Managing Sustainable Tourist Flows and Heritage Preservation in the Medina of Sousse: A Space Syntax and GIS-Based Approach

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Abstract. The Mediterranean's historic urban centres are often facing rising challenges due to overtourism**,** threatening both cultural heritage and local urban balance. This paper investigates the interplay between spatial configuration and tourist mobility in the historic Medina of Sousse, a UNESCO World Heritage Site facing rising tourism pressure. Despite the growing body of research on over tourism and heritage management, there remains a lack of spatially grounded analytical tools that diagnose tourist flow imbalances within historic urban fabrics. By combining Space Syntax and GIS-based spatial analysis, the study develops a diagnostic framework to assess connectivity, accessibility, and spatial vulnerability. The methodology identifies patterns of tourist concentration in highly integrated areas and highlights underutilized peripheral zones. These imbalances pose threats to both heritage conservation and social equity. The results support a spatial zoning strategy that redirects flows through alternative routes, promoting a more balanced and sustainable tourism model. The study provides practical insights for urban planners and heritage managers seeking to harmonize tourist experience with the protection of historic urban landscapes.

Keywords: Medina of Sousse · Tourism Management · Heritage Preservation · Spatial Vulnerability · Space Syntax · GIS

1 Introduction

Overtourism poses a significant challenge for historic cities, particularly for globally recognized sites that attract a massive influx of tourists from around the world. A series of spatial initiatives and regulatory measures have arisen to manage the impacts caused by overtourism. The Historic Urban Landscape (HUL) approach initiated by UNESCO, for example, serves as a useful tool for the protection of the cultural heritage in the

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cities and also facilitates their sustainable urban development [2]. In the case of Venice, the new regulations aim at controlling and managing the massive flow of tourists and short-term rentals [21]; in Dubrovnik, through the use of smart technologies, the tourist numbers in the old town have been tracked in real time, and therefore, the city has been able to devise flexible strategies [23]. Obtained results have also been the inspiration for cities like Barcelona to introduce an upper limit on tourism and shift the tourists from the historical city centre to the lesser-known neighbourhoods for a more even distribution of the population in the area.

However, despite these advancements, there is a notable methodological research gap. Current studies largely focus on policy frameworks and technological applications for managing overtourism, yet lack a systematic spatial method to assess patterns of tourist concentration in highly integrated areas and to identify underutilized peripheral zones. Moreover, there is a need for a practical analytical tool to support spatial zoning strategies that redirect flows through alternative routes, thereby promoting a more balanced and sustainable tourism model.

In this vein, the ground for this research is represented by the Medina of Sousse, a UNESCO World Heritage Site, where unequal distribution of tourists causes congested and underused areas. The high concentration of visitors in specific zones disrupts the balance of urban activity and increases the risk of structural degradation of historic buildings and streets. This Medina, known for its strategic coastal position, has evolved a hierarchical street system of main roads, which are connected to the main gates and are the ones that serve as commercial focal points and so accommodate the largest group of visitors and secondary alleys, which are mostly footpaths; hence, they are used by residents for walking, and the local businesses are located there. This differentiation creates socio-spatial imbalances since traffic flow led to the visit of some locations and imbalance in areas utilization, where only some of the main POIs Ribat, Great Mosque, and Kasbah are crowded along the most vibrant corridors. The research looks at how GIS and space syntax analysis can help find areas that are either underperforming or very crowded with tourists, which helps identify risks to heritage and the Medina management? based on the use of spatial analysis techniques to assess the impact of accessibility, integration values, and land utilization on the flow of tourists.

The current situation of the Medina seems to indicate that it is viable to change visitor flows and reach the sustainable goals of the community by using Space Syntax indexes in conjunction with POI location on GIS to make the analysis for movement patterns and area functionality redistribution. it provides indications about general logics of movement, highlighting underdeveloped areas through the examination of values, such as AGI and ACI, and placement of POIs, etc., which disaggregates Medina into zones based on the intensity of tourism impact and the urgency of conservation needs, thus enabling targeted vulnerability zoning and the redirection of visitor flows to promote balanced urban use.

Thus, the paper aim is to answer to the following question:

How can spatial configuration analysis, through Space Syntax and GIS tools, support sustainable tourist flow management while preserving the heritage integrity of historic urban areas like the Medina of Sousse?

To do that, the paper is organized according to the following structure: an introduction and background of the Medina's heritage followed by a section on methods describes the integration of space syntactic models, GIS spatial analysis, underlining important inequities in accessibility and congestion, a Results section showcasing spatial indicators (AGI, ACI, network density, POI, accessibility, etc.). A discussion Focusing on their consequences for Medina's planning, cultural heritage preservation, and sustainable tourism management, reinforcing it with a comparison to another case study, concluding with notes on key findings, identifying constraints, and advice for future research and intervention projects, particularly with similar historical sites like Casbahs and Ksours cities. Which highlights a historical preservation in line with local socioeconomic needs.

2 Background

2.1 The Medina of Sousse History and Urban Configuration

Medina of Sousse, declared in the list of World Cultural Heritage of UNESCO in 1988, originates from a coastal town in the central part of Tunisia, which was historically a strategic place for the power's dynamic control on the central coast of North Africa, it remains one of the few places in the world where urban life has eluded the otherwise settling process over more than 3000 years [25].

Sousse was rebuilt as a remarkable harbour city by the Aghlabid dynasty; its assured location on the seashore was the main factor in creating a tight trade network and defence system [23].

Foremost among the city's fortified installations the medina includes contour walls, ribat, and the grand mosque, the city of Sousse first existed as a military fortress and then became a spiritual centre [3].

Sousse, during the urbanization process, reconstructed urban layout, and went beyond the architectural development thus the city gradually took one of a kind urban fabric [4] especially after the arrival of the Maltese and Sicilians at the end of the 19th century to the 20th.

This, in turn, was the socio-cultural basis of Medina's economic and cultural transformation [13]. Management of tourist traffic flow and congestion in the medina mostly takes place with the road system and POI as the core elements into consideration.

2.2 Urban Morphology and Road Hierarchy

Medina of Sousse represents an example of urban planning during early Islamic times. It was a setting where the defensive strategy, the social organization, and the commercial vitality were all harmoniously combined to a coherent design. The scientific studies and the conservation work, e.g., carried out by the UNESCO, have proved that its layout reveals a decided hierarchical structuring.

Enclosure, Road and Gate System

The medina is enclosed by a wall, originally pierced by several gates. The actual number of gateways is not explicitly confirmed, but only eight are historically reported, yet of

these, two are the main access for a vehicle and pedestrian—Bab Kairouan (south) and Bab El Gharbi (west), aside from the fact that they form the network spaces they control the entry and exit organized the internal traffic.

Studies have found that a medina road is planned as an axis system. One of them goes through a key gate in a meridian direction to the ribat (a fortified religious structure) and the former interior port, while the other connects Bab El Jadid to Bab El Gharbi. This double-axis system was a platform for defence and commerce: the main roads were used for trade, public processions, and government functions and the in-between network composed of narrow, winding alleys was used for local residential life and pedestrian movement [23].

Moreover, scholarly case studies on the urban fabric of Sousse confirm that these primary hierarchies had been intentionally planned to make a spatial disposition that regularized the urban functions and later this system controlled the growth of the urban expansions patterns. The road network of the medina is designed with a two-level hierarchy:

- Primary Roads: These wide, straight streets begin from the main gates and go deep into the medina's heart which is one of the historical sites. They were the most important commercial roads containing large commercial activities and connected to the main public and religious buildings.
- Secondary Alleys: On the other hand, the smaller, interconnecting roads designed to meet local needs. Curvy paths that indicate the historical city fabric where pedestrian movements are the first priority while cars have access in the minimum way.

Principal Points of Interest (POIs)

The key monuments and landmarks within the medina are arranged along these historical axes. Below is a sequential guide to the most significant POIs, each of which contributes to the medina's multifunctional character (Table 1):

2.3 The Importance of Sustainable Multidisciplinary Approach

The UNESCO World Heritage site's recognition of the medina emphasized the international collaboration in heritage conservation [31]. The role of the medina extends to more than just a cultural object; it is also recognized as a place of social and economic change [16]. Nowadays, we need to focus even more on urban pressure. But one of the modern-day challenges is the growing gap between the city's social and environmental needs, which could potentially negatively influence the urban landscape and the cultural reality of the city [12].

In this context, the challenge needs to be addressed with a multidisciplinary approach to urban planning that combines the revitalization of the medina with the acknowledgment of the socio-economic needs of the present time [12]. Space syntax and GIS (Geographic Information Systems) are the primary tools for achieving this aim. They represent a complete approach to analysing the urban layout, especially as they provide insights on the predictive movement patterns, which opens new opportunities in an integrated urban environment that is economically productive. Space syntax-based models

Table 1. Historical POIs of the Medina

No	Site Name	Date	Description	Source
1	Ribat of Sousse	821 AD	Fortified religious retreat with watchtowers; essential to coastal defence and served as city landmark	[24]
2	Great Mosque of Sousse	9th century	Fortified prayer hall with minaret and walled courtyard; included defensive positioning	[32]
3	Bou Ftata Mosque	838–841 AD	Early Islamic architecture in Ifriqiya; features one of the earliest examples of Kufic script in North Africa	[11]
4	Medersa Zakkak	Ottoman period	Religious and educational building; reflects how the Medina integrated worship, trade, and education	[9]
5	Zaouïa Zakkak	Late Islamic era	Mausoleum-mosque-Medersa complex; aligned with a major urban axis; represents late Islamic decorative styles	[1]
6	Kasbah & Archaeological Museum	Various/Modern	Formerly public offices; now a museum hosting Roman mosaics and historical artifacts	[31]
7	Dar Echaraa	Modern use	Originally a courthouse; transformed into a cultural centre	[31]
8	Citterns de la Sofra	Byzantine period	Urban water management system in arid climate; demonstrates Byzantine engineering excellence	[15]
9	Tour de Khalef	Historical/Present	Former Kasbah tower; now a lighthouse; symbolizes the city's defensive and maritime heritage	[33]

have shown they can help understand how people think about space and how they move around in complicated city areas [8].

Recent studies have looked into detailed ways to map and evaluate the multiple vulnerabilities of outdoor spaces, showing that older urban areas are especially at risk from combined dangers [5]. This view matches earlier research that emphasized the need to combine geomatics data, agent-based simulation, and building performance assessment to enhance resilience in historic urban areas facing various risks [22]. These tools can help measure how different areas in Medina are connected and how people move

around, which helps create plans that balance tourist access with protecting historical sites [6, 7, 29, 30]. On the other hand, GIS is capable of providing information on spatial charts and also giving the ability to organize data, which is essential for the purpose of identifying and managing tourism, the number of visitors in every area, and the infrastructure. All support the creation of flexible and sustainable tourism strategies [14, 27].

In addition, the GIS-based methodologies of designing can be deployed to build the tourist routes that divert the tourists away from the main sites and facilitate them to explore the unknown architectural elements and structures constructed in the rest of the city. This will balance tourist traffic and reduce pressure on popular sites.

3 Methodology

3.1 Research Approach

The approach is a mixed method approach (quantitative/qualitative) based on the development of a research framework that integrates the use of space syntax analysis and geographic information systems to evaluate accessibility, congestion, and the impacts of tourism on heritage preservation (Fig. 1).

3.2 Data Collection

- Primary and secondary data are the basis of the research.
- Geospatial Data: These include roads, land use, and historical landmarks that were obtained through GIS databases and historical maps.
- Tourist Flow Data: The data was collected through GPS tracking.
- Urban Morphology: This information is obtained from satellite imagery and land surveys (Table 2).

3.3 Analytical Framework

The methodology outlines a triple process:

- **Step 1:** Spatial Network Analysis (Space Syntax)
  Objective: Identify the main places in which tourists move and their accessibility.
  Tools Used: Depthmapx, Space Syntax Software.
- **Step 2:** GIS-Based Spatial Analysis
  Objective: To distinguish the places characterized by high tourist density and the ones underutilized.
  Tools Used: ArcGIS, QGIS.

In the following section we have explained in a detail the indicators related to the study:

1. **AGI (Average Global Integration):** Measures global accessibility of streets in the axial map. It is computed as the mean value of global integration (Rn) across all segments using the formula: $\mathbf{AGI = (1/n) \times \Sigma\, Rn_i}$

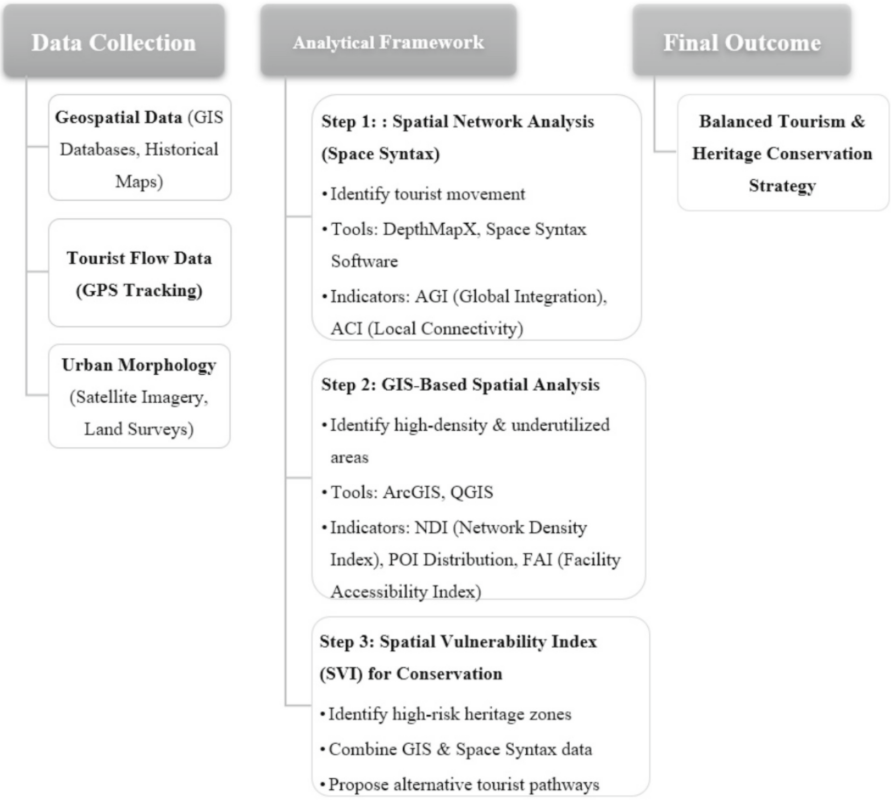

Fig. 1. Tourism Impact Assessment Framework

Table 2. Data Sources and Collection Methods.

Data Type	Source	Collection Method
Road Networks	OpenStreetMap, Municipal Maps	GIS Mapping
POI (Points of Interest)	Historical archives, Fieldwork	Spatial Analysis
Pedestrian Flow	GPS Tracking	Movement Analysis
Land Use	Satellite Images, City Records	GIS Classification

2. **ACI (Average Connectivity Index):** Reflects the average number of direct connections per street segment. It is calculated as the total number of connections divided by the total number of segments: $\mathbf{ACI = \Sigma\, k_i/n}$
3. **NDI (Network Density Index):** Indicates the density of the street network in relation to the study area. It is computed by dividing the total street length by the area: **NDI = L_total/A**

4. **NDI_n (Normalized Network Density Index):**A scaled version of NDI used in the SVI formula, calculated with min-max normalization: **NDI_normalized = (NDI − NDI_min)/(NDI_max − NDI_min)**
5. **POI Concentration:** Refers to the percentage of Points of Interest (POIs) located along highly integrated streets. This is measured by computing the proportion of POIs within a buffer of top quartile integration lines: **POI% = (POIs on integrated streets/Total POIs) × 100**
6. **FAI (Fabric Aging Index):** Measures the aging and degradation of the built environment. It is calculated as the sum of weighted degradation scores inversely proportional to their distance from the segment: $\mathbf{FAI_i = \Sigma\ (W_j/d_{ij})}$
7. **SAS (Spatial Attractor Score):** Indicates how strongly a segment is influenced by nearby heritage and tourist attractors. It is computed by summing the attraction weights of nearby nodes, inversely weighted by distance: $\mathbf{SAS_i = \Sigma\ (A_k \times 1/(d_{ik} + 1))}$
8. **LUII (Land Use Interaction Index):** Captures the intensity and diversity of land-use pressure on a segment. It is calculated as the sum of the product of land use diversity and conflict weights: $\mathbf{LUII_i = \Sigma\ (D_1 \times C_1)}$
9. **PRCR (Pedestrian-Road Conflict Ratio):** Measures spatial conflict between pedestrian pathways and vehicular roads. Computed as the ratio of pedestrian segments intersecting traffic to the total pedestrian network length: **PRCR = L_conflict/L_pedestrian**
10. **SVI (Spatial Vulnerability Index):** A composite index assessing spatial stress and congestion risk, calculated as a weighted sum of five sub-indicators: **SVI = 0.3 × FAI + 0.3 × SAS + 0.2 × LUII + 0.1 × NDI_normalized + 0.1 × PRCR**

3.4 Expected Outcomes

This particular methodology would identify areas with higher traffic flow known as congestion hotspots. Such congested points impact on the environment and heritage structures. This will then lead to the identification of strategies that will be utilized within this study and similar contexts for effective conservation and sustainable development of tourism:

- **Identification of Tourist Congestion Hotspots:** The research will map, analyse, and evaluate the tourism density of the areas involved, quantitatively revealing congestion hotspots that could negatively impact both their visitors' experience and the physical integrity of heritage structures. Enhance the visitors experience through enriching tourist itinerary planning
- **Detection of Underutilized and Peripheral Urban Areas:** Through sophisticated spatial analysis and mapping techniques, which will guarantee equal opportunities for all the parts of the Medina
- **A proposal for a spatial zoning strategy:** To control tourist flows effectively so that the experience is better balanced, more resolute, and inclusively satisfying, it will be necessary to develop a framework that could distribute them by promoting the use of less urbanized.
- **Formulation of a Heritage Preservation Plan:** That uses computational science, which can serve to map and archive the geographical and syntactical information of the Medina.

4 Results

(See Figs. 2, 3 and 5, Table 3).

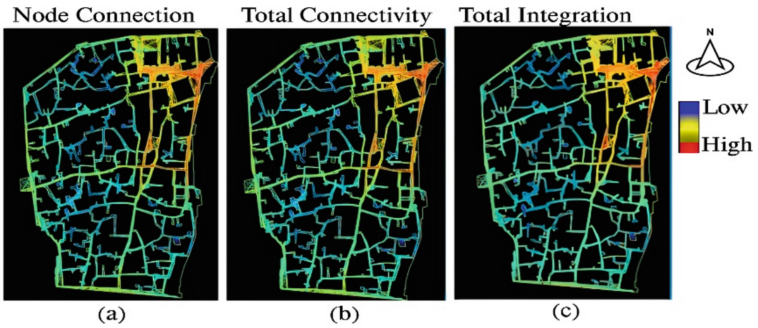

Fig. 2. Axial Analysis of the Medina (KHELIL CHERFI, 2023)



Fig. 3. Spatial Network of Roads and the Mechanics of Tourist Flow (GIS course by BENHAMOUCH, BOUALAM, 2023).

Then for each part of this Medina we calculated the SVI Formula

$$\mathbf{SVI} = \mathbf{0.3} \times \mathbf{FAI} + \mathbf{0.3} \times \mathbf{SAS} + \mathbf{0.2} \times \mathbf{LUII} + \mathbf{0.1} \times \mathbf{NDI_normalized} + (\mathbf{1})\,\mathbf{0.1} \times \mathbf{PRCR} \quad (1)$$

The SVI Formula results highlight a moderate level of spatial vulnerability, particularly in peripheral neighbourhoods. Notably, historical landmarks such as the Kasbah, the Ribat, and the main gates appear more exposed to spatial and infrastructural limitations.

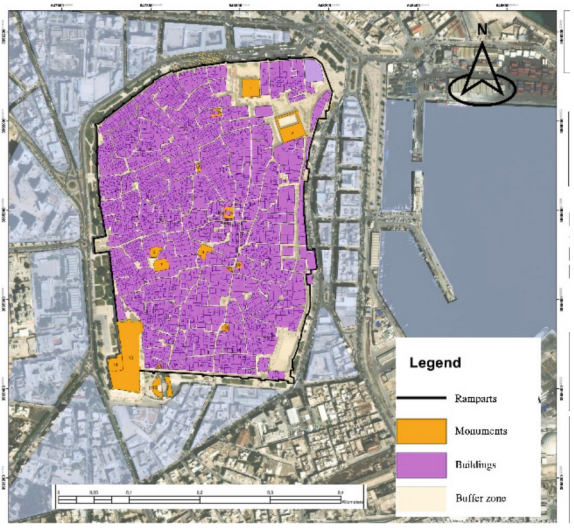

Fig. 4. Monuments of the Medina (GIS course by BENHAMOUCH, CHOUIAL 2024).

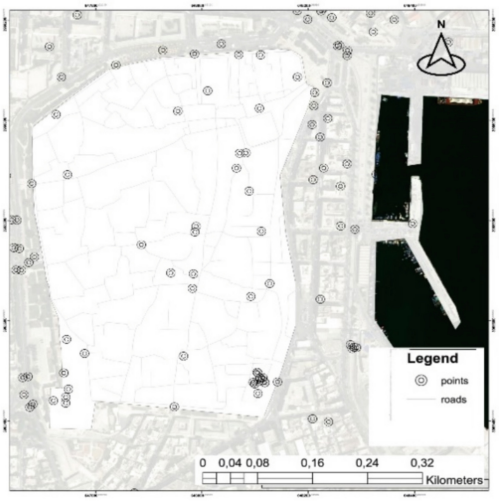

Fig. 5. Commercial and Historical Points of Interest of the Medina (GIS course by BENHAMOUCH, KHELIL CHERFI, 2024). (Map data: © OpenStreetMap contributors, available under the Open Database License (ODbL)).

These areas exhibit higher aging in the built fabric, reduced accessibility due to narrow alleyways, and lower infrastructure provision, as well as increased pedestrian-vehicular conflict—all contributing to their elevated vulnerability. This pattern is clearly illustrated in Fig. 4, where these peripheral zones stand out in contrast to the better-integrated and more accessible core of the Medina.

Table 3. Urban Spatial Structure Assessment: Key Metrics and Insights.

Category	Indicator	Highest value	Interpretation
Spatial Configuration	Average Global Integration (AGI)	0.75	High accessibility and movement potential in the northern sector of the Medina
	Average Connectivity Index (ACI)	12	Core streets are well-connected; peripheral areas (ACI < 5) are less integrated
Road Infrastructure	Network Density Index (NDI)	6.5 km/km^2	Moderately dense network with discontinuities in the southwest quadrant
Functional Distribution	POI Concentration	70%	Most commercial and service activities align with the most integrated axial lines
Structural Scheme	Spatial Vulnerability Index (SVI)	0.65	Indicates moderate vulnerability; peripheral areas show low accessibility and infrastructure deficits
	FAI: Fabric Aging Index	0.72	Represents structural aging; high values indicate deteriorated traditional buildings
	SAS: Spatial Accessibility Score	0.65	Measures accessibility from major entrances; low in narrow interior alleys
	LUII: Land Use Infrastructure Index	0.60	Evaluates infrastructure provision; lower in residential-dominant or informal zones
	PRCR: Pedestrian-Road Conflict Ratio	0.55	Captures the level of overlap between pedestrian paths and vehicular traffic areas

4.1 Spatial Configuration and Connectivity

Space syntax analysis demonstrates that the northern portion has the highest integration scores, with an average global integration (AGI) score of 0.75, which is the best place to

look for strong accessibility and directions first. Along with the Average Connectivity Index (ACI) being 12, it is revealed that streets in the core area are well connected, but streets toward the edge are not (ACI < 5), letting down spatial integration.

4.2 Road Infrastructure and Accessibility

The road network analysis gives the Network Density Index (NDI) the value of 6.5 km/km^2, which means it is a moderately dense road system. However, some sections, particularly in the southwestern periphery, lack connectivity, making it challenging for people to have fair and equal access.

4.3 Functional Distribution and Points of Interest (POI)

The POI results reveal that the most integrated streets, particularly in the central and northern sectors, host 70% of commercial and service, suggesting potential for densification or functional reinforcement.

4.4 Pertinence Area Analysis

The Spatial Vulnerability Index (SVI) = 0.65, indicating a moderate level of spatial vulnerability. This suggests that while core areas exhibit relatively stable accessibility and infrastructure, peripheral zones remain underserved, requiring targeted interventions to enhance connectivity and service distribution.

5 Discussion

5.1 Critical Reflection on Results in Relation to the Research Question and Hypothesis

The current research topic is the study that examined how spatial analysis techniques such as the space syntax and GIS-based modelling can assist in optimizing the tourist flow and consequently, help in the preservation of the heritage in the Medina of Sousse. The outcomes are scientifically supported that a high spatial integration and connectivity in the particular infrastructure of the Medina of Sousse creates concentrated tourist movements, whereas the peripheral areas are not properly utilized, which in turn is the cause of spatial and also economic imbalances.

The spatial configuration analysis is another reason that this assessment is valid; the north sector actually has the highest Average Global Integration (AGI) score of 0.75, highlighting its central role in attracting movement and activity. But, the lower the Average Connectivity Index (ACI) value which is (<5) in the peripheral streets the congested it becomes, and it also implies a lack of alternative paths, thus, there will be more traffic of cars in the central zones. The road network analysis further confirms by the fact that the Network Density Index (NDI) is 6.5 km/km^2, which means that there is a moderately dense network but it is still not continuous in the southwest sectors, hence there are unequal movements.

This distribution is functional from points of interest (POI) is another proof to the hypothesis. Unfortunately, 70% of commercial and service activities are found among the most integrated streets. Thus, there is under development in the other parts and balanced spatial planning is required as the most satisfied with the services. Therefore, the need for more balanced spatial planning is still essential.

The spatial analysis clearly confirms that high integration scores are directly correlated with tourist concentration. However, this condition, while useful for economic clustering, also exacerbates congestion, wear on infrastructure, and tourism dependency in a few streets, while neglecting peripheral heritage assets. These findings suggest that urban morphology itself is an active agent shaping tourism impact.

Therefore, sustainable tourism strategies should not only rely on branding and promotion, but on evidence-based spatial redistribution, supported by syntactic and GIS-based metrics.

Moreover, the presence of commercial and service activities (70% located along high-integration axes) reveals a reinforcing loop between functional centrality and spatial accessibility. This supports the need for planning policies that incentivize functional diversification and decentralization. Ultimately, these insights call for integrated planning approaches that treat heritage spaces as living urban systems, rather than static artifacts (Fig. 6).

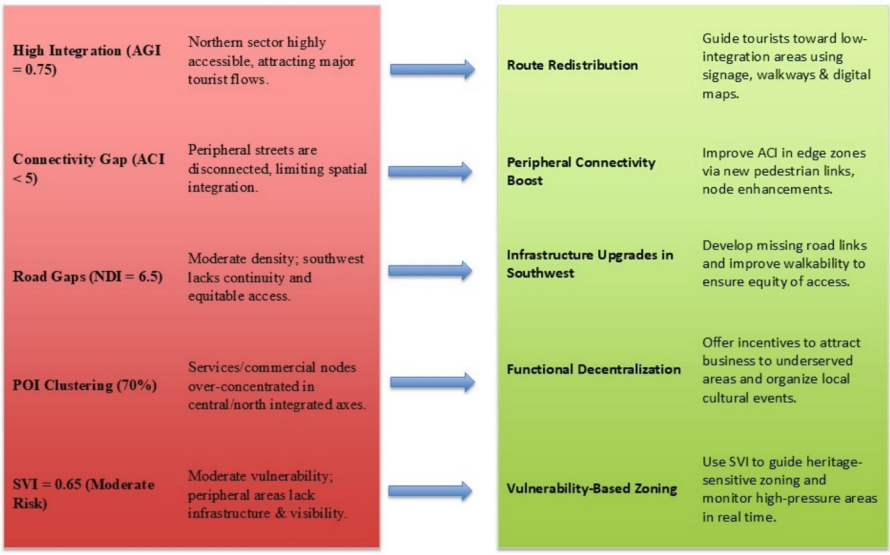

Fig. 6. Outcomes of the Study

5.2 The Implications of the Findings for Heritage Site Management, Urban Planning, and Tourism Regulation

Rebalancing Visitor Flow Through Secondary Networks
The fact that both the AGI and ACI values are high in the core areas confirms that the accessibility factor is the main reason for congestion. One way to address this issue is to steer the guests to the streets that are not crowded and are in-between. It can be made through the use of route descriptions, restricted access to saturating areas, and ameliorated paths to the pedestrians in the scarcely visited places.

Zoning and Commercial Redistribution for Sustainable Tourism
The concentration of the POIs and business activities (70% in the central areas) is a clear message for the management of the decentralized economy. The local government can award fiscal incentives to the local business units in the underutilized zones and create cultural events in the underestimated areas, thus both reducing the economic and tourism dependency on the northern corridors.

Urban Requalification to Enhance Peripheral Areas
The development of the infrastructure, the increase of walkability, and the reinforced connectivity is the main part of the issue, which has been neglected. Directing the resources into these areas can boost the social justice issues and thus the sustainability of tourism.

Integration of Vulnerability Zoning for Heritage Protection
This problem with the strong correlation between accessibility and congestion should be solved by the application of a Localized Spatial Vulnerability Indicator, which would serve to indicate the risk-prone areas allows for the quantification of vulnerability based on tourist pressure, accessibility, and historical fragility, ensuring targeted conservation efforts.

Smart Tourism and Real-Time Monitoring

The SVI results suggest that digital guidance tools, interactive maps, and real-time monitoring could optimize visitor experience while redistributing traffic. Implementing geofencing technologies and augmented reality navigation could encourage tourists to explore underutilized areas, balancing visitor distribution.

5.3 Consideration of Possible Limitations and the Applicability Boundaries of the Method

Comparative Case Study
A similar approach was applied in Beirut, combined with HBIM where vulnerability zoning and controlled access measures successfully redistributed tourist flows and minimized congestion. By integrating predictive modelling and smart tourism solutions, planners were able to mitigate risks to fragile heritage sites while maintaining economic viability. This example highlights the adaptability of GIS-based spatial analysis in different urban heritage contexts, though variations in local infrastructure and governance structures may affect outcomes [17].

While the methodology effectively diagnoses spatial imbalances, several limitations must be acknowledged:

Dependence on Spatial Configuration Metrics
The study relies on space syntax and GIS indicators, which capture structural accessibility but do not account for visitor motivations, behavioural patterns, or seasonal fluctuations. To expand our current understanding of the theme, forthcoming studies might focus perception surveys or movement tracking of visitor or local residents with the data processing of visitor density, occupancy rates, and user company's data.

Limited Socioeconomic and Stakeholder Engagement.

The methodology that focused on analysis of roads in computer models only seems to overlook the local businesses, and residents' perspectives as well. The utilization of participatory planning procedures could vastly improve the realization of set-forth methods.

Scalability to Other Heritage Sites. Moreover, the NDI, and AGI, etc. Are a good way to get things started, but the extent to which they may be used in other heritage cities is still unclear and will depend on the differences in morphology and governance among the cities.

A cross-sectional research design across different cities can provide a platform from which to measure these indicators across the various settings and spread the use of this methodology.

Challenges in Implementing Vulnerability Zoning
The formula of which (the SVI) is a useful framework, is fully a model of a good and innovative application. But it still needs a comprehensive examination period based on the collection of field data for visitor mobility, accessibility values, and different building types. In some heritage sites, the availability of data may not be the same as in others and the prescriptive zoning of permitted uses might not always be precise.

Future studies should also consider integrating real-time movement flow data or tourist attractor analysis to more accurately model dynamic visitor behaviour and better inform spatial interventions.

6 Conclusions

The spatial distribution of tourist flows in the Medina of Sousse reflects deep-rooted asymmetries in urban connectivity, infrastructure typology, and the location of attractions. Without proactive planning, tourism can aggravate congestion in core areas while marginalizing peripheral spaces. The study demonstrates that Space Syntax and GIS are powerful tools to visualize, quantify, and address such imbalances.

To preserve the integrity of Medina and promote equitable urban development, it is essential to diversify visitor routes, redistribute commercial functions, and invest in underserved areas. Additionally, introducing vulnerability-based zoning and smart monitoring systems can guide decision-makers in implementing adaptive and sustainable tourism strategies.

Future research should integrate behavioural, economic, and participatory data to enrich the spatial analysis and better capture the complexities of human interaction

with heritage environments. Only through a multidimensional, flexible, and community-cantered approach can historic cities like Sousse thrive in the face of urban and tourism pressures.

It is now clear that the differences in the passage of tourists in the Medina of Sousse are the outcomes of the spatial differentiation of the space integration models, the typologies of the road infrastructure, and also the presence of the mobility of attractions located close to the main accessibility lanes.

If not well planned, the excessive traffic in certain areas could lead to potential threats to the preservation of the heritage and also to the neglect of other valuable sites far located from main roads.

The conclusion drawn from the study is in line with the hypothesis that means of space GIS and syntax can provide comprehensive details to heritage protection. Such a method provides a valuable insight into the spatial and geographical specificity of the Medina weakness and potential zones.

Urban Governance and Policy Implications

From a policy perspective, the findings of this study provide actionable insights for urban decision-makers. Planners and heritage managers should not rely solely on static preservation principles, but adopt spatially-informed governance tools that monitor movement dynamics and anticipate pressure zones. Urban authorities should:

- Reconfigure signage and pedestrian routing systems to encourage alternative tourist paths and relieve congested core areas;
- Invest in infrastructure and services in low-integration, high-potential areas to balance visibility and access;
- Integrate spatial indicators (e.g., axial integration, visibility fields) into heritage protection guidelines and tourism zoning plans;
- Engage local communities through participatory mapping and co-design processes, reinforcing cultural identity and stewardship.

Ultimately, this evidence-based approach supports a transition from reactive to proactive heritage management, aligning daily urban operations with long-term sustainability goals. However, the study needs integrating other methods, especially behavioural, economic, and participatory views in subsequent research.

This study demonstrates that spatial configuration is not a neutral backdrop, but a powerful lever for shaping tourist behaviours and managing heritage sustainability. Integrating spatial analytics into urban policy is no longer optional—it is essential for the future of historic cities under pressure.

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