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Adopting GIS to Enhance Alexandrian Urban Cultural Heritage: The Case of Alexandria, Egypt

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ABSTRACT

Heritage conservation in Alexandria demands integrative, data-driven approaches that reconcile preservation efforts with satisfactory visitor access. This study investigates how Geographic Information Systems (GIS) can document, evaluate, and spatially optimise the city's cultural heritage. A four-stage framework was applied: (1) compiling a multi-source geodatabase of 294 heritage assets in addition to transport nodes; (2) digitising attributes for value scoring based on five National Organisation of Urban Harmony (NOUH) criteria; (3) conducting spatial analytics—hot-spot, nearest-neighbour, buffer, and network analysis—together with a six-parameter walkability index; and (4) translating findings into policy-relevant interventions and interactive web maps. Results reveal pronounced clustering in the historic downtown;however 83 high-value assets lie outside a 400 m walk from transit, notably in Foad Street, Kafr-Abdo, and Ancient Catacombs sub-areas. Proposed measures—two bus-stop extensions, and one new tram halt would reduce unserved sites to 8.5 per cent. Six optimised cultural routes cut average walking time within heritage clusters to maximise exposure to unique assets. A dashboard links routes, heritage metadata, and multimodal travel options as well as enabling user-defined preference customisation. The research demonstrates GIS's capacity to integrate qualitative heritage evaluation with quantitative mobility analytics, offering a transferable model for sustainable, economically beneficial urban heritage management.

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Highlights:

- GIS adoption contributes to optimising the walkability index along six cultural routes as well as mobility options between heritage clusters.
- GIS-based value scoring pinpoints 83 high-value assets beyond 400 m transit access , steering targeted mobility upgrades.
- Hot-spot analytics uncover significant downtown clustering versus three underserved sub-areas, informing balanced heritage regeneration.
- Network analysis optimises six tourist itineraries, trimming mean walking time and widening heritage site coverage on the city-scale.
- Interactive GIS dashboard drives real-time heritage–mobility integration and visitor engagement, amplifying sustainable tourism marketing.

Contribution to the field statement:

By integrating value-based heritage scoring with GIS-driven mobility and walkability analytics, this study produces transferable dashboards that reveal underserved cultural clusters, propose transit–heritage synergies, and quantify tourism gains. It extends urban heritage scholarship by embedding socio-economic accessibility metrics within asset documentation and evaluation processes. In doing so, it proposes scalable, replicable, and policy-ready tools for sustainable urban development.

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1. Introduction

1.1 Background and Context

Architectural heritage is a key aspect of communities' history, having witnessed the evolution of civilisation and remaining as a historical, spiritual, and cultural wealth for future generations (Liang et al., 2023). The development and structuring of cities with a tourist vocation are significantly influenced by the preservation and promotion of such heritage. It becomes an invaluable asset that stimulates the development of associated economic activities, promotes investment, generates employment, and boosts tourism (Diego et al., 2024). Nowadays, heritage conservation can no longer be comprehended from a single perspective; however, it should be approached within a larger regional context. Thus, heritage conservation should be promoted holistically in integration with urban development (Liang et al., 2023).

Founded by Alexander the Great, Alexandria has been a centre of intellectual and scientific activity since 331 BC, particularly during the Greek and Roman Empires. Stretching thirty-two kilometres along the Mediterranean coast, serving as the country's main harbour, it is the second-largest city in Egypt, with a population of 5.48 million according to the 2022 census. Historically, it is a cosmopolitan city that was a key city in the Hellenistic and Roman eras (Hussein et al., 2020b). Alexandria is a major Mediterranean metropolis with a rich multicultural heritage and a unique urban fabric shaped by European architects (Abdelhamid et al., 2023). However, many coastal heritage sites in Alexandria, like Qaitbay Citadel, face significant threats from natural hazards such as earthquakes, land subsidence, and sea level rise caused by climate change, which endangers their preservation (Abdelaal et al., 2024). Additionally, rapid urban expansion driven by population growth often leads to gentrification, loss of memory, and erosion of place identity. To address this, UNESCO introduced the historic urban landscapes (HUL) concept, which integrates urban conservation with planning by emphasising the social and cultural values people attach to their environments (Hussein et al., 2020a). Also, the Venice Charter of 1964 and the International Council on Monuments and Sites (ICOMOS) Washington Charter of 1987 established global principles for conserving historic urban areas, emphasising context and social involvement (Abdelhamid et al., 2023).

Alexandria’s heritage sites face challenges in balancing preservation efforts with the demands of modern infrastructure (Idrus Malik & Kwei Haliday Nyingchia, 2024). They are increasingly isolated from one another, creating a disconnection between the integral value of these sites and the sightseeing value they offer. This segregation is further compounded by an unsustainable transportation system contributing to severe traffic congestion, lengthy delays and queues, and environmental degradation (Darwish et al., 2024). An article by Elsorady & Hussein (2024) explores the revitalisation of Alexandria's historic Turkish District through the enhancement of pedestrian pathways. Their study emphasises the importance of integrating heritage conservation with adequate pedestrian infrastructure to promote sustainable urban tourism. Thus, such evidence to promote Alexandria as a premier day trip destination strengthens the paper’s argument.

Recognising the importance of heritage assets, Egypt authorised Rule No. 144 of 2006 to protect such assets, with heritage catalogues created in each governorate, emphasising that both authorities and local communities share responsibility for preservation (Ezz Eldin & Magdy, 2024). While the government’s Technical Secretariat of the Heritage Conservation Commission is officially responsible for heritage conservation in the city of Alexandria, most heritage preservation efforts are carried out by NGOs like the Alexandria Preservation Trust. The Trust was created in 1999. It developed an inventory documenting over a thousand buildings and numerous heritage sites, which was published in 2008. However, by 2016, this list had drastically reduced (Abdelhamid et al., 2023). Such initiatives are the base resource of heritage data collection for this research.

As for mobility, Alexandria’s road infrastructure follows the east-west strip of the city, with five key arterial roads: Abu Qir Road, Mahmoudiya Road, Coastal Road, Al Cornish Road (also known as El Geish Road), and El Max Street. It depends on public transportation via three main systems:

Tramlines (City and Raml), Railway lines (Abu Qir and Borg El-Arab), and Bus lines (Darwish et al., 2024). In 2025, the city is planning to include the Metro. Taxis and microbuses are also popular paratransit modes. The historic city centre remains a key transportation hub, featuring the tram "Ramleh Station" and train "Misr Station," connecting regional and local travel routes in addition to a main bus stop located on El Geish Road at the entrance to Saad Zaghloul Street, one of Alexandria's main commercial streets. Alexandria's street system has followed a grid-iron pattern since the 19th century, which supports walkability. However, vehicular traffic and parking issues hinder pedestrian movement and access (Ammar, 2018). In the study, Ammar (2018) devised a survey that concluded other challenges in Saad Zaghloul Street and the city centre zones. These challenges include inconsistent sidewalk widths, damaged pavements, poorly maintained ramps, insufficient, poorly placed street furniture obstructing pedestrian flow, and a lack of greenery.

The "Alexandria New Vision 2032" strategic urban plan promotes sustainable development. With input from the General Organisation for Physical Planning (GOPP) and the United Nations Development Program, the plan focuses on preserving the city's heritage while enhancing its appeal as a tourist destination. This creates a further motivation for the research to apply its methodology in Alexandria as a case study.

1.2 Problem Statement and Research Gap

This paper aligns with the broad aim of proposing actionable strategies that contribute to a more inclusive and resilient user experience of the urban heritage. Accordingly, the research problem can be discussed in two sections. Firstly, Heritage sites are often poorly integrated into existing public transportation networks, resulting in:

i. Over-tourism in easily accessible areas;
ii. Underutilisation of less accessible sites, reducing their economic and cultural potential;
iii. Increased private vehicle use, contributing to traffic congestion and pollution;
iv. Lack of efficient multimodal connections, limiting visitor mobility between different heritage zones.

Secondly, investigating the clustering of heritage sites is facing key obstacles, including:

i. Lack of comprehensive documentation with incomplete or outdated records;
ii. Gaps in understanding how clustered heritage sites influence local communities, tourism, and the economy;
iii. Underexplored, smaller, or less-recognised sites that may be part of important cultural clusters;
iv. Unclear integration with urban planning strategies, including land use zoning, as well as heritage preservation and conservation policies.

According to Salem et al. (2025), historic urban heritage sites face challenges due to increasing tourism. Existing research often examines factors such as visitor flow, route length, walking speed, and environmental impact in isolation. However, a comprehensive, integrated framework incorporating spatial, temporal, and comfort dimensions remains globally absent. In this regard, Salem et al. (2025) introduce innovative tools to evaluate balancing tourism and preservation in Cairo's historic urban fabric, revealing disparities across different areas, with key challenges including overcrowding, conflicting land uses, and insufficient infrastructure.

In Egypt, heritage protection laws focus on physical sites listed in official registers. Stakeholders are primarily government agencies, including the National Organisation of Urban Harmony (NOUH), the Ministry of Antiquities, the Governorates, and little involvement from local communities, highlighting another gap (Teba et al., 2025).

In this regard, an interdisciplinary approach to understanding and documenting heritage clusters in urban environments is essential for urban development. This approach aims to improve the utilisation of heritage sites to overcome the discussed downsides. Gagula et al. (2025) mention that GIS offers innovative solutions by mapping, route optimisation, and visualisation, enhancing traveller

experience and cross-cultural interaction. By designing GIS-enabled optimised routes that highlight significant landmarks, the paper aims to enhance the user-driven experience while fostering the preservation of these sites.

A study by Al-Jaberi and Hasan (2022) emphasises that cultural routes serve as catalysts for historical revitalisation by integrating these routes into development plans through a framework highlighting environmental preservation, socio-cultural engagement, and economic development. According to Nugraha et al. (2023), the EU has implemented "Cultural Routes," which link historic and cultural attractions. Cultural routes are thematic itineraries that connect heritage sites, landscapes, and cultural landmarks to promote cultural tourism, education, and sustainable development. According to UNESCO and ICOMOS, cultural routes are networks of tangible and intangible heritage elements that reflect the movement of people, ideas, goods, and traditions over time (Ruchinskaya et al., 2025).

In recent studies, Zouridaki et al. (2024) conducted a systematic literature review, involving screening 117 publications from various disciplines, including tourism, heritage studies, and urban planning, which highlighted a gap in academic research at the intersection of sustainable mobility and cultural routes. According to Zouridaki et al. (2024), publications on cultural routes and sustainable mobility were minimal between 1987 and 2016, but interest grew after 2011, with 76% of studies published between 2017 and 2022. Additionally, most research follows a qualitative, case study-based approach, while quantitative, mixed methods and literature reviews remain limited. Thus, this paper aims to support sustainable tourism by directing users to heritage sites through cultural routes based on spatial analysis workflows and principles in a comprehensive methodology balancing qualitative and quantitative analysis.

1.3 Study Objectives

The study explores the extent to which GIS technologies can be adopted and utilised to enhance the cultural heritage experience through four main objectives:

i. To identify, document and assess heritage assets;
ii. To employ cultural mapping tools, enhancing user experience;
iii. To analyse spatial interrelations between heritage sites and transportation networks;
iv. To propose GIS-based Urban planning strategies that balance heritage conservation and sustainable tourism development.

1.4 Significance and Structure of the Paper

While the research gaps exist within the little theoretical framework that adopts GIS directly into heritage conservation efforts, the spatial analysis field, on the other hand, witnesses an increase in literature over time. In response, this paper aims to bridge the gap between the theory and practice of utilising GIS. In the following sections, the paper tackles the topic in question through the structure presented in Figure 1.

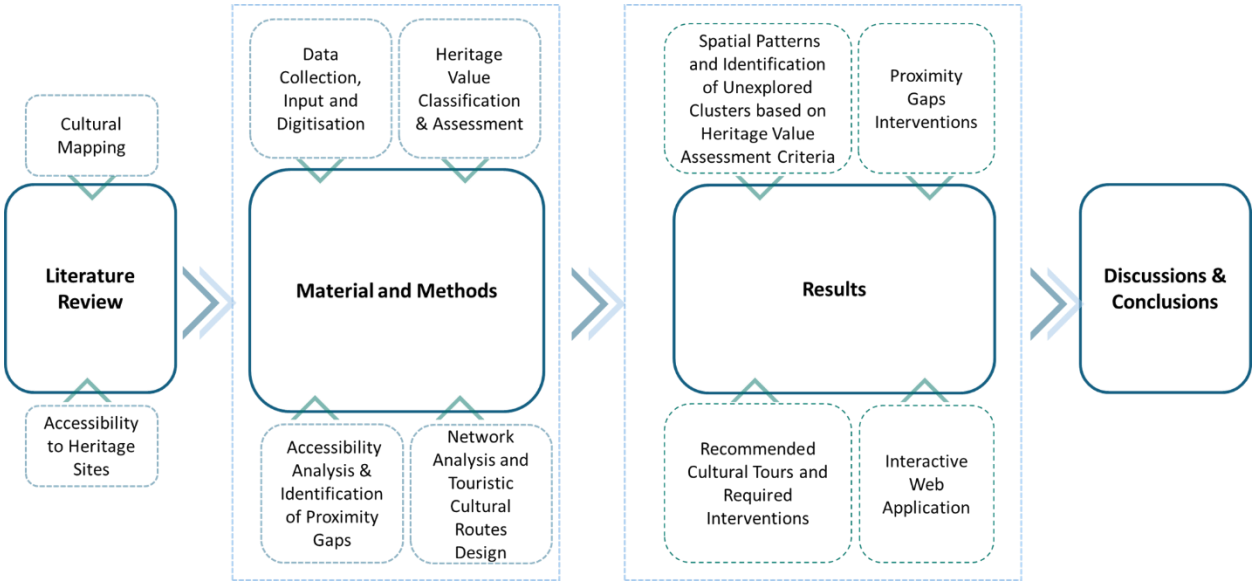

Figure 1. Structure of the Study.

This structure includes a literature review introducing the relevance of cultural mapping and accessibility to heritage sites in adopting GIS to propose walkable cultural routes. It also involves a detailed display of conducted analysis highlighting materials and methods, followed by reporting and interpreting results in order to discuss findings and concluding outcomes.

2. Literature Review

2.1 Cultural Mapping as a tool and the Importance of GIS in its application

The digital age has significantly transformed how information is shared and accessed through electronic media. This is why visualisation plays a crucial role in mapping cultural heritage (Mahadzir et al., 2024). Cultural mapping is important in urban planning, considering the complexity of mapping different potentials for the tangible and intangible (Freitas, 2016). Cultural mapping could involve various techniques, ranging from community-based participatory data collection to advanced GIS tools (Rashid, 2015). Researchers are increasingly utilising GIS in addressing spatial challenges, considering destinations' distribution, users' mobility, and infrastructure needs. Through spatial analysis, GIS helps in making informed decisions, and guiding tourism towards more sustainable practices (Sang & Piovan, 2019; Xing, 2024).

It has become a common approach among urban planners to involve citizens and stakeholders in expressing what they value in their surroundings (Jeannotte, 2016). This is why it is essential to explore examples of visual interactive mapping efforts such as the Cairo Urban Initiatives Platform (CUIP), which is a directory highlighting initiatives in Cairo related to architecture, art, advocacy, urban development, and public spaces. It provides an interactive map and resources for navigating the city's urban cultural landscape. The platform is managed by CLUSTER (Cairo Lab for Urban Studies, Training and Environmental Research), established in 2011, and aims to address urban and environmental issues in Cairo and other Egyptian cities (Panetta, 2018). However, their latest issue supporting cultural routes in Alexandria was last updated in 2017.

2.2 Accessibility to Heritage Sites

The potential of existing opportunities in a location for human interaction or development via various modes of transportation, taking into account the limits in the environment, is known as accessibility (Diego et al., 2024). In its entirety, cultural heritage is a collection of historical-cultural values, traditions, and knowledge that must be accessible to all (Marconcini et al., 2021). Within heritage-rich cities, while the use and exploitation of heritage assets are crucial and serve as strong economic drivers, studying mobility patterns associated with such development efforts is essential. In this regard, inefficient planning and management result in congestion issues and negative impacts on these cultural assets themselves (Diego et al., 2024). Rapid and uncontrolled urbanisation causes historic neighbourhoods to decay and lose their cultural identity. The sustainability and preservation of an urban character depend on the successful integration of newly planned regions with historic urban areas (Şahin Körmeçli, 2024).

Since heritage sites are usually arranged into clusters unevenly, transportation networks have a direct impact on the development of these sites. Transportation accessibility also helps with national heritage tourism forecasting and regulation (Liang et al., 2023). According to Liang et al. (2023), analysing the accessibility of sites can contribute to the advancement of heritage tourism through three key dimensions:

1. Destination Selection: In this regard, remote sites would consume more time, money, and even physical effort to access, which influences the travellers' decision.
2. Tourist Satisfaction: Several criteria play a role in the overall quality of tourism, including transportation speed and convenience.
3. Traffic Impact on Tourism Resources: On several occasions, traffic could impact the attractiveness of a certain site or location, weakening the potential advantages of this tourism resource development.

Therefore, proper consideration of road network connectivity and impactful mobility nodes is essential for heritage preservation on the city scale (Diego et al., 2024). In this regard, a need to improve the accessibility of heritage sites arises, where a macro-to-micro scale analysis of spatial patterns and features is required (Şahin Körmeçli, 2024).

2.3 Planning of walkable cultural routes

Due to walking's fundamental role in mobility, Guillen and Santa (2025) explore walking tours as effective tools for advocacy, recreation, and promoting tourism. Despite this, there is a critical need for research that better understands pedestrian experiences in spatial frameworks (Guillen & Santa, 2025). The article by Hijriyah et al. (2025) analyses existing research on walkability. It identifies key gaps, particularly the limited integration of psychological, socio-cultural, and technological dimensions in assessing walkable environments. Their study emphasises that most walkability research is skewed toward physical and environmental factors affecting user experience. It calls for interdisciplinary approaches to enrich the understanding of walkable urban spaces.

Furthermore, the assessment framework of Ma et al. (2025) integrates GIS technology to evaluate urban walkability. By digitising and analysing geospatial data, their study produces thematic maps indicating areas of higher or lower walkability. This GIS-based approach bridges the gap between theory and application, aiming to guide planners in creating healthier, more walkable cities. Also, Lättman et al. (2025) explore a nuanced understanding of the factors influencing walking satisfaction, such as safety, accessibility, comfort, and the presence of amenities. Their study examined overall walking satisfaction in Dortmund, Genoa, and Gothenburg, where Leisure and recreational walks yielded greater satisfaction than trips to fixed destinations. Key determinants of satisfaction across all cities included accessibility and social context (walking alone vs. in company). These findings underscore the importance of local context, trip purpose, and individual preferences in shaping user satisfaction.

The study by Russo et al. (2025) explores tourism not just as static physical access points to destinations but as dynamic systems with various forms of mobility. It argues that approaches analysing accessibility overlook how urban infrastructures actively shape tourist movements and call for a holistic approach to planning that enhances tourism experiences. While Luo et al. (2025) state that advances in mobile and location-based technologies have enhanced the ability to analyse crowd behaviour in real time. Their research argues that spatiotemporal behaviour varies daily, weekly, and seasonally, influenced by urban form and climate, and these variations offer an understanding of actual usage patterns.

Besides, Sannazzaro et al. (2025) explore strategies to revitalise less-developed inner areas in the Basilicata region in Southern Italy through cultural routes to stimulate local economies, preserve heritage, and enhance identity. Their proposed methodology unfolds in three phases: review of existing assets, collaboration with local authorities to collect visitor data, and field surveys to assess site conditions along the cultural routes. However, the authors highlight constraints, including limited financial resources among local authorities and the lack of consistent visitor data.

Moreover, Gagula et al. (2025) used GIS-based network analysis on Siargao Island, Philippines, to identify optimal routes connecting forty-one tourist destinations. Researchers introduced an interactive web map to explore routes and access tourist information. Their findings suggest adding socio-cultural and environmental factors to create a more realistic route analysis. Nevertheless, this only focuses on mobility from or to the airport or the port; it is insightful to examine how a network database is incorporated in support of connecting tourist attractions.

3. Materials and Methods

3.1 Study Design and Setting

The methodology of the research involves four main sequential steps, where a comprehensive approach ensures thorough data collection, analysis, and application. As shown in Figure 2, the methodology follows a systematic reapplied for database updates, testing interventions, or analysis of other cities beyond the case in Egypt.

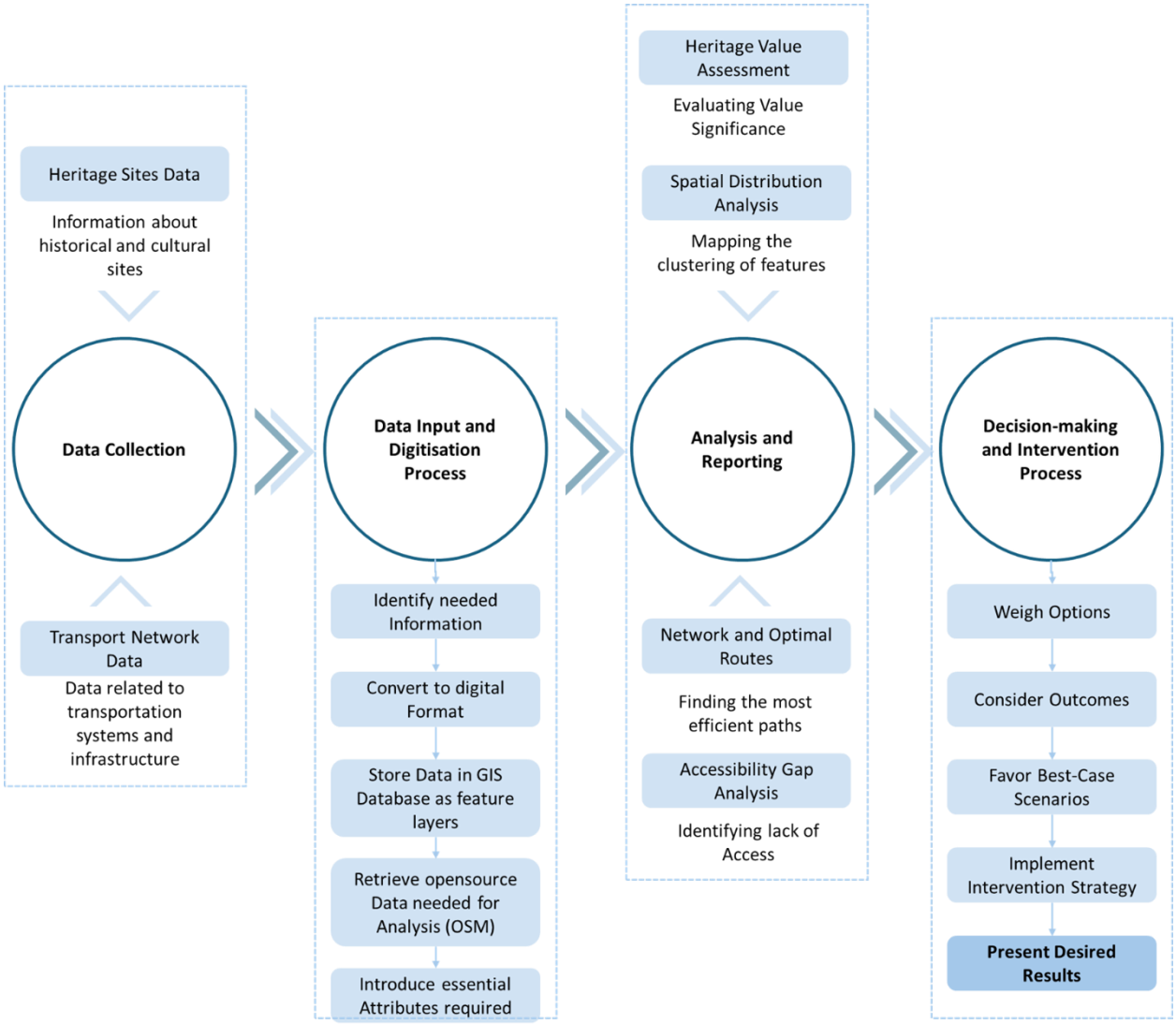

Figure 2. Methodology steps of the Study.

First, data collection involves gathering relevant information from various sources, including historical records, architectural studies, and previous research. The collected data is organised into categories such as sites' locations, architectural styles, names of sites, and heritage values and maintained into datasets for easy referencing. In this step, sampling excludes those demolished before 2024.

The second step, data input and digitisation, focuses on converting the collected data into digital formats using GIS databases. It involves adding attributes that support spatial analysis, such as relevant notes from site visits and must-see heritage assets. This includes exploring crowdsourcing tools like Google Maps to identify attractions the public associates with Alexandria to add culturally significant assets if missing from existing records. This step is concluded by creating digital maps that visualise and identify the distribution, patterns, and relationships of assets.

In the third step, analysis, and reporting, both quantitative and qualitative methods were used to examine the digitised data. These analyses provide a deeper understanding of heritage value assessment. Detailed reports, charts, graphs, and maps were generated to present notable discoveries. The ArcGIS Pro tools supporting this step include Field Calculator, Overlay, Optimised Hot Spot Analysis, Network Analyst Shortest Route, Buffer, Near, and Spatial Queries.

Finally, the fourth step involves using the analysed data to inform decisions and implement appropriate actions. This step includes proposed adjustments to optimise existing walking routes in

Alexandria as well as suggesting walkable routes that combine the competence of the heritage value assessment and network analysis.

The ultimate goal is to deploy advanced GIS algorithms to generate routes that can be later customised based on individual preferences and limitations. For example, users interested in historical sites would prioritise a route connecting nearby museums and landmarks with accessible transportation options such as bus stops or stations. Others might plan their visit based on the available time they have regardless of the type of sites they might see as long as they are of a unique value. This means that temporal aspects help assess user frequencies over time to reduce congestion and improve the overall experience. Responding to such needs, GIS spatial analysis tools can identify patterns of movement and pinpoint hotspots of heritage assets. This enables interventions, such as optimising signage placement, improving wayfinding criteria, or creating alternative routes to circulate user movement. Moreover, GIS can also consider factors like proximity to services and environmental restrictions if available (Xing, 2024).

3.2 Data Collection, Input and Digitisation

A geodatabase is a relational database schema that effectively defines spatial entities and geographical data. This structure allows for a unified management making it possible for multiple users to access and edit. In the context of this research, once a heritage geodatabase is created for Alexandria, it can be shared on a local enterprise network or online, allowing the creation of user-friendly data acquisition and mapping. Additionally, various operations can be performed including:

i. Visualisation: Displaying geographic data in formats easy to comprehend by all users.
ii. Data Overlay and Browsing: Layering different data for comparison, helping to view multiple aspects of heritage assets and their values.
iii. Data Retrieval: Extracting specific information from the database for targeted analysis in any step of the study.
iv. Analysis of Data: Organising and analysing spatial data to find trends, patterns, and relationships within the heritage assets.
v. Thematic Mapping Customisation: Customising maps to highlight themes or features, aiding in the visualisation of heritage assets and the suggested routes connecting them.

The creation of the Alexandrian Urban Cultural Heritage geodatabase is an unending process, where data acquisition and site investigations are in continuous updates. In Figure 3, resources of data in this research are displayed.

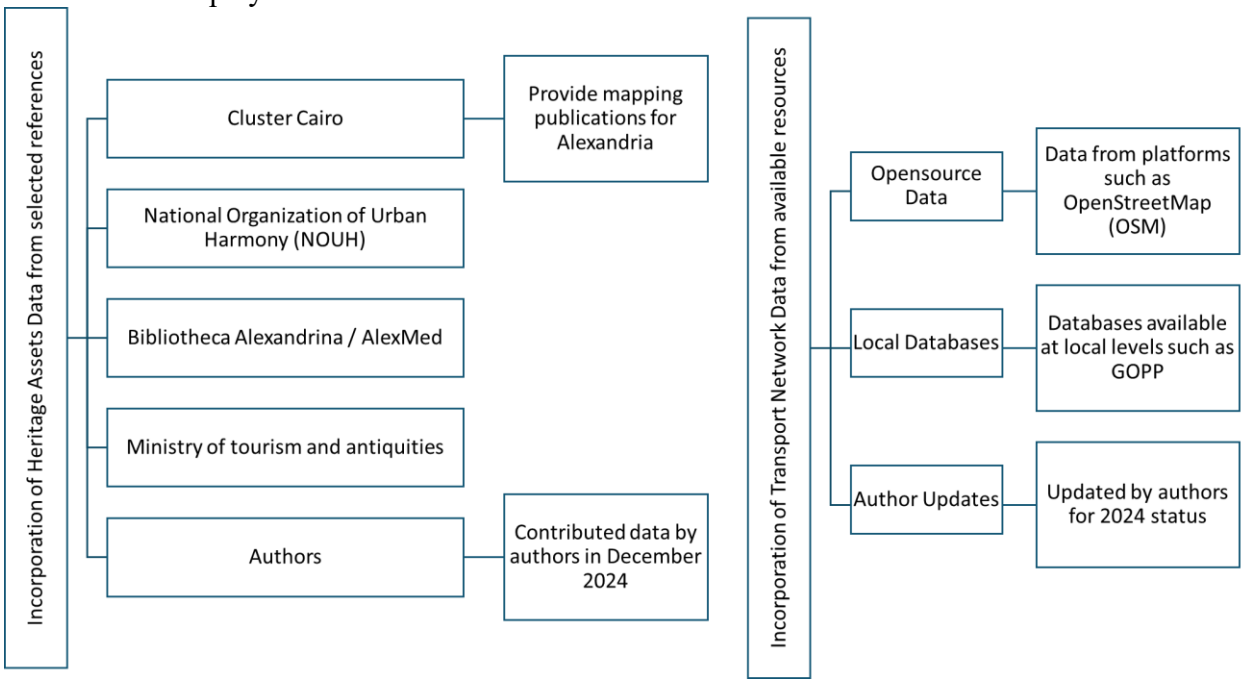

Figure 3. Research Data Collection Resources.

Local governments and cultural ministries in Egypt typically serve as the primary sources for official records on heritage sites. Additionally, academic studies, reports, and publications by archaeologists and entities interested in heritage offer other in-depth records. Also, public transportation data, such as bus routes, metro systems, and tram lines, are mapped and managed by local transportation authorities or municipal planning departments, who also provide information on routes and schedules.

Private sector reports and open-source GIS platforms, including OpenStreetMap further enhance data collection as well as mobile apps like Google Maps that can be used to track movement around heritage sites. This real-time data can offer insights into the actual experience of over-congestion at certain points. Overall, the types of data in the research were divided into two groups as follows:

i. Heritage Site Data Documentation: including location and significance of heritage sites (monuments, museums, cultural landmarks), in addition to visitor footfall data (where available) to understand demand patterns.
ii. Transport Network Data Collection: including public transportation routes (buses, metro, and trams) and stops, road networks and walking paths, including barriers to access, as well as planned or proposed transport projects (e.g., metro extensions).

The documented assets were categorised based on their local, urban, social, architectural, or historical significance. The study uses the categorisation methods developed in 2017 by CLUSTER in the Alexandria Mapping Project, highlighting the city's rich heritage with three walking tours in the Downtown area. By incorporating the assets identified by CLUSTER and the additional sources mentioned in Figure 3, a deeper understanding was achieved in terms of the heritage asset types in Alexandria in the downtown area and outside of it. The created database reveals that:

i. Approximately 65% of the assets fall under the category of Heritage Buildings.
ii. The second largest category includes vintage cafes and restaurants at around 8%, followed closely by arts and culture (6%) and parks/public spaces (5%).
iii. The remaining 16% comprises vintage stores, statues/monuments, vintage hotels, clubs/associations, vintage signs, and market spaces.

3.3 Data Analysis

3.3.1. Heritage Value Classification and Assessment

According to NOUH, values that contribute to the evaluation of heritage assets are:

1. Historical Value: Significance of a site in terms of its role in history such as past events or important personalities.
2. Architectural or Artistic Value: The aesthetic, design, and craftsmanship of a site such as uniqueness of design, materials, or architectural elements.
3. Context Value: The importance of a heritage site within its surroundings which could be social, or historical contexts for example.
4. Social and Spiritual Value: The meaning of a site for the local population, often being bound to rituals, ceremonies, or identity.
5. Cultural Value: Significance of a heritage site’s contribution to the sense of belonging, pride, or memories.

These values can overlap and influence each other, where each one plays a critical role in how heritage is conserved, understood, and valued within both local and national contexts.

A number-based scoring system assigning 0 or 1, indicating the absence or presence of NOUH values, is proposed to evaluate and rank assets based on a predefined quantitative criterion. These Criteria are seen in Table 1, while the resulting thirty-two combinations are depicted in Table 2. The visualisation of such criteria is represented in Figure 4.

Table 1: Number-Based Criteria for Heritage Value Assessment.

Value Type	**Historical Value**	**Architectural or Artistic Value**	**Context Value**	**Social and Spiritual Value**	**Cultural Value**	**Maximum Value for a single site**	**Number of Combinations available to exist in the database**
Numerical value to be assessed	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	Sum of the maximum of all previous values = 5	2^5 = 32 (31 values not equal 0)

Table 2: Combinations available to exist in the database regarding Heritage Values of Sites.

Combination	Historical Value	Architectural/ Artistic Value	Context Value	Social/Spiritual Value	Cultural Value	Overall Sum	Number of assets with the combinations in the Alexandrian Database and Possible Interpretations
0	0	0	0	0	0	0	No identified assets
1	1	0	0	0	0	1	4 Assets
2	0	1	0	0	0	1	101 Heritage Buildings
3	0	0	1	0	0	1	No identified assets
4	0	0	0	1	0	1	12 Assets including 8 Vintage Café Bars & Restaurants
5	0	0	0	0	1	1	9 Assets in the Downtown area
6	1	1	0	0	0	2	4 Assets (statues and monuments)
7	1	0	1	0	0	2	2 Vintage Café Bars & Restaurants
8	1	0	0	1	0	2	No identified assets
9	1	0	0	0	1	2	No identified assets
10	0	1	1	0	0	2	3 Heritage Buildings including Alexandria Primary Court
11	0	1	0	1	0	2	4 Assets (majority are clubs)
12	0	1	0	0	1	2	37 Assets
13	0	0	1	1	0	2	2 Public Squares
14	0	0	1	0	1	2	2 Assets
15	0	0	0	1	1	2	10 Assets all with supporting commercial activities
16	1	1	1	0	0	3	2 Assets
17	1	1	0	1	0	3	1 Heritage Building
18	1	1	0	0	1	3	8 Assets
19	1	0	1	1	0	3	No identified assets
20	1	0	1	0	1	3	No identified assets
21	1	0	0	1	1	3	3 Assets
22	0	1	0	1	1	3	2 Assets
23	0	1	1	1	0	3	No identified assets
24	0	1	1	0	1	3	No identified assets
25	0	0	1	1	1	3	No identified assets
26	1	1	1	1	0	4	No identified assets
27	1	1	1	0	1	4	2 Assets
28	1	1	0	1	1	4	7 Assets (the majority are Museums)
29	1	0	1	1	1	4	5 Assets
30	0	1	1	1	1	4	4 Assets
31	1	1	1	1	1	**5**	41 assets

The combinations correspond to available information where Architectural/Artistic Value dominates the database (101 assets). These represent buildings recognised for their physical and design merits. Also, combinations involving Architectural/Artistic Values paired with other values appear frequently, strengthening the integrated nature of heritage in Alexandria, where physical form, social, and cultural significance overlap.

Figure 4. Maps of the categorisation of heritage assets in the database, Left: by types – Right: by Uniqueness (Developed by Authors using ArcGIS Pro).

Visualisation based on value and size allows for a clear representation of data by using varying sizes to represent the magnitude of each value. In a chart of five values, it became apparent which values were witnessed in each asset, as shown in Figure 5. This visual approach helps quickly convey the relative importance of each value.

Figure 5. Maps of the Visualisation of Heritage Assets in Downtown Alexandria, Left: by Colour and size according to the type of heritage value for each asset vs. Right: by Size according to the overall heritage value of asset regardless of type (Developed by Authors using ArcGIS Pro).

3.3.2. Urban Heritage Accessibility Analysis and Identification of Proximity Gaps

The evaluation of accessibility to heritage sites has been conducted in multiple ways in previous research, for example, Liang et al. (2023) relied on "Near" analysis to acquire the distances between main traffic routes and heritage destinations. In this sense, different accessibility indices were given based on the hierarchy of the closest route in addition to the distance value itself. Moreover, Diego et al. (2024) concluded the average accessibility of the historic centre based on its connectivity to major transport hubs. Consequently, the proximity and connectivity of heritage sites to the city's transportation system determine their accessibility. For the sake of this study, the transportation accessibility study is pursued for walking and public transit as the two main modes of transportation to assess heritage accessibility for both locals and visitors.

To evaluate the proximity of heritage sites to the Alexandrian transportation network, the ArcGIS "Buffer" tool was used to identify two main isochrones for each transit node based on the two chosen modes of mobility. On the one hand, a 5-minute walking buffer was generated for all public transit nodes allocated within the database. This isochrone is considered equivalent to a 400-meter walk from each node based on the average walking speed (Barton et al., 2006; Silitonga, 2020). In this regard, the question of how far individuals are willing to walk to transit is a challenging one to answer, as the distance varies depending on the circumstance, whether it be demographic, socioeconomic, or land-use profile (Noh, Mohamad, & Hamid, 2021). Across previous research, a range between two hundred meters and eight hundred meters has been widely tested and employed. However, in terms of physical distance, the majority of previous researchers deemed a 400-meter walk to be reasonable. This was observed in ground surveys that tested the distance that bus riders were willing to walk to or from a bus stop (Noh, Mohamad, & Hamid, 2021; Hsiao et al., 1997; Murray & Wu, 2003; Zhao et al., 2003). Consequently, several thresholds were tested for this research, as shown in Table 3, leading to the selection of the more prominent value of four hundred meters (0.25 mile). Moreover, Eldeeb et al. (2024) have previously relied on the same walkability

buffer within the Alexandrian context to analyse access to public transit, which was rooted in ground and on-board surveys conducted, capturing GPS data regarding public transit modes in Alexandria. According to findings in Figure 6, heritage locations corresponding to four hundred meters and above (83 sites) were rendered unreachable within a walking distance from the public transit network. As for the public transit mode, 15-minute transit service polygons were computed for the transit stops that were found within the vicinity of heritage sites. In this context, access to city heritage sites was evaluated across all city districts. The definition of this isochrone is based on the empirical insights published by Transport for Cairo and the World Resource Institute, where the findings of on-board surveys indicate that the average vehicle speed on inner-city roads is approximately 5-15 km/hr, with some arterial roads exceeding 30 km/hr (Eldeeb et al., 2024). Coupling these findings with Alexandria's urban fabric and scale, a 15-minute isochrone is regarded as a reasonable accessibility criterion. Additionally, according to H. Seoudy et al. (2023) and within their pursuit of sustainable urban development of transit-built environment, a transport node's catchment area within the city of Alexandria is defined as a 10 - 15 minutes' drive that extends from 800 m to 6 Km.

Table 3: Variations in walking distance buffer and their corresponding impact on inaccessible heritage sites.

Isochrones Threshold Distance	**200 m**	**300 m**	**400 m**	**500 m**	**600 m**	**700 m**	**>700 m**
Number of Unserved Heritage Sites	176	126	83	47	14	2	1

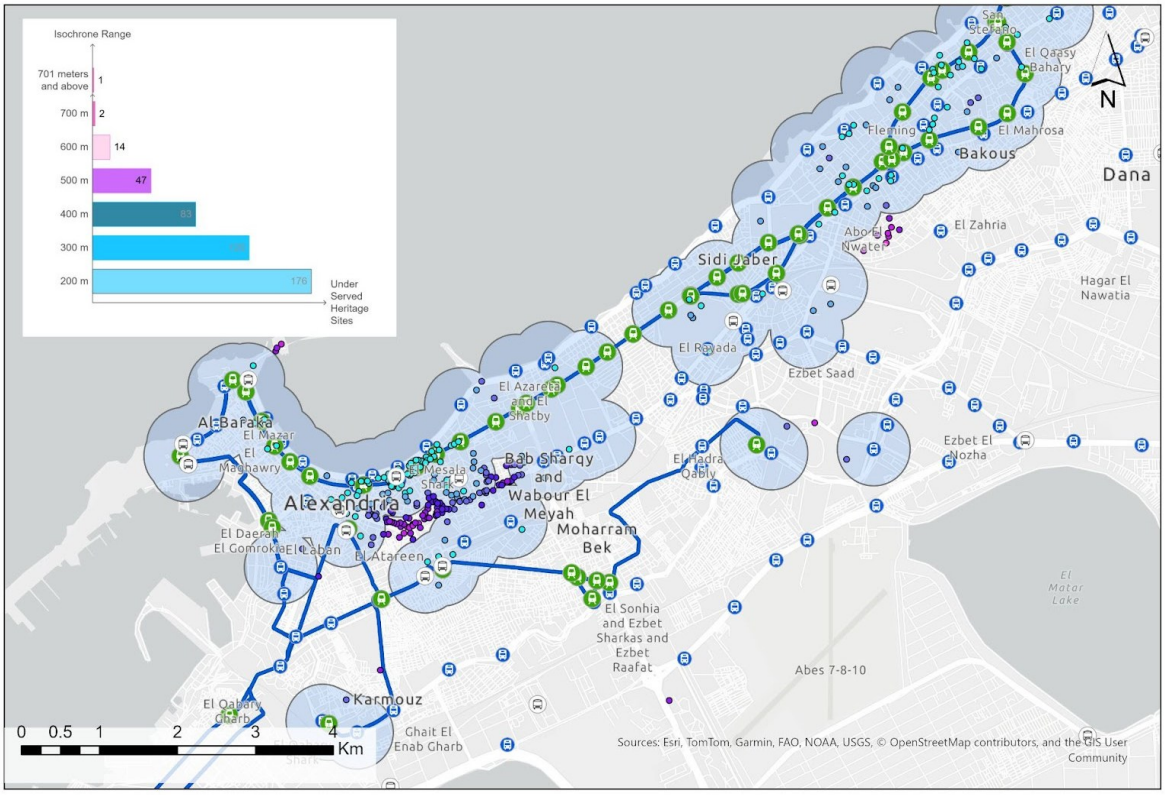

Figure 6. Accessibility analysis map (Using Buffer Tool) for the walkability mode displaying a 5-minute isochrone generated from each public tram or public bus node, where a colour ramp was visualised to identify the extent of accessibility for each site (Developed by Authors using ArcGIS Pro).

Based on the walking mode proximity analysis, an additional inspection reveals that the concluded locations were spatially distributed into three main clusters, as shown in Figure 7:

i. Foad Street Cluster (includes forty-five inaccessible sites),
ii. Kafr-Abdo Neighbourhood Cluster (includes eight inaccessible sites)
iii. Catacombs Region Cluster (includes one inaccessible site).

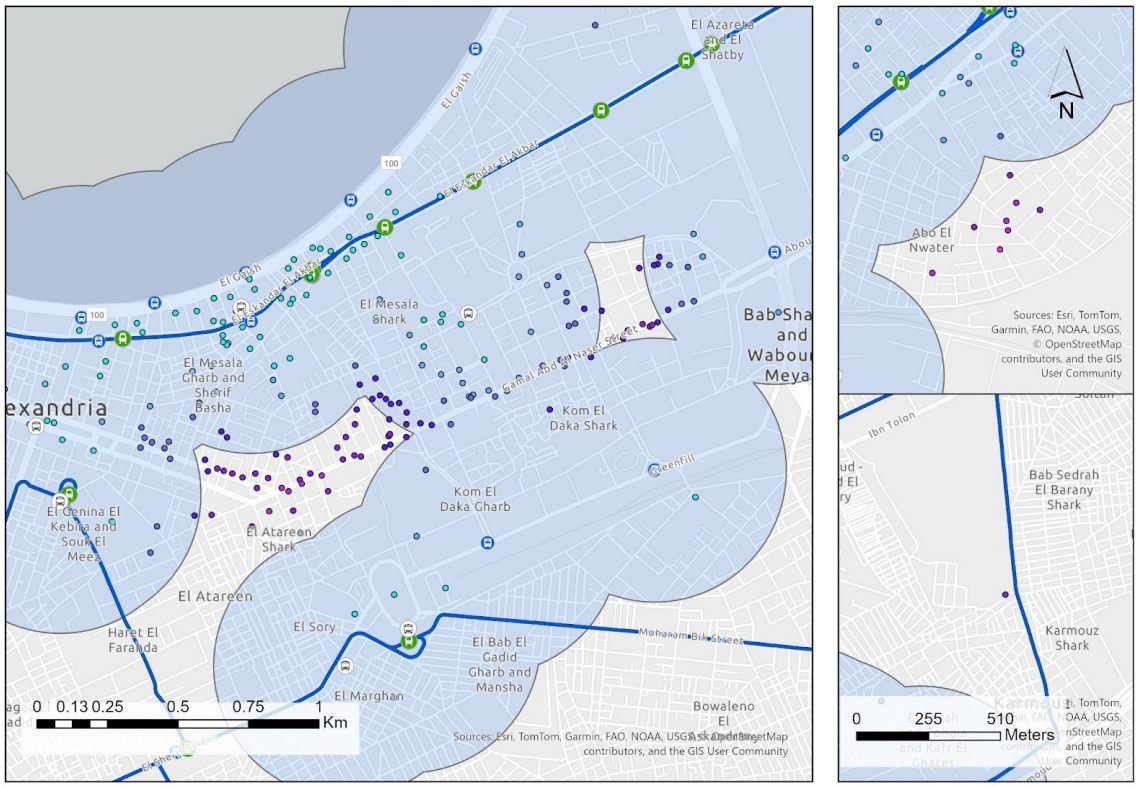

Figure 7. Map of identified proximity gaps for walkability mode based on the conducted accessibility analysis, Left: Foad Street cluster, Right: Kafr-Abdo neighbourhood and Catacombs region cluster (Developed by Authors using ArcGIS Pro).

As for the public transit mode proximity analysis, findings reveal the following:

i. Two out of seven city districts: Al-Ameriyah and Borg Al-Arab (which encompass around 22.4% of the city's population as Mohamed (2023) indicates) are located completely out of the service boundary of accessing heritage clusters.
ii. Foad Street, although considered one of the oldest axes of the Alexandrian urban morphology, is only dedicated to private vehicle transit, adding to the problem that the majority of downtown heritage sites along its axis were inaccessible within walking distance.
iii. Kafr-Abdo neighbourhood is spatially introverted, where public transportation serves along its edges rather than interfering within.

3.3.3. Network Analysis and Touristic Cultural Routes Design

Relying on the proper technologies to manage tourism would eventually lead to a smarter and more sustainable urban system (Şahin Körmeçli, 2024). In this regard, GIS has the potential to advance tourism applications upon optimal routing, closest facilities analysis, and spatial queries, all consolidated with unique map visualisation (Prameshwori et al., 2021). Among the challenges faced by users are selecting destinations based on preferences and strict time schedules. Therefore, itineraries that present heritage sites as interconnected networks rather than isolated locations serve a significant role in supporting heritage tourism (Hassanshahi et al., 2023).

In this sense, a "cultural route" is defined as a group of Points of Interest (POI) that span a region and have similar characteristics, a common theme, and unique historical or architectural elements in addition to infrastructure, buildings, and natural landscapes. From a theoretical standpoint, a cultural route is a geographical expression of continuity based on the exchange notion or movement dynamics. Thus, the primary force behind cultural routes is their placement within the territorial network (Iakovaki et al., 2023). Hence, it was important to conduct the network analysis on two scales: cluster-based routes and city-based routes, based on the spatial distribution of heritage sites in Alexandria and the varying lengths of touristic trips.

The walking tours suggested by CLUSTER in 2017 have three main advantages such as the inclusion of diverse heritage categories, a well-paced number of stops per tour, and balanced tour durations. Therefore, this research inherits CLUSTER's grouping of heritage sites into tours as a base for further analysis and optimisation according to the framework displayed in Figure 8.

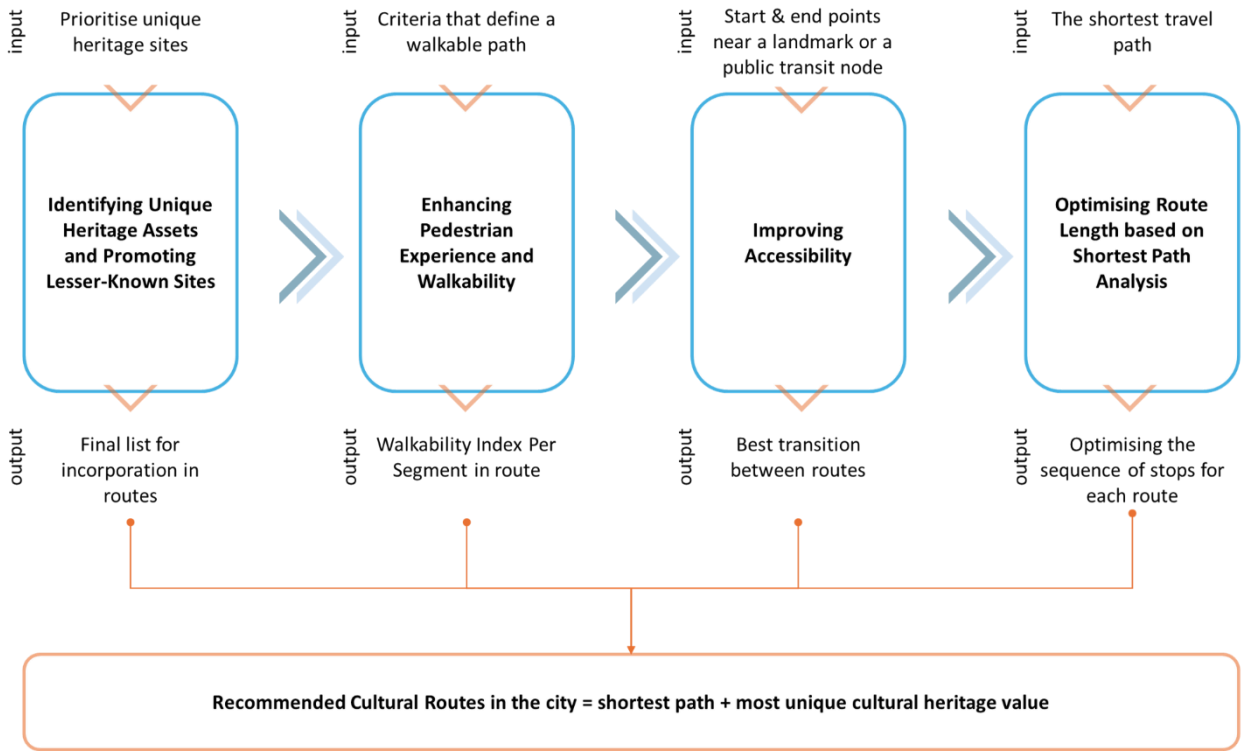

Figure 8. Framework for Cultural Routes Analysis and Optimisation.

1. Identifying Unique Heritage Assets and Promoting Lesser-Known Sites:

In this step, the authors prioritise unique heritage sites to formulate the final list for incorporation in routes. This list reveals a significant skew toward heritage buildings, which make up 80% (94 out of 117) of the unique assets in Alexandria. Statues and monuments (5%) and parks/public spaces (6%) were modestly represented but still significantly less than buildings. However, other categories (9%) were less formally documented but can be just as meaningful to local identity. According to spatial distribution, 50% of these assets were in Alexandria's Downtown (59 out of 117). This reinforces the hypothesis that cultural routes beyond the downtowns hold equivalent significance for tourism and should be given equal consideration.

2. Enhancing Pedestrian Experience and Walkability:

Mengiste et al. (2025) highlight the role of walkability in shaping sustainable and liveable urban environments. Walkable downtowns in cities are much preferred by visitors due to their flexible routing compared to other modes of transportation (Hassanshahi et al., 2023). Several researchers have investigated criteria that define a walkable path, including comfort and convenience, safety and security, proximity to public transport, imageability, environmental qualities, land use and activities, human scale, etc. (Hassanshahi et al., 2023). Convenience in the context of urban tourism

refers to minimising walking effort and includes elements like sidewalk quality, signage, a barrier-free environment, and pedestrian amenities like benches and pedestrian shades. The condition of the vegetation may also indicate that walkability is significantly influenced. Narrow walkways and heavy traffic flow negatively impact walkability, as well as a zone's crime rate. Therefore, surveillance and street lighting can be used to elevate security levels. On the other hand, cultural routes are strongly concerned with a district's imageability, where the presence of landmarks along a path positively serves its perception. Furthermore, human-scale design is defined as one of the qualities that impact the duration of a walking tour (Hassanshahi et al., 2023).

This research focuses on six main parameters to evaluate the walkability per segment along each proposed cultural route. These parameters are:

i. Sidewalks Quality,
ii. Natural Shading and Vegetation,
iii. Street lighting,
iv. Presence of Surveillance,
v. Imageability and Visual Interest,
vi. Noise Levels and Comfort.

In this regard, parameters including slope and terrain, urban shades, and seating areas were ignored in Alexandria, where the terrain is almost flat and the presence of urban furniture such as canopies, benches or signage is scarce. However, the surveillance of heritage sites in Alexandria was assessed through two primary factors: the deployment of security cameras, installed by business owners, and surrounding activity levels. As for imageability and visual interest, streets that were overlooked by a heritage building/façade were identified as visually interesting, as well as those passing by urban landmarks or green areas (Marconcini et al., 2021). Lastly, noise levels were implied from traffic levels along each street in addition to different street activities and land uses.

In this sense, each parameter was given a value of 0 or 1 (existing or not) based on field visits. Hence, each segment, as shown in Figure 9, has an overall walkability index out of 6 (W_i), where an equal weight was considered for all parameters. The index was then weighed by the segment length (l_i) to calculate the total walkability index per route (W_{Total}) as follows:

$$W_{Total} = \frac{\sum_{i=1}^{n} W_i \,.\, L_i}{\sum_{i=1}^{n} l_i}$$

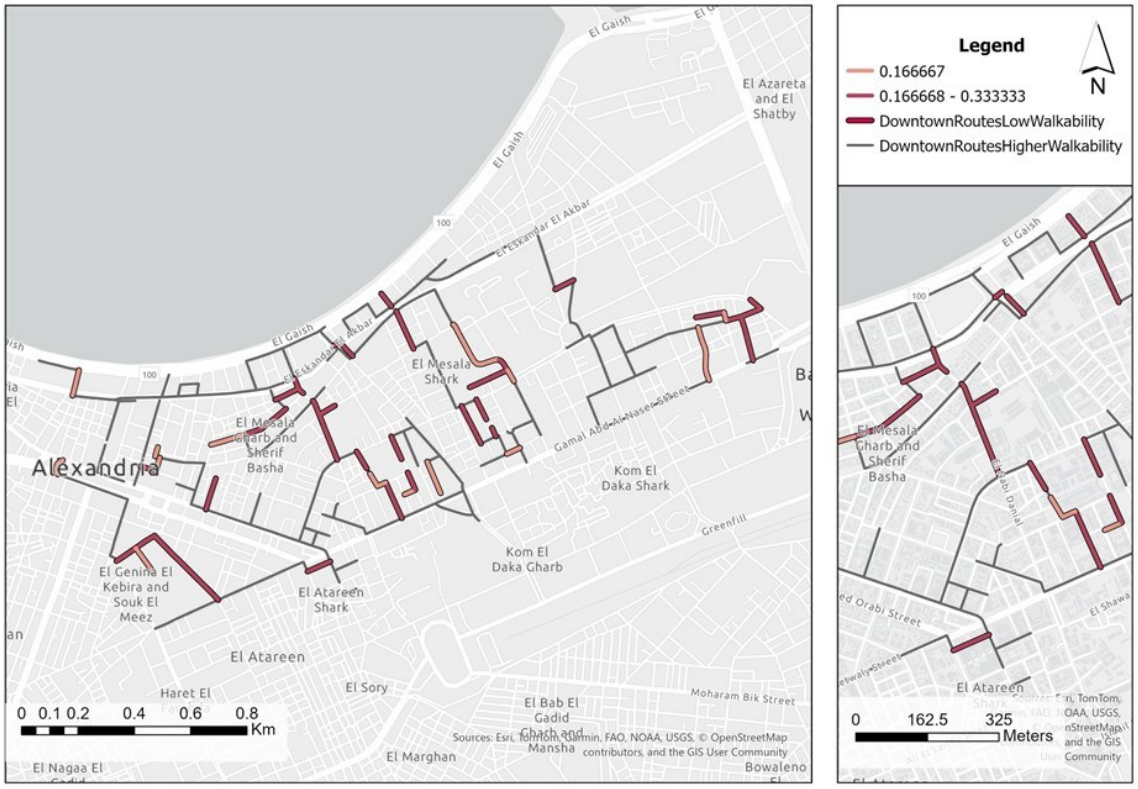

Figure 9. Map of Overall Walkability Index Per Segment for Downtown Cultural Routes (Developed by Authors using ArcGIS Pro).

3. Improving Accessibility:

Deriving from accessibility and walkability analysis, cultural routes were optimised in a way that the start and end points were selected as key points of interest based on their proximity to either a landmark or a public transit node. Additionally, the endpoint of each route was planned to seamlessly transition into the starting point of the subsequent route to ease the flow between the different tours.

4. Optimising Route Length based on Shortest Path Analysis:

The final phase of the cultural route redesign involves optimising the sequence of stops for each route by determining the shortest travel path while adhering to predefined starting and ending points. This analysis was conducted using ArcGIS Pro's Network Analyst, with "walking time" selected as the routing mode to ensure efficiency in pedestrian navigation.

4. Results

4.1 Spatial Patterns and Identification of Unexplored Clusters

Hotspot analysis tools are commonly used to identify clustering patterns, highlighting clusters of high or low values based on predetermined weights (Fischer& Getis, 2010). The optimised hotspot analysis identifies spatial clusters using the Gi_Bin field. Features with a Gi_Bin value of 0 are not significant, while other values are classified into 99%, 95% and 90% confidence levels as seen in Figure 10 (Elfadaly & Lasaponara, 2019). A hot spot was evident in the city centre, with a nearby cold spot to the east.

Additionally, the nearest neighbour index analysis was a spatial indicator of proximity between points. In this regard, if N is equal to 1, then the points are distributed randomly; however, a value less than 1 indicates clustering patterns, and a value more than one indicates uniform distribution (Liang et al., 2023). This index in Alexandria equals 0.082316 with a z-score of -30.102169, which confirms the clustering pattern of urban heritage sites, particularly within Alexandria's downtown.

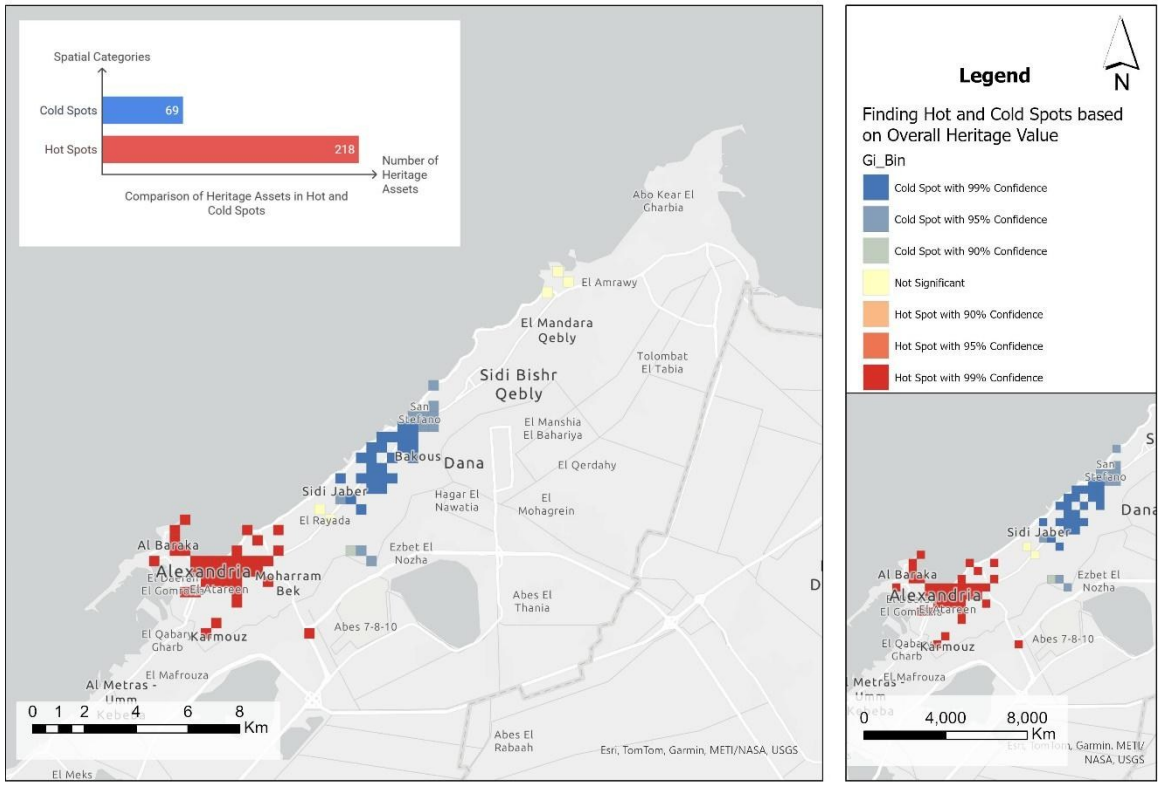

Figure 10. Map of Optimised Hotspot Analysis and Number of heritage assets contributing to each cluster (Developed by Authors using ArcGIS Pro).

It was then deduced that Alexandria's historic city centre, 'Sharq' and 'Wasat' districts, boasts the highest concentration of listed heritage assets, including residential buildings, schools, theatres, and gardens, showcasing a blend of Renaissance, Neoclassical, and Art Deco architecture.

4.2 Proximity Gaps Interventions

To minimise the limited accessibility identified within the three main clusters of heritage sites, interventions were investigated and presented in Figure 11, including:

i. Extending existing bus routes;
ii. Adding new tram stops;
iii. Integrating green mobility modes.

Firstly, for Foad Street Cluster, two existing bus routes were observed with the potential to extend in proximity to these heritage locations In this regard, an added stop along "Kafr Ashry-Mansheya" route could potentially serve 25.3% of the unserved sites, while another stop along "Abo Qir" axis could raise this percentage by 4.8%. The remaining unattended sites were more condensed towards the central part of Foad Street, as well as another critical axis of the downtown known as 'Safeya Zaghloul' Street. From a comprehensive development point of view, adding tram or bus routes within this area could contribute to negative environmental impacts and subsequently risk damage to the heritage assets themselves. Therefore, more sustainable, and eco-friendly modes were suggested to overcome this challenge, where dedicated lanes and parking zones for electric scooters or bikes could be added along those two major axes. In this regard, these modes provide an extension of the existing transport network but with a better exploration experience of the downtown.

Secondly, no possible physical alterations could be proposed for the Kafr-Abdo neighbourhood, where the fabric is planned such that it is detached from its surroundings. Therefore, relying on green alternative modes was also proposed along the neighbourhood's main road.

Thirdly, an existing dysfunctional tram line is detected surrounding the Catacombs region. Thus, a new tram stop was recommended along this route, which shall direct visitors along the main road connecting Pompey's pillar with the Catacombs, serving a seamless heritage experience.
On the other hand, for the mega-scale analysis, extending the city's road infrastructure towards the west to serve the Al-Ameriyah and Borg Al-Arab districts is indispensable.

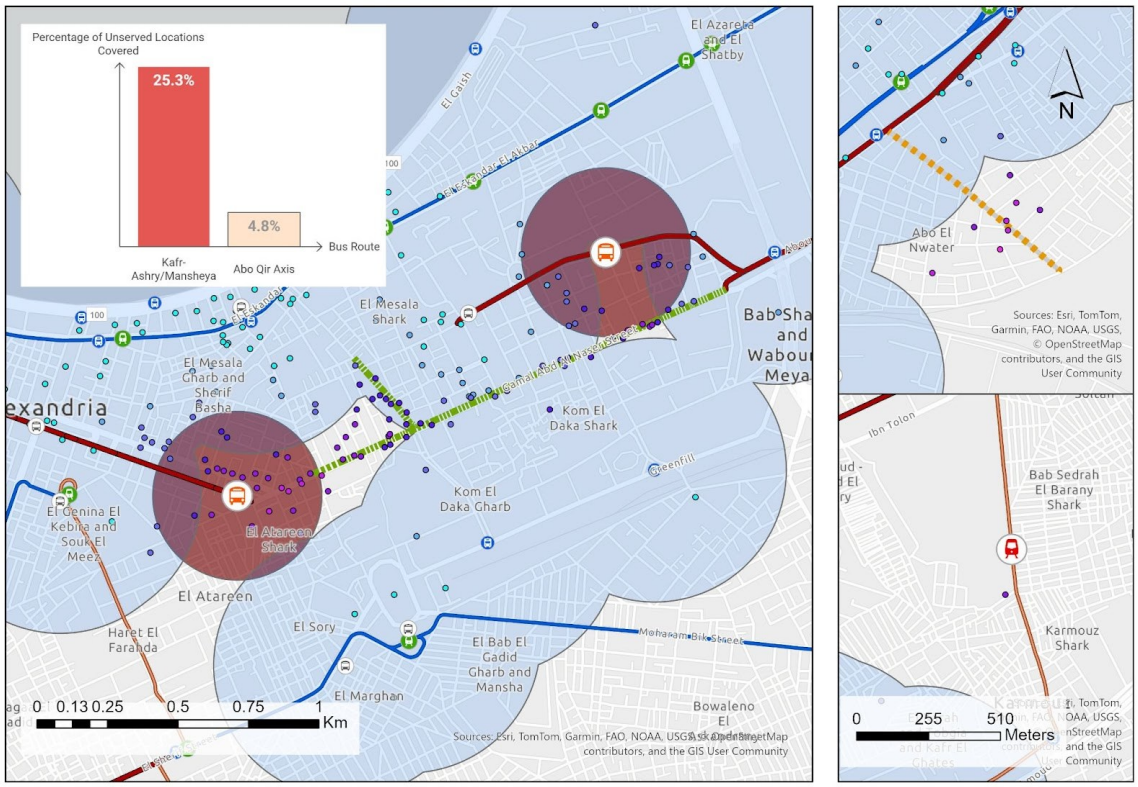

Figure 11. Map of Proximity gaps interventions based on each cluster context, Top: Foad street cluster, Bottom left: Catacombs region cluster, and Bottom Right: Kafr-Abdo neighbourhood cluster (Developed by Authors using ArcGIS Pro).

4.3 Recommended Cultural Routes and Required Interventions

4.3.1. Cluster-based Tours (Figure 12)

For the downtown area, a comparative analysis between the original tours suggested by CLUSTER and the three optimised routes resulting from network analysis includes overall path duration, average walkability index, and number of stops. The results exhibited in Table 4 reveal the superiority of the new proposed routes regarding the overall walkability indices. However, the number of stops was moderately higher for CLUSTER routes, which stems from the fact that the heritage value assessment phase filters and excludes non-unique stops. In this regard, the final three suggested routes were explored for required interventions to maximise their walkability, including improving sidewalk quality, street lighting maintenance, boosting surveillance, or adding pedestrian crossings.

Table 4: Alexandrian Downtown Cultural Routes Comparative Analysis.

Heritage Tour	Overall route Duration	Average Walkability Index	Number of Stops
CLUSTER Foad Street Tour		0.5640223656	71
Optimised Foad Street Tour	67.3 Minutes	0.5630143751	58
CLUSTER Mansheya Tour		0.5866388309	57
Optimised Mansheya Tour	71 Minutes	0.5912682825	35
CLUSTER Downtown Tour		0.4750916397	65
Optimised Downtown Tour	51.8 Minutes	0.5382871795	58

As for the newly identified cluster within the previously discovered cold spot, a new set of tours was proposed to explore this area, which includes the Gleem Tour, Roushdy Tour, and Stanley Tour. Since these tours were part of the action to promote tourism outside the downtown, they can collectively be a 3–4-hour day trip or segmented into three 1-hour trails as shown in Table 5, separated by breaks for food and rest. Additionally, the number of stops in each tour was chosen to be similar, with an average of twelve stops, some of which can be entered.

Table 5. Alexandria's newly identified Cultural Routes outside the downtown in a cold cluster.

Heritage Tour	Overall route Duration	Number of Stops
Gleem Tour	60 minutes, not including time spent inside museums, i.e., Royal Jewelry Museum & Mahmoud Saeed Museum	11
Roushdy Tour	60 minutes	13
Stanley tour	60 minutes	12

Other tours were also identified to either connect previously mentioned tours via walking or to explore important heritage outside clusters (outliers) such as Bibliotheca Alexandrina or the western District of ‘Bahari’, with a total of 12 assets that were worthy to be included, distributed equally between 3 tours as shown in Table 6.

Table 6. Alexandria's newly identified Cultural Routes outside the downtown clusters.

Heritage Tour	Overall route Duration	Number of Stops
From Downtown to Abo-il-Abbas Context Tour	17 minutes	4
Far West Walking Tour	19 minutes	4
Bibliotheca Alexandrina Tour	21 minutes	4

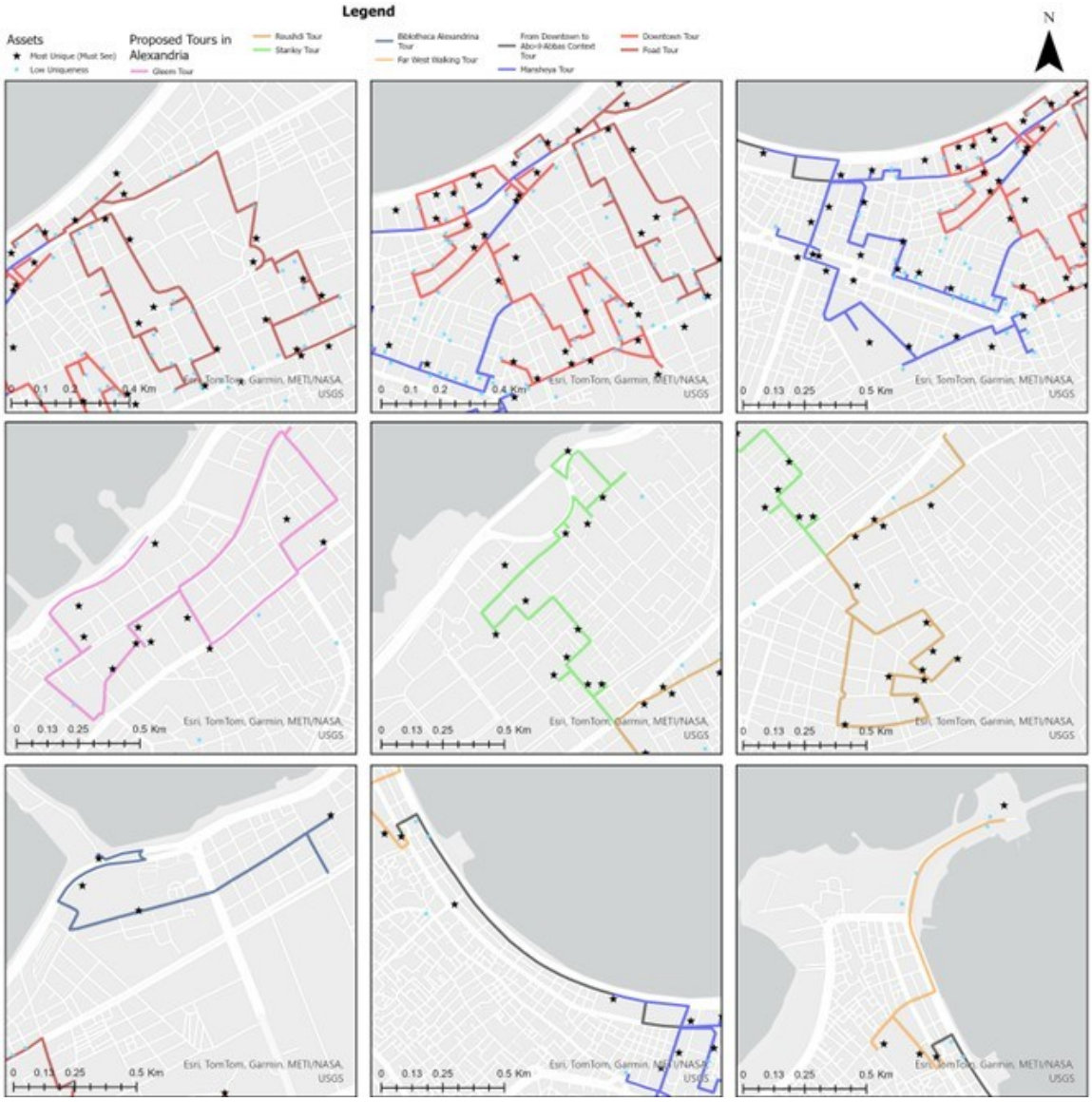

Figure 12. Map of Cluster-based tours (Developed by Authors using ArcGIS Pro).

4.3.2. City-based Tours

There is a need in Alexandria city for different mobility choices between proposed tours and clusters, not only by walking but also by using different modes of existing transportation. For example, the gardens of Montazah in the Far East can be accessed either by driving or by bus. Tours in the cold cluster can be approached by several tram stations. Additionally, Alexandria is known for Pompey's pillar and the Catacombs; however, they are situated in the 'Karmouz' district with poor access by bus or tram, but a 44-minute drive from the city centre. Table 7 and Figure 13 show these mobility options on the city scale.

Table 7. Alexandrian proposed mobility routes for touring between clusters on the city scale.

Heritage Tour	**Overall route Duration**
From East to West tram Route	65 minutes
From East to West bus Route	17 minutes
Downtown Context walking Route	94 minutes
Eastern Alexandria's main heritage assets driving route	80 minutes
Ancient Monuments driving route from nearest stops in tours, i.e., Pompey's Pillar	44 minutes

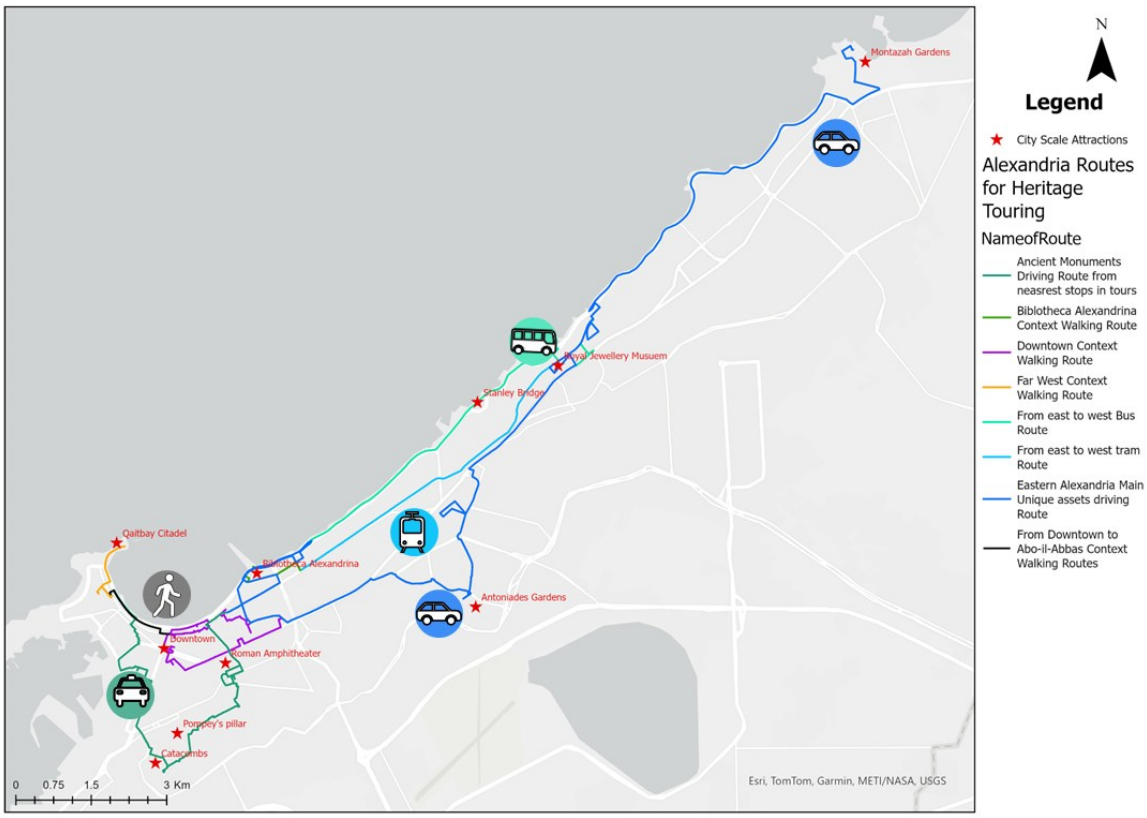

Figure 13. Map of City-based Tours and relevant mobility options (Developed by Authors using ArcGIS Pro).

4.4 Interactive Web Application

The findings support the development of an interactive web-based map application, enabling users to explore the best cultural routes. In this regard, dashboards enable interactive presentations that help communicate information between urban planners and users in the interest of improving urban quality of life. It is a tool to quantify the needs of users by easily accessing and interacting with interpretable data about their cities. Roles of dashboards in enhancing urban management include creating transparency and encouraging users to engage in decision-making processes. Technologies used in dashboards include free or commercial Web-GIS tools such as ESRI ArcGIS, which was used in this research. Dashboards can be used to display maps and charts according to several narratives. Its functionality also allows data analysis, data selection, comparison, and aggregation (Pluto-Kossakowska et al., 2022).

Since many cities still lack interactive tools that allow users to allow both users and experts to explore data (Pluto-Kossakowska et al., 2022). It was then encouraged to attempt to propose a dashboard for the findings of this research in Alexandria. The purpose of this dashboard was to become a prototype that can be later proposed to local authorities for promoting tourism in the city. The dashboard maps points and polylines of heritage assets and cultural routes that were optimised or newly introduced in the analysis in a user-friendly interface, shown in Figure 14.

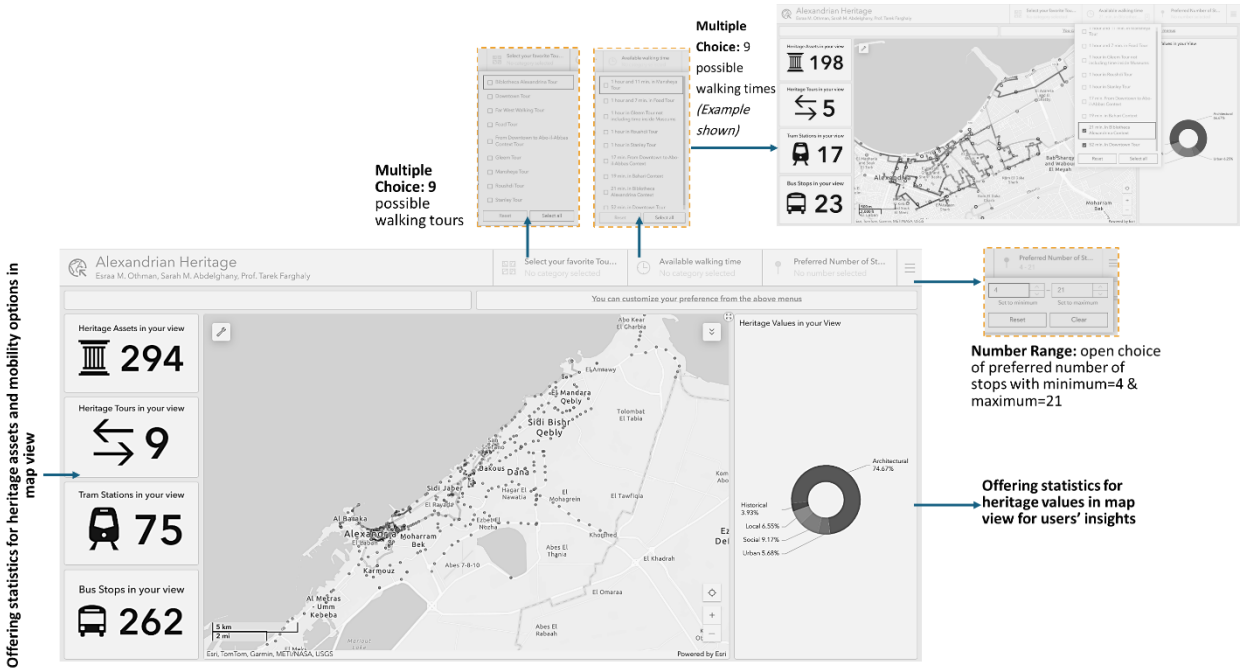

Figure 14. ESRI Online Dashboard (Developed by Authors using ArcGIS Online Applications).

These geometries can be filtered by three groups of decisions by the application user, including:

i. Preferred route based on pre-knowledge of the available route (establishing that brochures or flyers were to be distributed across heritage destinations);
ii. Available walking time;
iii. preferred number of stops to visit.

5. Discussion

5.1 Interpretation of Key Findings

Most heritage assets in Alexandria are heritage buildings that reflect the city's rich architecture and tangible history, which continue to be integral to its heritage today. Based on the spatial patterns in Alexandria, a critical need for balanced heritage promotion arises. In this regard, enhancement and maintenance of heritage clusters located outside of downtown is essential to conserve heritage as well as distribute visitor rates.

On the other hand, the accessibility analysis, as well as cultural route design phases, confirm the need for alignment between urban and heritage management endeavours. Conclusively, strategies for public realm enhancement directly affect the cultural routing experience regarding aspects of infrastructure, street design, as well as urban plazas and nodes. Additionally, implementation and enforcement of urban policy gaps can be seen in outlawed practices, such as the encroachment of sidewalks by street vendors and shops, which need to be addressed.

Moreover, accessibility to heritage sites is impacted by public transit network design. In this regard, the number and location of public transit stops should be analysed in relation to heritage clusters, as well as the potential to integrate green transit modes by adding designated lanes and stops.

5.2 Strengths and Limitations

A key strength of the research was initiating discussion on the diachronic analysis of heritage to inform decision-making by quantifying and visualising heritage value. Tourism brings economic revitalisation and increased visibility to heritage sites, triggering the urban economy (Altaba Tena, Ginés Sánchez, Querol Vicente, & García-Esparza, 2025; Lin et al., 2024). The paper also bridges spatial analysis with socio-economic research, given that:

i. Cultural routes attract both domestic and international tourists.
ii. Highlighting cultural assets along cultural routes boosts revenue for small businesses.
iii. Heritage-led developments often lead to increased land values around cultural zones, which stimulates public-private partnerships and investments in public services.

iv. Cultural tourism creates employment opportunities across service sectors.
v. Economic gains from tourism can provide local governments with funds for maintenance and restoration. Economic returns from tourism can be reinvested in maintenance.

On the other hand, challenges in collecting data for the research involve difficulty in acquiring accurate visitor rate statistics for heritage sites. Additionally, dependence on open-source data for traffic and congestion rates requires time-consuming ground truthing. Given that the focus of the study was directed towards testing GIS capabilities, collaborations with local authorities to collect data were not attempted. However, such collaborations are crucial in the long run.

6. Conclusion

This research examines the role of GIS in enhancing the cultural heritage in Alexandria, Egypt. The findings support the hypothesis that cultural heritage assessment, incorporating spatial attributes, is essential for promoting tourism. They also highlight the relevance of heritage value assessment in relation to cluster locations. This research contributes to existing knowledge across Urban Design, Socio-economic studies, Culture, Tourism, Mobility, Spatial and Statistical Analysis, Sustainability, and Architecture. Unlike prior studies that focus on the qualitative values of heritage, this research aspires to combine both qualitative and quantitative approaches in a comprehensive methodology. In this regard, quantitative analysis was assured to be as important as spatial analysis. Also, utilising mathematical equations and correlations programmed within GIS emphasises the scientific contribution to investigating cultural heritage in the 21st century.

While the case of Alexandria provides valuable insights into heritage value assessment and how to associate values with spatial distribution, the findings are also relevant to cities with rich heritage facing similar challenges. The conceptualisation of the methodology is flexible to adapt to contexts beyond Alexandria.

In conclusion, GIS technologies have proven efficient as they enable:

1. Sustainable and unified heritage documentation workflow,
2. Engaging and illustrative heritage map visualisation,
3. Comprehensive heritage management approaches through improving connectivity and spatial integration with transportation networks, qualitatively and quantitatively.

This integration exhibits the potential to include users in interactive experiences that eventually support sustainable tourism development through:

1. Providing an open-access database for Alexandrian tangible and intangible heritage.
2. Including public participation for feedback loops in the future.
3. Developing mobile applications for cultural touring and marketing.
4. Launching websites with interactive dashboards in cities for stakeholders' incorporation in decision-making.

Future work can expand on the research methodology and findings by approaching local governance to test the proposed cultural routes and employ tour guides to accompany users. Moreover, field validation of walkability scores could be of high value to refine walkability evaluation across a diverse sample representing several age, gender, and socio-economic groups, as well as national and international tourists. Furthermore, partnerships and collaborations with business sectors on the walking routes would allow the growth of the database to include commercial activities supporting tourism. Additionally, ongoing advancements in GIS technologies such as virtual reality simulations, 3D visualisations, and real-time monitoring of visitor rates and traffic can be introduced to urban interventions.

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The author(s) declare(s) no conflicts of interest.

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