-based Planning are an enabling tool for policymakers in Xi'an to produce strategies which aim at promoting sustainable environmental issues coupled with protection of the city's great rich cultural heritage (Garzulino, Borgarino, & Del Curto, 2021).

The further integration of participatory planning with GIS technology facilitates the securing of future prospects on sustainable urban development. Participation, both from the community and from stakeholders, integrated with heritage expertise, may offer a more holistic design of contextual urban policies in which modernity can be tolerated without sacrificing the preservation. By using GIS to visualize different urban planning scenarios, stakeholders can assess the potential impacts of development projects and collaborate on solutions that protect both heritage sites and the environment. This participatory approach can ensure that urbanization in Xi'an is not only efficient and modern but also respects and enhances the city's unique historical and cultural identity. Through these combined efforts, Xi'an has the potential to set an example for other heritage cities navigating the challenges of sustainable urban development.

Table 2. Summary of Conflicts and Opportunities Identified through GIS Analysis

Aspect	Conflicts	Opportunities
Urban Expansion	- Encroachment of modern infrastructure on heritage sites (e.g., road networks, buildings). - Increased urban sprawl is affecting the integrity of historical areas.	- GIS analysis can identify areas of potential conflict and guide urban planning that avoids heritage sites. - Buffer zones can be established around heritage areas to limit encroachment.
Traffic Congestion	- Overcrowded streets around heritage sites due to high tourist footfall and inadequate infrastructure. - Traffic-related pollution and congestion are impacting air quality and heritage zones.	- GIS can help identify high-traffic areas and propose alternative routes or public transport solutions to ease congestion. - Sustainable mobility options, such as pedestrian zones and eco-friendly transportation, can be integrated using GIS data.
Green Space Preservation	- Loss of green spaces due to urban development and road expansion. - Reduction of environmental quality impacts both residents and heritage areas.	- GIS can map existing green spaces and identify locations for potential green infrastructure development. - Urban parks and green belts can be strategically placed near heritage zones to improve environmental quality and visitor experience.

Aspect	Conflicts	Opportunities
Tourism Management	- Overcrowding and excessive tourism impact the preservation of cultural sites. - Strain on local infrastructure, waste management, and services.	- GIS can analyze visitor patterns and suggest measures to distribute tourism more evenly across heritage areas. - Development of sustainable tourism strategies using GIS to minimize environmental and infrastructural strain.

RESULTS

Key Findings from GIS Analysis

The GIS analysis of Xi'an's urban landscape reveals significant spatial relationships between its road networks and heritage sites (Figure 3). A prominent finding is the presence of several heritage zones, particularly around the City Wall, the Giant Wild Goose Pagoda, and the Muslim Quarter, where road expansion projects have intersected with or encroached upon historically significant areas. Overlay analysis of GIS data points out that the urban road network passes directly through or at the edge of heritage sites, especially in the high-density districts, which creates a threat to its preservation as well as its visual value. These findings indicate that recently constructed highways or expressways have initiated fragmentation in heritage zones, preventing the adoption of a continuous historical landscape. In addition, buffer analysis method in GIS tools like ArcGIS or QGIS was used to create zones around heritage sites, measuring their proximity to green spaces and assessing environmental protection levels, others are poorly buffered and thus more susceptible to development pressures.

The buffer analysis conducted in this study highlights the varying degrees of protection afforded to Xi'an's heritage sites based on their proximity to major road networks and urban developments. The findings indicate that sites with well-defined buffer zones, such as green spaces or pedestrian areas, experience lower environmental degradation and reduced structural stress from vibrations caused by traffic. Conversely, heritage sites close to dense networks of roads experience higher risks in the form of air pollution, noise intrusion, and physical intrusions due to expanding infrastructure. The absence of proper buffer zones in some zones indicates a demand for tighter zoning controls and planning interventions to help ensure long-term sustainability. Through the use of GIS-based buffer analysis, policy makers are able to create strategic measures to curb the negative impacts of urbanization while promoting accessibility and conservation initiatives.

A key implication of these findings is the concern with accessibility and sustainability. The integration of heritage sites within the broader urban fabric is necessary to ensure their protection and public access. However, some of the road infrastructure in Xi'an obstructs or isolates certain heritage zones from the rest of the city, limiting public access and reducing the ability of local communities to engage with their cultural heritage. Furthermore, the road networks around heritage sites often experience high levels of traffic congestion, contributing to pollution and diminishing the environmental quality of the areas. The outputs of the GIS analysis of traffic flow patterns confirmed that these congested areas, particularly within the city center, are susceptible to air and noise pollution, thereby harming the heritage environment. Tools such as ArcGIS, QGIS, or TransCAD can be used to map congestion hotspots and assess pollution levels. ArcGIS is commonly used for spatial analysis, integrating traffic and environmental data, while TransCAD specializes in transportation planning. Additionally, remote sensing and air quality models (e.g., ENVI or Sentinel-5P data) may have been used to link traffic density with pollution levels. All the more reason to be in a rush to adopt greener transportation and urban planning, since excessive vehicular traffic is an agent of environmental degradation that threatens heritage sites. The GIS analysis further indicates serious environmental sustainability issues, specifically air quality and noise pollution within heritage areas. Traffic zones around historical monuments, like the Bell Tower and Drum Tower, have high pollution levels, which are detrimental to both the preservation of the cultural landmark and the health of the public. Noise pollution due to crowded roads also endangers the atmosphere and tourist experience of these places. By integrating GIS-based pollution mapping, urban planners can identify critical areas requiring intervention, such as traffic rerouting, green buffer zones, and stricter vehicular regulations, to enhance sustainability while preserving Xi'an's heritage. The map illustrates Xi'an's urban expansion and heritage site distribution. Different shades of gray represent urban growth from 1949 to 2020, with darker shades indicating earlier development. Orange dots mark heritage sites, while red symbols indicate the national (star) and provincial (circle) capitals. Blue lines show rivers, and the cyan area highlights a key urban zone.

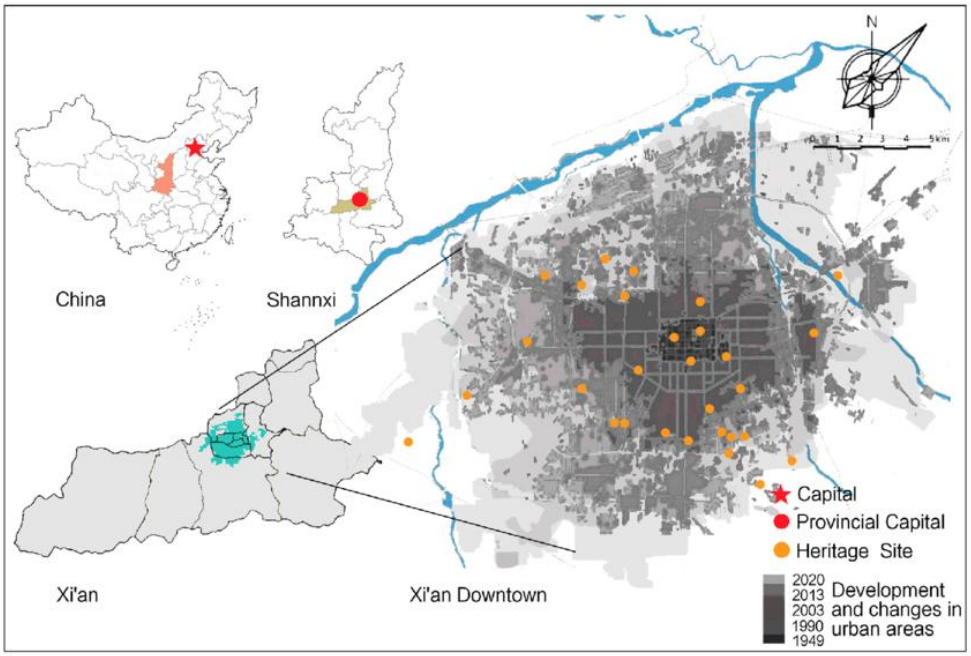

Figure 3. Heatmap of Accessibility to Heritage Sites via Urban Road Networks

Urban Planning Implications

The findings of this study have significant implications for urban planning in Xi'an, particularly with respect to road infrastructure and heritage conservation. The integration of sustainability in urban road planning is of high importance for continued growth in the city without destroying its cultural identity. One of the key recommendations involves the creation of more effective buffer zones around heritage sites to protect them from encroachment by road developments and other high-density urban projects. The areas can be identified through GIS analysis as buffers. They are considered protective areas, ensuring that there are spatial separations between heritage zones and the modern infrastructure involved. Buffer zones can be green spaces, pedestrian pathways, and low-density urban developments. This therefore, minimizes the footprint that urban growth attains on the environment and protects the integrity of heritage sites.

This paper aims to demonstrate that a necessity exists in the design of alternative solutions in transportation that would be more ecological and reduce the traffic pressure on historical zones. The public transport concept of bus lanes, subway routes, or the dedicated routes of electric vehicles will drastically reduce pressure on Xi'an's heritage zones, resulting from high vehicular traffic. The use of GIS tools could indicate traffic congestion areas and then redesign a road network with increased efficiency and sustainability. This is also an avenue through which access to heritage sites can be improved while conserving the sites. Using GIS to prepare high-resolution, multi-layered maps that reflect traffic patterns, environmental impact, and heritage locations may guide future urban planning policies with both sustainability and conservation in mind.

Including heritage conservation goals in the process of urban planning could help better coordinate the actions of city planners, heritage preservation authorities, and other local stakeholders. The argument of the paper is very rightly made that heritage preservation and urban growth complement rather than compete with each other. Heritage should become part of long-term strategic planning for urban planners. Indeed, policies need to recognize the value of historical sites as an element of the city's cultural identity and sustainable development. Using GIS in comprehensive analysis should ensure that infrastructure projects are compatible with heritage protection, therefore making for a balanced approach in all urban development schemes.

Generalizability of Results

While this study is focused on Xi'an, the findings have significant implications for other Chinese heritage cities facing similar challenges of urbanization and heritage conservation. Other Chinese heritage cities facing similar urbanization and conservation challenges include Beijing, Suzhou, and Hangzhou, where GIS has been used for traffic management, heritage site monitoring, and urban planning. For example, Beijing employs GIS to analyze tourism impact near the Forbidden City, while Suzhou integrates GIS for historic canal preservation. Such applications highlight GIS's role in balancing urban growth and heritage conservation. Many cities in China, including Beijing, Hangzhou, and Suzhou, are rich in cultural heritage but are also experiencing rapid urban

growth, leading to conflicts between development and preservation. The GIS methodologies used in this research study can serve as a model to evaluate the spatial interaction between heritage sites and urban infrastructure in other cities. Other city planners using GIS can thus determine areas of conflict and then create targeted strategies for mitigation of the adverse impacts while preserving cultural resources. More broadly, the generalizability of the results extends beyond the context of Chinese cities as well. The approach can be adapted to other countries with significant historical and cultural landmarks, such as those in Southeast Asia, the Middle East, and Europe. Cities like Cairo, Tehran, and Rome, which also face the challenge of managing urbanization around valuable cultural heritage, could benefit from applying GIS to monitor the spatial relationship between infrastructure and heritage zones. Furthermore, the lessons learned from Xi'an's experience — such as the importance of buffer zones, sustainable transportation, and integrated planning — can inform global best practices for balancing urban development with heritage preservation. As urbanization continues to accelerate worldwide, GIS will play an increasingly critical role in supporting cities to preserve their historical legacy while embracing modernity. The map in Figure 4 pinpoints the spatial concentration of high-density urban nodes around the dominant heritage sites in Xi'an, with a focus on zones of congestion and potential conservation risk. The overlapping road networks reflect accessibility but also the potential for urban encroachment into heritage zones. The buffer zones reflect strategic intervention zones, where controlled development and traffic management can balance urban growth with heritage conservation.

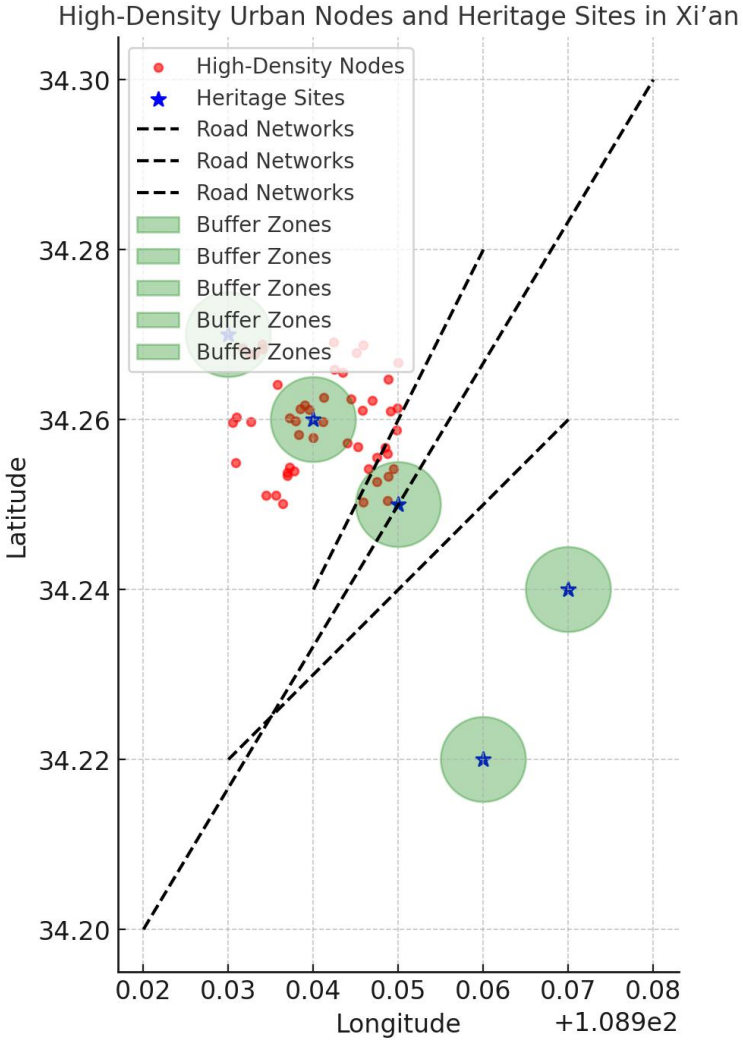

Figure 4. GIS-based Visualization

DISCUSSION

The results of this study shine a light on the controversial relationship that exists between urban development and heritage preservation in Xi'an, which is a city full of culture and rich in history and undergoing rapid

urbanization (Salameh, Touqan, Awad, & Salameh, 2022). This study about road networks and heritage sites reveals several key issues with tremendous implications for urban planning. The spatial conflicts between heritage sites and modern infrastructure pinpoint a crying need for reassessing the planning and expansion of road networks in historic cities (Khavarian-Garmsir et al., 2023). The findings are in line with previous literature, which presents that heritage cities around the world are facing a lot of problems, especially in areas where rapid urbanization is happening. For example, in Cairo and Tehran, the same issues have been well-documented regarding sprawl and infrastructure encroachment on heritage sites (Vafadar, Rahimzadegan, & Asadi, 2023). The case of Xi'an is not an exception because it requires the integrated planning of the city with a balance between the preservation of historical sites and modern development.

Analysis revealed that heritage zones, such as those built around the Xi'an City Wall or the Giant Wild Goose Pagoda, present zones most vulnerable to pressure for urban development. Such locations find themselves where major road intersections and high-density urban area exist, leaving behind often-degraded and visually fragmented sites. This finding aligns with scholars who have commented that rapid urbanization in heritage cities tends to adversely affect the preservation of cultural landmarks (X. Yang, Z. Zhao, C. Shi, L. Luo, & Tu, 2023). In Xi'an, road expansion, including new highways and arterial roads, is a major cause of this conflict. Overlay analysis showed that these historical areas are overlain with the constructed urban road networks, which in many cases were constructed with little consideration for heritage. Several scholars have advocated for the creation of buffer zones as effective measures to reduce these conflicts, the need for buffers around the heritage sites (Dang & Li, 2021). These findings are significant because they underscore the need for strategic thinking in urban development, one that will harmonize heritage conservation with the demands of a growing city.

In addition, the GIS analysis highlighted significant challenges in accessibility and environmental quality around heritage sites. High traffic volumes near cultural landmarks, coupled with inadequate pedestrian infrastructure, reduce the quality of the visitor experience and increase pollution levels. High traffic volumes near cultural landmarks can be identified using traffic counters, GPS/mobile data, CCTV with AI analytics, and transportation modeling software like VISUM or Aimsun. Air pollution sensors can also serve as proxies for traffic density. Additionally, manual surveys and field observations help validate data. This finding further supports the works that have appeared on the impact of urban congestion around heritage sites, which often mirrors the findings of studies related to cities like Rome and Istanbul. Here, tourism and traffic congestion are observed to have detrimental impacts on cultural sites preservation as well as residents' quality of life (Ni & Wei, 2024). The challenge in Xi'an is that most heritage areas are concentrated in the city's central districts, which happen to be the most congested districts. The alternative routes, like subways, electric buses, and pedestrian pathways, are evident from the analysis. Urban planners should thus focus on developing sustainable transport modes, which are not only easing congestion but also improving the environmental quality of the surroundings around such valuable heritage sites. This finds alignment with the ever-growing consensus of scholars that sustainable transportation is an effective tool to combat the adverse impacts of urbanization on heritage areas (P. Zhang et al., 2024). In cities like Rome and Istanbul, Geographic Information System (GIS) technologies have been used to monitor urban expansion and assess the impact of infrastructure development on cultural heritage areas. For example, in Rome, GIS-based spatial analysis has been used to map tourism flows and identify areas of increased risk of heritage deterioration, leading to improved visitor management policies (Dang & Li, 2021). Similarly, in Istanbul, GIS has been used to study the impact of expanding road networks on historic neighborhoods, enabling urban planners to implement protective zoning laws (P. Zhang et al., 2024). These examples point to the potential of Xi'an to adopt GIS technologies in a similar manner to balance urban development and heritage preservation.

In Xi'an, GIS-based network analysis can optimize public transportation routes by identifying the shortest and most efficient paths for buses and subways, minimizing vehicular congestion near heritage sites. Accessibility mapping can help planners determine underserved areas where new transit stops or pedestrian-friendly pathways are needed, ensuring that visitors and residents can reach cultural landmarks without relying on private cars. Besides, transport demand forecasting with GIS-enabling software packages such as TransCAD or VISUM can also predict passenger demand and suggest adjustments in transit frequency to suit the peak tourist months without leading to overcrowding. Case studies conducted in Rome and Istanbul have confirmed the viability of incorporating environmentally friendly transport means like electric buses, trams, and pedestrian lanes to shield the historical landmarks from the negative impact of urban jams. Xi'an can adopt similar strategies by expanding its subway network near cultural landmarks and increasing the use of GIS-based heat maps to monitor public transport efficiency and adjust routes dynamically based on demand. Furthermore, incorporating real-time GIS tracking and mobile data analytics can improve transit scheduling and minimize delays, enhancing overall accessibility to heritage districts. By leveraging GIS in transportation planning, Xi'an can develop sustainable transit solutions that not only alleviate congestion but also improve environmental quality around heritage sites. This aligns with the growing scholarly consensus that sustainable transportation is a key tool in mitigating the

negative impacts of urbanization on cultural heritage.

The results of the study show that there is a vital importance of green spaces for both ecological and cultural integrity in heritage zones. By means of GIS analysis, it was established that areas in proximity to heritage places lacking the sufficient green infrastructure are more prone to environmental quality degradation and decline in urban livability. According to existing literature, it is established that green spaces enhance the aesthetic quality and environmental setting of a city and have major contributions to making sustainable cities in their heritage conservation purposes and also to combat the pollution-related issues and mitigating the Urban heat island effect for recreational areas by the public in a city (Toku, Amoah, N-yanbini, Sarfo, & Tornyeviadzi, 2024). Integration of green infrastructure around heritage sites can dramatically increase both environmental sustainability and social accessibility in such areas in Xi'an. Therefore, analysis reveals that this area has potential to expand further in terms of green spaces or buffer zones and enhance the preservation of heritage as well as improve the urban environment as a whole. These findings indicate the critical role that green infrastructure can play in balancing the needs of urban development with the preservation of cultural heritage (W. Zhou, Song, & Feng, 2022).

The research also throws out another most significant finding - integrating GIS into urban planning practices is of fundamental importance. One very important issue identified by the use of GIS for spatial analysis and mapping is spatial areas of road network conflict or tension with a heritage site; maps and over lays at that spatial level offered an unspoken but clear urban growth impact profile in heritage zones to planners. This approach provides a comprehensive understanding of the spatial dynamics at play in Xi'an by combining qualitative insights with quantitative GIS data. The value of GIS in urban planning has been widely recognized, with many scholars highlighting potential usage that informs decision-making and improves the efficiency of urban development processes (Ramos-Escudero, Gil-García, García-Cascales, & Molina-Garcia, 2021). With GIS modeling of alternative urban planning scenarios, Xi'an will be in a better position to predict the impacts of new infrastructure projects on heritage areas and devise more sustainable urban strategies. Results from this study depict the need for applying sophisticated technological aids such as GIS in culturally vibrant cities to merge the heritage conservation activity into all levels of urban development (X. Liu et al., 2024).

This finally places the findings of this research into the wider discourse on urban sustainability and heritage preservation in China and beyond. Cities, like Xi'an, have various issues that emerge as a result of higher speed in global urbanization. There is a wide spread debate concerning several cities globally as they try to find ways of preserving their cultural heritage as populations continue to rise and more modern infrastructure takes place (Fan & Sun, 2024). Lessons from the experience of Xi'an from this research can be applied to other Chinese heritage cities, including Beijing, Hangzhou, and Suzhou, in urban planning. These cities all experience similar problems in urban sprawl and congestive traffic problems despite preserving ancient landmarks, such as those in Xi'an (W. Zhou et al., 2022). Adoption of GIS-based planning approaches with sustainable transportation and green infrastructure may solve the problem of balancing urban growth with heritage conservation. The findings of this study may be applicable to other heritage cities worldwide, which are currently facing the problems of urbanization. This type of GIS-based approach can, therefore, be applied to the cities of Cairo, Tehran, and Rome-important locations hosting significant cultural attractions to maintain the heritage along with sustainable urban development in those cities (Sánchez-Aparicio et al., 2020).

From this study, heritage conservation should be integrated into urban planning processes to ensure that rich cultural histories of cities like Xi'an are respected. The analysis of the data using GIS also showed significant spatial conflicts between heritage sites and urban development, therefore requiring more sustainable and strategic planning. Emphasizing the worth of GIS tools in the discovery of these conflicts and in advising urban planning choices that are attentive to the preservation of cultural heritage yet also consider modern infrastructure demands, the study finally recommends that a very crucial contribution to the attenuation of negative urbanization impacts on heritage sites might be achieved with the integration of green infrastructure with sustainable transportation solutions (M. Baglioni, Poggi, Chelazzi, & P. Baglioni, 2021). The lessons of Xi'an may be applied in the development of sustainable urban planning strategies in heritage cities, whether in China or globally. Through heritage preservation, environmental sustainability, and the application of technological tools such as GIS, cities will be able to better navigate the challenges of urbanization while safeguarding their cultural legacy for the future.

IMPLICATIONS

Significant in the theoretical contribution of this research is how the understanding of serving as a powerful tool by Geographic Information Systems (GIS) in the sustainable interplay that exists between the process of sustainability and heritage conservation becomes advanced. Through application to the context of Xi'an's urban planning and heritage conservation, this research demonstrates the utility of spatial analysis in the identification

and redress of the spatial conflicts arising between modern urban infrastructure, such as road networks, and cultural heritage sites. The integration of GIS allows for a deeper understanding of the way in which urban development encroaches on historic areas, giving an objective basis for the appraisal of the effects of infrastructure on cultural landmarks. This is also in line with theoretical perspectives where technology is at the forefront as a facilitator of sustainable development and cultural preservation. The research extends the current literature by demonstrating that GIS is not only a mapping tool but also a strategic instrument for decision-making in urban planning that takes into account environmental and cultural factors. The overlay of road networks with heritage site locations and other sustainability metrics provides a new approach to urban planning that balances development needs with heritage protection.

In addition, the research contributes to the expanding literature of urban sustainability with an insight into the complex relationship between the urban road network and heritage planning. Results have underlined the importance of both tangible and intangible cultural heritage in the design of urban infrastructure. Findings of the research have shown that the road networks in Xi'an and probably other heritage cities disturb the physical and aesthetic integrity of the cultural sites. This also falls in line with frameworks used in urban sustainability, which would call for development on a balanced platform that does not sacrifice cultural conservation for the growth of cities in terms of extension. It further calls for better integrated processes in urban planning to combine infrastructure development with cultural and environmental conservation; hence, promoting planning models beyond the conventional zoning laws that reflect the long-term impacts of developments on heritage sites. Theoretical contributions of this nature can enrich the academic dialogue on sustainable urbanism by incorporating the dimensions of cultural value and heritage protection into broader discussions of urban resilience and sustainability.

From a practical point of view, this research delivers policy recommendations to urban planners and conservation officers with the mission to guide challenges in preserving cultural heritage in rapidly urbanizing cities. One of the practical policy recommendations about buffer zones around heritage sites is achieved through spatial planning models that restrict the development of heavy infrastructure in areas adjacent to or surrounding heritage landmarks. However, developing GIS-based tools for planning should be able to easily identify these fragile zones and eliminate any development practices that may negatively affect them. In addition to this, use of GIS technologies in monitoring continuous heritage sites with urban developments shall be recommended within this study. Using spatial data to monitor changes in road networks and land use over time, urban planners can make informed decisions based on data, predicting potential conflicts and mitigating the negative impacts of urbanization before they occur. The practical recommendations above underline the need to integrate advanced technology, such as GIS, into urban policy frameworks, enabling more precise and proactive approaches to heritage conservation and urban sustainability.

In addition to this, there are practical implications in the findings for urban transport and environmental policy. One of the critical results from this study is that heritage site traffic congestion and pollution do have major negative impacts both on visitor experiences and on preservation efforts. Therefore, from this research proposal, the development of sustainable transport networks should be emphasized with public transit, pedestrian routes, and non-motorized forms of transportation such as cycling paths. The road network designs should be made by city planners in a way that reduces congestion around cultural landmarks while emphasizing alternative modes of transportation, which minimize negative impacts on the environment. Some of the policy measures can be the development of low emission zones and incentives for electric vehicles, as well as the promotion of green transport infrastructure that connects heritage sites with broader urban areas without compromising their cultural significance. Such recommendations reveal growing concern regarding restructuring the transport policy for environmental sustainability and the protection of cultural heritage; as voiced globally by the best practice heritage city management model of operation as emphasized in Heritage Europe (2019). As recommended and practical approaches implemented in city management planning of the City of Xi'an, just like the case for most heritage cities around the globe, help close this gap of a contemporary world without any meaningful erosion.

LIMITATIONS AND FUTURE DIRECTION

One of the primary limitations of this study is its reliance on secondary data, which poses certain challenges regarding the accuracy and completeness of the datasets used. While GIS databases for Xi'an's road networks and heritage sites provided a solid foundation for spatial analysis, secondary data often suffers from issues such as outdated information, inconsistencies, and potential biases in data collection methods. Sometimes, the high-resolution, updated datasets are limited because of the constraints related to data accessibility or satellite imagery resolution. Moreover, the data applied to urban planning may not be the real-time development, such as newly

planned roads or construction projects that can change heritage conservation. These limitations place more importance in future studies through more robust and updated real-time access to data when aiming for maximum precision in conducting GIS-based urban planning and preservation activities. Yet, another constraint will be the setting for this paper- Xi 'an -such that its case might not readily be generalisable to cities that are very different or diverse in any form. Thereafter, future studies would focus on the detailed collection and validation of data so as to account for the disparities and enhance reliability in GIS-based tools in the scope of urban planning.

Future research directions might include integrating cutting-edge technologies like Artificial Intelligence and Virtual Reality to create more realistic models for use in urban planning or heritage conservation activities. For example, AI capabilities could be incorporated into the platform to allow analysis of large-scale data automatically or to identify patterns in spatial data which human analysts fail to detect themselves. For example, AI-powered predictive modeling may predict the effects of a new infrastructure development on heritage sites before such a move is made, giving urban planners the foresight they need. Similarly, VR can simulate an immersive experience of an urban space, enabling stakeholders to better visualize impacts of proposed developments on heritage sites and explore alternative design options in more interactive ways. Further expansion of the focus could comprise other cities, especially those with diverse cultural, geographical, and urbanization characteristics, to observe comparative levels of GIS applications in heritage conservation across different regions. This wider perspective would allow generalizations of the findings, leading toward developing global best practices in HERITAGE CONSERVATION INTEGRATION WITH URBAN DEVELOPMENT. Integration of these cutting-edge technologies into future research would address the limitations of this study and deepen and make it more comprehensive on the complex dynamics between urbanization and heritage conservation.

CONCLUSION

In summary, this research emphasizes the significance of Geographic Information Systems (GIS) in promoting sustainable urban planning and heritage city conservation. GIS provides important spatial information about the interaction between road networks, urban growth, and heritage conservation that helps identify challenges and opportunities for equitable development. The findings from Xi’ an demonstrate how GIS can be used to assess the spatial relationships between infrastructure and cultural sites, a methodology that can be applied to other heritage-rich regions, such as historic districts in the Middle East and temple complexes in Southeast Asia, where urban expansion threatens cultural landmarks. In addition, the research identifies the significance of interdisciplinarity in solving issues of heritage conservation, particularly through cooperation between policymakers, conservationists, and urban planners. Successful models, such as conservation-led urban development projects in Cairo and Penang, illustrate how integrating GIS with expert knowledge from a range of disciplines can lead to more effective heritage protection measures. With more urbanization, further research needs to continue to learn from these results to further develop GIS-based approaches and enhance cooperative structures for sustainable heritage city management.

REFERENCE

Adeyelure, T. S. (2022). Geographical information system readiness assessment framework in the South African private health sector for pre-and-post-covid-19 pandemic management. In *Proceedings of Sixth International Congress on Information and Communication Technology: ICICT 2021, London, Volume 4* (pp. 9-14).

Agustina, I. H. (2021). GIS approach to spatial analysis of heritage settlement: Case study of Magersari Kasepuhan palace, Indonesia. *Journal of Engineering Science and Technology*, *16*(2), 1614-1629.

Alp, S. Ç. (2024). Use of advanced digital technologies in re-presentation of an Ottoman caravanserai and its surrounding historic built environment in Bursa, Turkey. In A. Olanrewaju, & S. Bruno (Eds.), *Advancements in Architectural, Engineering, and Construction Research and Practice. DTIIC PACT 2023 2022. Advances in Science, Technology & Innovation* (pp. 13-27).

Anser, M. K., Adeleye, B. N., Tabash, M. I., & Tiwari, A. K. (2022). Services trade-ICT-tourism nexus in selected Asian countries: New evidence from panel data techniques. *Current Issues in Tourism*, *25*(15), 2388-2403.

Baglioni, M., Poggi, G., Chelazzi, D., & Baglioni, P. (2021). Advanced materials in cultural heritage conservation. *Molecules*, *26*(13), 3967.

Cheshmehzangi, A., Butters, C., Xie, L., & Dawodu, A. (2021). Green infrastructures for urban sustainability: Issues, implications, and solutions for underdeveloped areas. *Urban Forestry & Urban Greening*, *59*, 127028.

Cugurullo, F., Acheampong, R. A., Gueriau, M., & Dusparic, I. (2021). The transition to autonomous cars, the redesign of cities and the future of urban sustainability. *Urban Geography*, *42*(6), 833-859.

Dai, S., Tang, D., Li, Y., & Lu, H. (2025). Digital trade, trade openness, FDI, and green total factor productivity. *International Review of Financial Analysis*, *97*, 103777.

Dang, H., & Li, J. (2021). The integration of urban streetscapes provides the possibility to fully quantify the ecological landscape of urban green spaces: A case study of Xi'an city. *Ecological Indicators*, *133*(4), 108388.

Elghazouly, H. G., Elnaggar, A. M., Ayaad, S. M., & Nassar, E. T. (2024). Framework for integrating multi-criteria decision analysis and geographic information system (MCDA-GIS) for improving slums interventions policies in Cairo, Egypt. *Alexandria Engineering Journal*, *86*, 277-288.

Fan, X., & Sun, L. (2024). Geographic distribution characteristics and influencing factors for industrial heritage sites in Italy based on GIS. *Sustainability*, *16*(5), 2085.

Frangedaki, E., Gao, X., Lagaros, N. D., Briseghella, B., Marano, G. C., Sargentis, G. F., & Meimaroglou, N. (2020). Fujian Tulou rammed earth structures: Optimizing restoration techniques through participatory design and collective practices. *Procedia Manufacturing*, *44*(2019), 92-99.

Garzulino, A., Borgarino, M. P., & Del Curto, D. (2021). When GIS joins the conservation management plan of a 20th-century architectural heritage. *Sustainability*, *13*(7), 3881.

Ghasemi, K., Behzadfar, M., & Borhani, K. (2023). Spatial analysis of leisure land uses in Tehran: Assessing inequity using the MARCOS method within a GIS framework. *Heliyon*, *9*(9), e19691.

Gilman, L. (2022). 'Our Culture is dying: Safeguarding versus representation in the implementation of the UNESCO ICH Convention. *International Journal of Intangible Heritage*, *17*, 39-54.

Haldorai, A., & Ramu, A. (2021). Canonical correlation analysis based hyper basis feed forward neural network classification for urban sustainability. *Neural Processing Letters*, *53*(4), 2385-2401.

Heshmati, M., Gheitury, M., & Shadfar, S. (2022). Factors affecting possibility of ecotourism development and sustaining natural resources using SWOT approach in west Iran. *International Journal of Geoheritage and Parks*, *10*(2), 173-183.

Höhl, W. (2020). Official survey data and virtual worlds—designing an integrative and economical open source production pipeline for XR-applications in small and medium-sized enterprises. *Big Data and Cognitive Computing*, *4*(4), 1-15.

Hsiao, T., & Shen, S. (2023). A study of digital architectural heritage preservation based on blockchain technology. *The Journal of Engineering*, *2023*(1), 1-17.

Imtiaz, S., Arif, S., Nawaz, A., & Shah, S. A. R. (2024). Conservation of socio-religious historic buildings: A case study of Shah Yousuf Gardez Shrine. *Buildings*, *14*(7), 2116.

Jarzebski, M. P., Elmqvist, T., Gasparatos, A., Fukushi, K., Eckersten, S., Haase, D., . . . Pu, J. (2021). Ageing and

population shrinking: implications for sustainability in the urban century. *Npj Urban Sustainability*, *1*(1), 17.

Kan, S., Chen, B., Han, M., Hayat, T., Alsulami, H., & Chen, G. (2021). China's forest land use change in the globalized world economy: Foreign trade and unequal household consumption. *Land Use Policy*, *103*, 105324.

Khavarian-Garmsir, A. R., Sharifi, A., & Sadeghi, A. (2023). The 15-minute city: Urban planning and design efforts toward creating sustainable neighborhoods. *Cities*, *132*, 104101.

Li, D., Wang, J., & Shi, K. (2023). Research on the investigation and value evaluation of historic building resources in Xi'an city. *Buildings*, *13*(9), 2244.

Li, W., Wang, H., Zhang, S., Jiang, B., & Lee, S. Y. (2022). Spatial and temporal evolution of urban green space pattern based on GIS sensors and remote sensing information: Taking Xi'an as an example. *Journal of Sensors*, *2022*(1), 3648880.

Li, Y., Zhao, L., Chen, Y., Zhang, N., Fan, H., & Zhang, Z. (2023). 3D LiDAR and multi-technology collaboration for preservation of built heritage in China: A review. *International Journal of Applied Earth Observation and Geoinformation*, *116*, 103156.

Liu, J., Zhang, L., Zhao, J., Liang, Y., Han, Q., & Chirwa, S. (2023). Exploration of the spatial relationship between Xi'an City and its mausoleums from the perspective of time evolution. *Frontiers in Ecology and Evolution*, *11*, 1158563.

Liu, X., Shao, S., & Shao, S. (2024). Landslide susceptibility zonation using the analytical hierarchy process (AHP) in the Great Xi'an Region, China. *Scientific Reports*, *14*(1), 1-19.

Luo, H., Gao, X., Liu, Z., Liu, W., Li, Y., Meng, X., . . . Sun, L. (2024). Real-time characterization model of carbon emissions based on land-use status: A case study of Xi'an City, China. *Journal of Cleaner Production*, *434*, 140069.

Luo, H., Li, Y., Gao, X., Meng, X., Yang, X., & Yan, J. (2023). Carbon emission prediction model of prefecture-level administrative region: A land-use-based case study of Xi'an city, China. *Applied Energy*, *348*, 121488.

Matrone, F., Colucci, E., Iacono, E., & Ventura, G. M. (2023). The HBIM-GIS Main10ance platform to enhance the maintenance and conservation of historical built heritage. *Sensors*, *23*(19), 8112.

Moyano, J., Carreno, E., Nieto-Julián, J. E., Gil-Arizón, I., & Bruno, S. (2022). Systematic approach to generate Historical Building Information Modelling (HBIM) in architectural restoration project. *Automation in Construction*, *143*, 104551.

Nasiri, R., Akbarpour, S., Zali, A., Khodakarami, N., Boochani, M., Noory, A., & Soori, H. (2022). Spatio-temporal analysis of COVID-19 incidence rate using GIS: A case study—Tehran metropolitan, Iran. *GeoJournal*, *87*(4), 3291-3305.

Nawaz, A., Su, X., & Nasir, I. M. (2021). BIM adoption and its impact on planning and scheduling influencing mega plan projects-(CPEC-) quantitative approach. *Complexity*, *2021*(1), 8818296.

Ni, B., & Wei, S. (2024). Research on urban land suitability evaluation based on GIS—A case study of Xi'an City. *International Journal of Global Economics and Management*, *2*(2), 65-73.

Pang, Y., Dong, W., & Liu, Y. (2021). Research on the conservation and sustainable development strategies of modern historical heritage in the Dabie Mountains based on GIS. *Open Geosciences*, *13*(1), 717-735.

Pretorius, O. R. (2024). Regional integration and industrialisation in the SADC. *Regional Policy in the Southern African Development Community*, 192.

Ramos-Escudero, A., Gil-García, I. C., García-Cascales, M. S., & Molina-Garcia, A. (2021). Energy, economic and environmental GIS–based analysis of shallow geothermal potential in urban areas—A Spanish case example. *Sustainable Cities and Society*, *75*, 103267.

Salameh, M. M., Touqan, B. A., Awad, J., & Salameh, M. M. (2022). Heritage conservation as a bridge to sustainability assessing thermal performance and the preservation of identity through heritage conservation in the Mediterranean city of Nablus: Heritage conservation as a bridge to sustainability. *Ain Shams Engineering Journal*, *13*(2), 101553.

Sánchez-Aparicio, L. J., Masciotta, M. G., García-Alvarez, J., Ramos, L. F., Oliveira, D. V., Martín-Jiménez, J. A., . . . Monteiro, P. (2020). Web-GIS approach to preventive conservation of heritage buildings. *Automation in Construction*, *118*, 103304.

Shah, S. A. R., Hussan, S., Kahla, N. B., Anwar, M. K., Baluch, M. A., & Nawaz, A. (2024). Performance evaluation and optimization of binder-toner and mixing efficiency ratios in an e-waste toner-modified composite mixture using response surface methodology. *Infrastructures*, *9*(11), 200.

Shen, L., Sun, M., Wei, X., Bai, Y., Hu, Q., Song, S., . . . Liu, K. (2022). Spatiotemporal association of rapid urbanization and water-body distribution on hemorrhagic fever with renal syndrome: A case study in the city of Xi'an, China. *PLoS Neglected Tropical Diseases*, *16*(1), e0010094.

Shen, L., Yang, Q., & Yan, H. (2023). Spatial characterization analysis of residential material stock and its driving factors: A case study of Xi'an. *Buildings*, *13*(3), 581.

Son, T. H., Weedon, Z., Yigitcanlar, T., Sanchez, T., Corchado, J. M., & Mehmood, R. (2023). Algorithmic urban planning for smart and sustainable development: Systematic review of the literature. *Sustainable Cities and Society*, *94*, 104562.

Stroscio, A., Barone, G., De Guidi, G., Fugazzotto, M., Occhipinti, R., Carnemolla, F., . . . Mazzoleni, P. (2021). Photogrammetric surveys and GIS application for Cultural Heritage conservation management: A case study from Catania's historical buildings. *Italian Journal of Geosciences*, *140*(3), 464-476.

Sukwai, J., Mishima, N., & Srinurak, N. (2022). Balancing cultural heritage conservation: Visual integrity assessment to support change management in the buffer zone of Chiang Mai historic city using GIS and computer-generated 3D modeling. *Land*, *11*(5), 666.

Toku, A., Amoah, S. T., N-yanbini, N. N., Sarfo, A. K., & Tornyeviadzi, P. (2024). Analysis of land-use and livelihood transformations in peri-urban areas: Insights from North-Western Ghana. *Heliyon*, *10*(19).

Vafadar, S., Rahimzadegan, M., & Asadi, R. (2023). Evaluating the performance of machine learning methods and Geographic Information System (GIS) in identifying groundwater potential zones in Tehran-Karaj plain, Iran. *Journal of Hydrology*, *624*, 129952.

Wang, F., & Gu, N. (2023). Exploring the spatio-temporal characteristics and driving factors of urban expansion in Xi'an during 1930-2014. *International Journal of Urban Sciences*, *27*(1), 39-64.

Wang, Z., Liu, J., Li, T., Chao, J., & Gao, X. (2021). Factors affecting new agricultural business entities' adoption of sustainable intensification practices in China: Evidence from the main apple-producing areas in the Loess Plateau. *Agronomy*, *11*(12), 2435.

Wierzbicka, A. M., & Arno, M. (2022). Adaptation of places of worship to secular functions with the use of narrative method as a tool to preserve religious heritage. *Muzeológia a Kultúrne Dedičstvo*, *10*(4), 63-77.

Yang, X., Zhao, Z., Shi, C., Luo, L., & Tu, W. (2023). The dynamic heterogeneous relationship between urban population distribution and built environment in Xi'an, China: A case study. *Remote Sensing*, *15*(9), 2257.

Yi, P., Li, W., & Zhang, D. (2021). Sustainability assessment and key factors identification of first-tier cities in China. *Journal of Cleaner Production*, *281*, 125369.

Yuan, K., Abe, H., Yasufuku, K., & Takahashi, A. (2022). A comparative study of the change in townscape in historical blocks of Xi'an, China, and Kyoto, Japan. *GEOMATE Journal*, *22*(89), 47-54.

Yuan, X., Liu, R., & Huang, T. (2024). Analyzing spatial–temporal patterns and driving mechanisms of ecological resilience using the driving force–pressure–state–influence–response and environment–economy–society model: A case study of 280 cities in China. *Systems*, *12*(8).

Zhang, P., Gao, S., & Ma, C. (2024). Simulation of groundwater quality in Xi'an, Shaanxi Province based on visual modflow. *International Journal of Natural Resources and Environmental Studies*, *2*(1), 1-13.

Zhao, P., Md Ali, Z., Nik Hashim, N. H., Ahmad, Y., & Wang, H. (2024). Evaluating social sustainability of urban regeneration in historic urban areas in China: The case of Xi'an. *Journal of Environmental Management*, *370*, 122520.

Zhou, W., Song, S., & Feng, K. (2022). The sustainability cycle of historic houses and cultural memory: Controversy between historic preservation and heritage conservation. *Frontiers of Architectural Research*, *11*(6), 1030-1046.

ETHICAL DECLARATION

Conflict of interest: No declaration required. **Financing:** No reporting required. **Peer review:** Double anonymous peer review.