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A GIS-Based Genetic Algorithm-Travelling Salesman Problem Integration for Heritage Tourism Route Optimization

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Abstract

Heritage tourism route planning frequently encounters spatial and accessibility challenges, particularly in older urban areas where cultural heritage sites are concentrated within a small, narrow, and irregular layouts. Although the Travelling Salesman Problem (TSP) model is widely used for route optimization, it has limitation in addressing real-world tourism constrain related to the user diversity, dynamic environment, physical access, and route efficiency in complex heritage environments. This paper proposes a methodological framework that integrates the Genetic Algorithm (GA) and TSP within a Geographical Information System (GIS) based environment to improve route optimization for the heritage tourism. The model uses simulated data from thirteen heritage attractions in Ipoh, Perak, Malaysia to compare the performance of GA-TSP and traditional TSP approaches. GIS-based network analysis, Origin-Destination cost matrix generation, and heuristic optimization techniques were applied to evaluate route efficiency and sequencing. The findings shows that GA-TSP generates a more effective routes with shorter distance travel and a smoother flow that reducing any unnecessary and excessive backtracking which is very useful for mobility disabilities visitors and tourists. The proposed framework demonstrates the potential of integrating GIS and evolutionary optimization techniques to support more efficient and scalable heritage tourism route planning and provides a foundation for future implementation using real-world tourism and accessibility data.

1. Introduction

Heritage tourism promotes global tourism industry because it supports cultural preservation, local economic development, and urban revitalisation. Heritage attractions give visitors to experience historical, cultural, and architectural structure while strengthening community identity (Bitušíková, 2021; Zakaria & Hua, 2024). Due to their cultural landscapes, colonial architecture, museums, and historical sites, Malaysia's heritage locations like George Town, Melaka, and Ipoh, draw tourists from both domestic and international (Ismail et al., 2014). However, many heritage locations were built before modern accessibility standards were introduced creating challenges for visitor movement and inclusive tourism planning (Nasir et al., 2022; Nocca, 2017).

Accessibility remains one of the issues in heritage tourism. Heritage districts are usually identified as narrow streets, uneven pathways, preserved historical structures, and spatial limitations that restrict mobility movement. Elderly, mobility impairments, and families with children are affected by these issues (Hooi & Yaacob, 2019). Despite Malaysia's adoption of the United Nations Convention on the Rights of Persons with Disabilities and the Persons with Disabilities Act 2008, many heritage environments still have accessibility issues due to outdated infrastructure, preservation restrictions, and poor spatial planning (Economic Planning Unit, 2021; Zahari et al., 2020).

In heritage tourism environments, accessibility problems are also linked to inefficient route planning. Visitors may experience unnecessary walking distance, repeated movement, disorientation, and fatigue when routes between multiple attractions are not logically organised (Sanmargaraja, 2015). These issues are more significant in compact urban heritage districts where attractions are located close to one another but connected through complex street networks. Therefore, route planning should consider not only the ability to visit all attractions, but also route continuity, pedestrian comfort, and spatial practicality (Dumitraşcu et al., 2023; Yfantidou et al., 2020). Geographic Information Systems (GIS) provide an effective platform for analysing spatial relationships in tourism planning (Jankowski, 1995). GIS enables the integration of geographical and attribute data for tourism planners to visualise, analyse, and evaluate route in real spatial environments (Ali, 2020; Longley et al., 2015). In heritage tourism, GIS has been applied for site inventory, accessibility assessment, cultural resource mapping, and spatial decision-making (Liu et al., 2023; Xiao et al., 2018).

Several GIS-based approaches have been used to support accessibility assessment and route optimization. Network Analysis determines optimal travel paths based on road or walkway connectivity, while Cost-Distance Analysis models travel difficulty across terrain conditions (Prameshwori et al., 2021). Spatial Overlay Analysis combines multiple criteria for suitability or barrier detection, and shortest path or network centrality methods support navigation and visitor movement assessment. Specifically, Network Analysis is commonly applied to identify the best path using roads or walkways and is particularly suitable for structured urban heritage sites. Cost-Distance Analysis is used to model terrain-related travel difficulty, making it appropriate for rural or uneven heritage areas. Spatial Overlay Analysis combines multiple spatial criteria for accessibility evaluation and is widely applied for suitability mapping and barrier detection. The Travelling Salesman Problem (TSP) optimises tour routes involving multiple destinations and is commonly used for tourist route and loop planning. Shortest Path Algorithms identify the fastest or shortest route between two locations and support navigation and emergency planning, whereas Network Centrality highlights important nodes for accessibility flow and assists in analysing visitor movement and bottleneck detection.

Among these approaches, the Travelling Salesman Problem (TSP) is widely used to determine efficient travel sequences between multiple destinations. TSP aims to identify the shortest route that visits each of the destination once before returning to the starting point (Sathya & Muthukumaravel, 2015). In tourism applications, it is commonly used to reduce travel distance between attractions (Choi et al., 2022). However, conventional TSP models mainly focus on distance minimisation and may not adequately represent heritage tourism environments, where accessibility constraints, clustered attractions, and pedestrian movement patterns influence route practicality. Traditional TSP approaches also become computationally challenging as the number of destinations increases because the problem is NP-complete (Pop et al., 2024).. For this reason, heuristic and metaheuristic optimization techniques are often used to generate efficient solutions within acceptable computational time (Youssef et al., 2001). GA are particularly suitable for complex route optimization because they use selection, crossover, and mutation to explore large solution spaces and improve candidate route sequences over repeated generations (Awad & Chiban, 2015; Azevedo et al., 2024; Goldberg, 1989).

Previous studies demonstrate that GIS, TSP-based route sequencing, and evolutionary optimization provide similar contributions to tourism route planning. GIS studies have mainly been used to represent transport networks, evaluate accessibility, assign travel impedance, and visualise route alternatives. Huang et al. (2006) provided an early example of integrating GIS with a bi-level GA to solve a multi-objective sightseeing itinerary problem. Similarly, Gill & Bobba (2013) applied GIS network analysis to identify shortest and quickest tourist route in New Delhi. Subsequent studies have extended this approach through multi-objective GIS for urban tourism routing, GIS accessibility, vehicle-routing analysis, and heritage-trail design using GIS and TSP. For example, Du & Hu (2018) applied a GIS-based evolutionary optimization approach for forest wetland tourism route planning, while Xiao et al. (2018) highlighted the role of GIS in cultural heritage conservation and tourism promotion. Damos et al. (2021) further integrated multi-objective GA, AHP, and GIS to support urban tourism path planning.

In parallel, TSP-related and evolutionary optimization approaches have also improved destination sequencing and route selection under multiple constraints. Choi et al. (2022) developed a GA-based model for multi-day itinerary planning in Macau by incorporating opening hours and stay-duration limitations. Cao (2022) proposed an improved GA for round-trip tourism planning, while Li et al. (2022) introduced an improved knowledge ant-colony algorithm for tourism route optimization. More recently, Benchekroun et al. (2024) combined GIS, A*, and GA to optimise tourist routes in Fez. These studies show that TSP-style models are useful for sequencing destinations while GA and related heuristic methods are effective for exploring broader solution spaces and generating efficient route alternatives.

Overall, previous studies confirm the effectiveness of GIS-based network analysis and evolutionary optimization techniques for tourism route planning. Nevertheless, the literature remains limited in integrating GIS network analysis, OD cost matrix generation, and GA-enhanced TSP within a heritage tourism context. Existing studies commonly focus on sightseeing, urban tourism, or natural tourism applications, whereas relatively few studies address route optimization in compact urban heritage environments where walkability, route continuity, and spatial practicality are critical considerations. Therefore, this study proposes a GIS-based GA-TSP framework that integrates network analysis, OD cost matrix generation, and evolutionary optimization to support more efficient and practical heritage tourism route planning. Although ArcGIS-based accessibility and route design approaches have been reported (Pei et al., 2022) the integration of OD cost matrix generation with GA-enhanced TSP for heritage tourism route optimization remains limited. To addresses this gap, this study proposes a GIS-based GA-TSP framework for heritage tourism route optimization. The framework integrates GIS network analysis, OD cost-matrix generation, and evolutionary optimization to produce route sequences that are both efficient and spatially practical.

Ipoh, Perak was selected as the case study because its heritage attractions are concentrated within a compact urban setting characterised by colonial buildings, historic streetscapes, cultural landmarks, and pedestrian-oriented tourism activities. This spatial setting makes Ipoh an appropriate case for evaluating route optimization approaches that consider route efficiency, walkability, and continuity within a heritage-tourism environment.

The scientific contribution of this study is it provides an integrated methodological framework that combines GIS network analysis and evolutionary optimization within a single heritage-tourism workflow. Second, it extends the application of GA-TSP into a heritage tourism context where accessibility-oriented route planning, compact urban setting, and route continuity are important planning considerations. Third, it contributes to accessibility-oriented tourism planning by demonstrating how spatial optimization can support more efficient and practical visitor movement. Specifically, this study aims to develop a GIS-based GA-TSP framework, compare TSP-only and GA-TSP routes using simulated heritage-tourism data, and evaluate whether the integrated framework improves route efficiency and spatial practicality.

2. Methodology

The study uses a simulated heritage attraction dataset and GIS-based network analysis to compare two routing approaches of a manually configured TSP-only model and an automated GA-TSP model. The methodological framework used in this study integrates GIS, TSP, and GA to develop an optimized heritage tourism route, as shown in Figure 1. This comparison evaluates whether GA can improve route sequence and

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reduce total travel distance compared with the TSP-only approach. GIS provides the spatial platform for network-based analysis, while TSP and GA support multi-destination route optimization (Ali, 2020; Longley et al., 2015; Sathya & Muthukumaravel, 2015; Yousuf et al., 2025).

The methodology consisted of four stages: data acquisition, data processing, data analysis, and data visualisation. Data acquisition involved preparing simulated heritage attraction points and road network data. Data processing included coordinate preparation, network cleaning, topology checking, and integration of attraction points with the road network in ArcGIS Pro. The analysis stage involved generating a TSP-only route using ArcGIS Network Analyst and developing a GA-TSP route using OD Cost Matrix output processed in Python. The final stage mapped and compared both outputs based on total travel distance, route sequence, and spatial movement logic.

The optimization process was mainly based on network travel distance. Although the study is positioned within accessibility-oriented heritage tourism planning, detailed accessibility attributes such as slope, pavement condition, walkway width, resting points, and temporary barriers were not included. Therefore, the methodology should be understood as an initial framework for testing GIS-based GA-TSP route optimization using simulated data before application with real-world tourism and accessibility datasets.

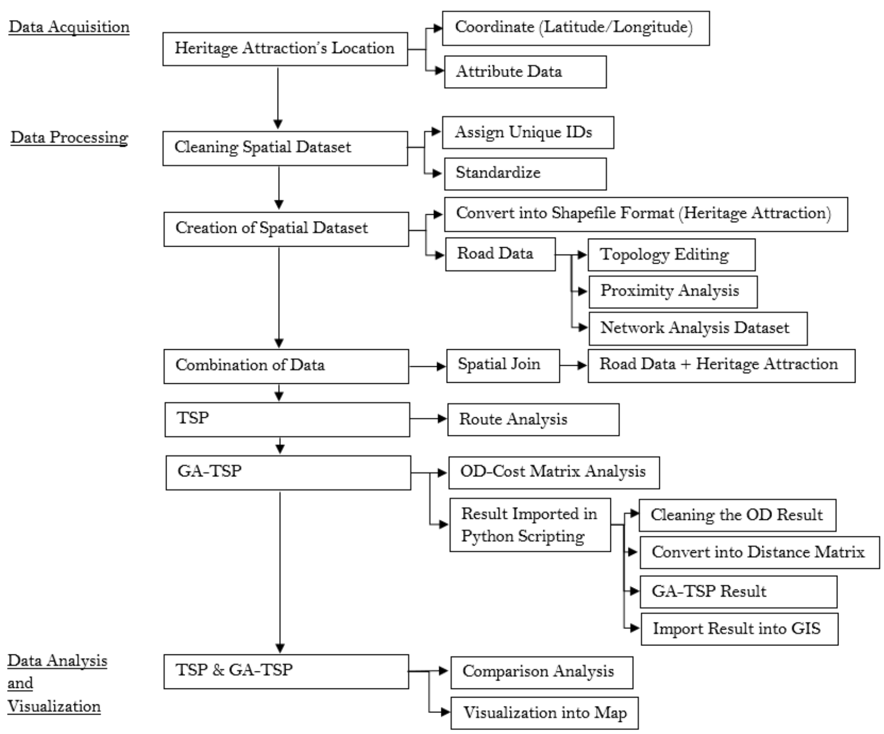

Figure 1. Methodological Framework for GIS-based GA-TSP Heritage Tourism Route Optimization

2.1. Simulated Dataset Design

This study was conducted in Ipoh Old Town, Perak, Malaysia. Ipoh, Perak one of a compact urban heritage area known for its colonial buildings, cultural street area, museums, murals, and heritage themed attractions. The selected study area contains a high volume of heritage attractions located within a walkable urban environment which making it very suitable for evaluating heritage tourism route optimization. Thirteen heritage attractions were used as simulated destination points in the routing analysis including Concubine Lane, Time Tunnel Ipoh, Ho Yan Hor Museum, Platform Coffee, Street Art - Tiger & Tree, Pekan Ipoh, Chloe.co, Cipta Karya, Ipoh Mural - Old Town Relieves Nostalgia with Trishaw, Mural Spot - 2nd Concubine Lane, 22 House Cafe, Lim Ko Pi, and Funtasy House Trick Art. Figure 2 shows the location of the study area in Ipoh, Perak, Malaysia.

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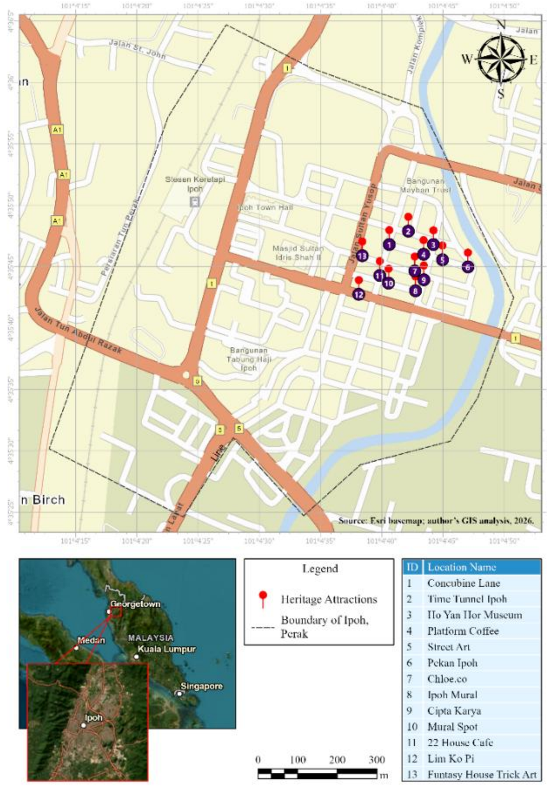

Figure 2. Ipoh Old Town, Perak, Malaysia

Table 1. Simulated Data of Heritage Attractions in Ipoh, Perak

Location ID	Location Name	Latitude	Longitude
1	Concubine Lane	4.596325611	101.0779449
2	Time Tunnel Ipoh	4.596704686	101.0783974
3	Ho Yan Hor Museum	4.596304553	101.0790502
4	Platform Coffee	4.596075988	101.0787145
5	Street Art - Tiger & Tree	4.595943531	101.0791413
6	Pekan Ipoh	4.595831931	101.0797305
7	Chloe.co	4.595835996	101.0785533
8	Cipta Karya	4.595552868	101.0786674
9	Ipoh Mural - Old Town Relieves Nostalgia with Trishaw	4.595292706	101.0785409
10	Mural Spot - 2nd Concubine Lane	4.595454992	101.0779307
11	22 House Cafe	4.595609876	101.0778173
12	Lim Ko Pi	4.595096591	101.0772239
13	Funtasy House Trick Art	4.595974488	101.0773048

The data used in this study consisted of simulated heritage attraction points, coordinate data, road network data, and network-based distance outputs. The coordinates of the heritage attractions were obtained from Google Maps and cross-checked using Google Earth Pro before being organised in Microsoft Excel and imported into ArcGIS Pro. The road network dataset was obtained from OpenStreetMap and processed in ArcGIS Pro to support network-based route analysis. The network was cleaned and checked for connectivity before being used in the TSP-only route analysis and OD Cost Matrix generation for the GA-TSP optimization process.

Simulated data allows the model to be evaluated using complete and consistent attributes before being applied to real-world scenarios. The simulated dataset of heritage attractions used in this study is presented in Table 1. This approach also helps verify the technical capability of the proposed GIS-based GA-TSP workflow without the influence of missing or incomplete field data. Spatial and non-spatial attributes including location names and geographical coordinates were prepared and converted into a GIS compatible format. By representing an urban heritage environment, the dataset enabled comparison between manual route sequencing and automated GA-based optimization. Thirteen heritage attractions in Ipoh were selected, including museums, street art murals, heritage-themed cafes, and other cultural points of interest. Each attraction was assigned a unique identifier, location name, latitude, and longitude. Coordinates were obtained from Google Maps and cross-checked using Google Earth Pro before being organised in Microsoft Excel and imported into ArcGIS Pro for spatial analysis.

2.2. GIS-Based Network Dataset Creation

A GIS-based network dataset was created as the spatial foundation for route optimization. The network represents road or walkway connectivity and enables travel distance to be calculated based on actual network movement rather than straight-line distance (Vallone et al., 2013). Network-based analysis is appropriate for tourism and accessibility studies because it reflects spatial connectivity, pedestrian infrastructure, and movement constraints within the study area (Feizizadeh et al., 2023; Zahari et al., 2023). Therefore, the network dataset was used as the main spatial input for both the TSP-only route analysis and the OD Cost Matrix applied in the GA-TSP process. The heritage attraction coordinates were imported into ArcGIS Pro using the Display XY Data function and exported into a geodatabase. Road network data obtained from an OpenSourceMap were then processed with relevant attributes, including segment length, direction, pedestrian walkways, and one-way streets where available. Before route analysis was conducted, the road network was cleaned and checked for topological accuracy. This process included correcting disconnected segments, identifying gaps and dangling nodes, and ensuring that crossing lines were properly connected. A connected network is important because topology errors can affect distance calculation and route output.

The attraction points were connected to the road network using proximity analysis through the Near tool. A spatial join was then used to integrate location IDs, coordinates, and network-related attributes. The resulting dataset served as the input layer for both the TSP-only route analysis and the OD Cost Matrix used in the GA-TSP process. By using network-based distance, the analysis better represents actual movement through the road and walkway network compared with straight-line distance (Mondal & Srivastava, 2023).

2.3. TSP Model Implementation

The TSP model was implemented using the Route Analysis tool in ArcGIS Network Analyst (Prameshwori et al., 2021). The TSP is widely used in route optimization because it identifies an efficient sequence for visiting multiple destinations while minimising total travel distance (Ishaya et al., 2019; Kowalik et al., 2023). In this study, the TSP model was used to simulate a heritage tourist's journey across thirteen heritage attractions in Ipoh. The objective was to generate a closed-loop route that visits each attraction once before returning to the starting location. To maintain the closed-loop structure, the starting location was duplicated manually in the attribute table so that it also functioned as the final destination (Antosiewicz et al., 2013; Yousuf et al., 2025). This allowed the route solver to interpret the movement as a round-trip journey rather than a one-way path.

The spatial input for the TSP route analysis consisted of the road network dataset and the simulated heritage attraction points prepared in the previous stage. The heritage attractions were added as stops, while distance in meters was used as the travel impedance to represent pedestrian-based travel. The resulting TSP-only route produced a complete sequence of stops, total travel distance, and route geometry, which were saved in the attribute table and visualised in ArcGIS Pro. In this study, the TSP-only model was used as a baseline comparison model. Although it follows the basic TSP concept of visiting each attraction once before returning to the starting point, the route was manually configured based on the predefined input sequence (Antosiewicz et al., 2013). Therefore, the TSP-only output represents a static or user-defined routing approach rather than a fully automated optimization process. This baseline was used to evaluate whether the GA-TSP model could improve route efficiency and reduce unnecessary backtracking.

2.4. *Integration of Genetic Algorithm*

GA was integrated with the TSP framework to automatically improve the visiting sequence of heritage attractions. GA is an evolutionary optimization method that improves route solutions through selection, crossover, and mutation (Goldberg, 1989; Holland, 1975; Sumida et al., 1990). The GA-TSP model used the same thirteen attractions and network dataset as the TSP-only model to ensure that differences in output were caused by the optimization approach rather than input data. The process began with the creation of an OD Cost Matrix in ArcGIS Network Analyst. All thirteen attractions were used as origins and destinations to produce a 13 × 13 network distance matrix. The matrix was exported to Python IDLE, cleaned, and converted into a symmetrical distance matrix suitable for GA-TSP computation.

The GA parameter values were selected based on recommendations from previous GA optimization studies and preliminary testing conducted during model development, as GA performance is strongly influenced by parameter configuration (Isa et al., 2024; Sharma et al., 2020). The population size was set to 100 to maintain sufficient route diversity while ensuring computational efficiency. The number of generations was set to 1000 to allow the algorithm to evolve through repeated iterations and improve solution stability. A mutation rate of 0.15 was applied to introduce route variation and reduce the risk of premature convergence, while a crossover rate of 0.7 was used to encourage recombination between parent route solutions. Tournament selection with a tournament size of 4 was applied, where four chromosomes were randomly selected and the chromosome with the shortest route distance was chosen as the parent solution. These parameter settings provided a balanced configuration for exploring alternative route sequences and identifying an efficient GA-TSP solution for the simulated heritage tourism dataset.

The GA-TSP process produced an optimized sequence of all thirteen attractions. The sequence was exported to Microsoft Excel, joined with the attraction coordinates using location identifiers, and imported back into ArcGIS Pro for visualisation. Both TSP-only and GA-TSP routes were compared using the same GIS environment and network dataset. The comparison focused on total travel distance, route sequence, and spatial movement logic. Since the study uses simulated data and distance-based optimization, the findings should be viewed as an initial validation of the framework rather than a complete representation of actual tourist movement.

3. Results and Discussion

3.1. *Route Derived using TSP*

The TSP route was generated using the Route Analysis tool in ArcGIS Network Analyst based on the manually configured sequence of thirteen heritage attractions. The route started and ended at Concubine Lane to represent the closed-loop structure required in the TSP framework. As shown in Figure 3 and Table 2, each heritage attraction was visited once before the route returned to the starting point, following the initial attraction sequence beginning from Concubine Lane, followed by Time Tunnel Ipoh, Ho Yan Hor Museum, Platform Coffee, and the remaining attractions listed in the dataset.

A closer examination of the TSP-only route reveals an important spatial inefficiency, as the route sequence between Chloe.co, Ipoh Mural – Old Town Relieves Nostalgia with Trishaw, and Cipta Karya is not fully practical because it creates unnecessary repeated movement. Based on the spatial arrangement shown in Figure 3, the route moves from Chloe.co towards Ipoh Mural – Old Town Relieves Nostalgia with Trishaw before reaching Cipta Karya, then backtracks towards the mural area again before continuing to Mural Spot – 2nd Concubine Lane. This repeated movement occurs even though the three attractions are located close to one another and could be visited more efficiently using a better route sequence.

This result indicates that a manually configured TSP route may fulfil the basic requirement of visiting all attractions and returning to the starting point, but it might be inefficient in producing a spatially logical pedestrian route when attractions are located within a compact heritage district. Manual sequencing may overlook important spatial relationships between nearby destinations and can result in unnecessary walking distance, repeated movement, and reduced route practicality (Kowalik et al., 2023). Similar limitations have been reported in previous route optimization studies, where fixed or manually defined, routes were found to generate unnecessary travel movement and route redundancy (Yan et al., 2021).

Figure 3. Optimized Heritage Attractions in Ipoh, Perak Using TSP-only

Table 2. Sequence of Optimized Heritage Attractions in Ipoh, Perak Using TSP-only

Sequence ID	Location	Location Name	Latitude	Longitude
1	1	Concubine Lane	4.596325611	101.0779449
2	2	Time Tunnel Ipoh	4.596704686	101.0783974
3	3	Ho Yan Hor Museum	4.596304553	101.0790502
4	4	Platform Coffee	4.596075988	101.0787145
5	5	Street Art - Tiger & Tree	4.595943531	101.0791413
6	6	Pekan Ipoh	4.595831931	101.0797305
7	7	Chloe.co	4.595835996	101.0785533
8	9	Ipoh Mural - Old Town Relieves Nostalgia with Trishaw	4.595292706	101.0785409
9	8	Cipta Karya	4.595552868	101.0786674
10	10	Mural Spot - 2nd Concubine Lane	4.595454992	101.0779307
11	11	22 House Cafe	4.595609876	101.0778173
12	12	Lim Ko Pi	4.595096591	101.0772239
13	13	Funtasy House Trick Art	4.595974488	101.0773048
Return	1	Concubine Lane	4.596325611	101.0779449

Therefore, the TSP-only route is useful as a baseline model, but its result demonstrates the need for a more adaptive optimization approach. In the context of heritage tourism, route efficiency should not only be measured by the ability to visit all attractions, but also by the logical flow of pedestrian movement between closely located destinations.

3.2. Optimized Route Derived Using GA-TSP

The GA-TSP route was generated using the network-based distance matrix obtained from the ArcGIS OD Cost Matrix analysis. The same thirteen heritage attractions and road network dataset were used to ensure consistency with the TSP-only route. The distance matrix was processed in Python, and the resulting GA-TSP sequence was imported back into ArcGIS Pro for route visualisation using the Route Analysis tool. The optimized route is shown in Figure 4, while the visiting sequence is listed in Table 3. Unlike the manually configured TSP-only route, the GA-TSP model automatically optimized the visiting sequence by evaluating alternative route combinations. This reduced dependence on the original input order and minimised the possibility of human bias in route sequencing (Ochelska-Mierzejewska et al., 2021). The GA-TSP approach was able to identify a more spatially logical route flow by reducing unnecessary backtracking and improving the continuity of movement between nearby attractions (Choi et al., 2022).

Figure 4. Optimized Heritage Attractions in Ipoh, Perak using GA-TSP

One notable difference is that the GA-TSP route started and ended at Platform Coffee rather than Concubine Lane. This occurred because the GA process did not depend on the first location listed in the input dataset. Instead, the algorithm evaluated the full route loop and selected a sequence that produced a shorter total travel distance. In this case, Platform Coffee functioned as the most efficient starting and ending point within the optimized loop. This demonstrates the adaptive nature of GA in route sequencing, particularly when compared with a manually configured TSP route. The GA-TSP route also improved the movement flow between closely located attractions (Mahmoudinazlou & Kwon, 2024).

In the TSP-only result, repeated movement occurred around Chloe.co, Ipoh Mural - Old Town Relieves Nostalgia with Trishaw, and Cipta Karya. In contrast, the GA-TSP route arranged these attractions in a more continuous sequence, reducing unnecessary back-and-forth movement. This improvement is important in compact heritage tourism areas because route continuity can influence walking comfort, navigation clarity, and visitor experience.

Table 3. Sequence of Optimized Heritage Attractions in Ipoh, Perak using GA-TSP

Sequence ID	Location	Location Name	Latitude	Longitude
1	4	Platform Coffee	4.596075988	101.0787145
2	6	Pekan Ipoh	4.595831931	101.0797305
3	5	Street Art - Tiger & Tree	4.595943531	101.0791413
4	7	Chloe.co	4.595835996	101.0785533
5	8	Cipta Karya	4.595552868	101.0786674
6	9	Ipoh Mural - Old Town Relieves Nostalgia with Trishaw	4.595292706	101.0785409
7	10	Mural Spot - 2nd Concubine Lane	4.595454992	101.0779307
8	11	22 House Cafe	4.595609876	101.0778173
9	12	Lim Ko Pi	4.595096591	101.0772239
10	13	Funtasy House Trick Art	4.595974488	101.0773048
11	1	Concubine Lane	4.596325611	101.0779449
12	2	Time Tunnel Ipoh	4.596704686	101.0783974
13	3	Ho Yan Hor Museum	4.596304553	101.0790502
Return	4	Platform Coffee	4.596075988	101.0787145

The findings support previous studies that highlight the potential of GA-based and hybrid GIS optimization approaches in improving route planning performance and reducing inefficient route sequences (Costa et al., 2025; Malashin et al., 2024; Mondal & Srivastava, 2023). However, the result should be interpreted within the scope of this study, as the current GA-TSP model is based on distance optimization and does not yet include full accessibility attributes such as slope, pavement condition, walkway width, or resting points. Therefore, the GA-TSP output provides a stronger basis for accessibility-oriented route planning, but further development is required before it can fully represent real-world accessible tourism movement.

3.3. Comparative Analysis

A comparative assessment was conducted to examine the performance of the TSP-only and GA-TSP approaches in determining the optimal route. The results demonstrate that the integration of the Genetic Algorithm improved route efficiency by reducing the total travel distance. As shown in Table 4, the TSP-only route yielded a distance of 1,152.118 m, while the GA-TSP route achieved a shorter distance of 1,061.925 m. This reduction of approximately 90.19 m corresponds to a 7.8% improvement in routing efficiency.

Table 4. Distance between TSP and GA-TSP Routes

No	Method	Starting Location	Total Distance (m)
1	TSP	Concubine Lane	1,152.11
2	GA-TSP	Platform Coffee	1,061.92

Although the reduction may appear modest in absolute distance, it is meaningful within a compact urban heritage environment where attractions are located close to one another and visitors are expected to move mainly on foot. In pedestrian-based heritage tourism, even small reductions in unnecessary walking distance can improve route practicality, reduce physical fatigue, and support a smoother visitor experience (Gomez-Heras et al., 2023). This is particularly relevant for elderly visitors, families with young children, and users with mobility limitations, where inefficient route movement may reduce comfort and participation.

The TSP-only route fulfilled the basic requirement of visiting all attractions and returning to the starting point. However, it did not fully account for spatial movement logic. The route produced redundant movement around Chloe.co, Ipoh Mural - Old Town Relieves Nostalgia with Trishaw, and Cipta Karya, even though these attractions are spatially close. This indicates that a manually sequenced TSP route may be mathematically valid but still spatially inefficient when applied to a real heritage tourism environment. Similar findings have been reported in previous studies, where fixed or manually defined route sequences generated route redundancy and unnecessary travel distance when spatial relationships were not adequately considered (Yan et al., 2021; Yousuf et al., 2025). In contrast, the GA-TSP approach reduced this inefficiency by evaluating a wider range of possible route combinations using the network-based distance matrix. Through selection, crossover, and mutation, the GA was able to search across multiple route permutations and identify a shorter route sequence. This supports previous studies which reported that GA-based and hybrid optimization models can improve route planning by exploring broader solution spaces and reducing inefficient movement patterns (Choi et al., 2022; Mondal & Srivastava, 2023; Ochelska-Mierzejewska et al., 2021).

The GA-TSP optimization used the network-based distance matrix generated from the ArcGIS OD Cost Matrix. The matrix was processed in Python to evaluate alternative route sequences and identify a shorter route with improved route continuity and reduced backtracking (Ochelska-Mierzejewska et al., 2021). The findings demonstrate that the scientific contribution of the proposed framework is not limited to achieving a shorter route distance. More importantly, the GIS-based GA-TSP approach improves route continuity and spatial practicality within a heritage tourism setting. By integrating GIS network analysis, OD Cost Matrix generation, and GA-based route sequencing, the framework provides a spatial decision-support approach that is more flexible than manually configured route planning (Yu & Lu, 2012). This is important for heritage tourism areas such as Ipoh, where attractions are clustered within a compact urban layout and route efficiency depends on both distance and logical movement flow.

Nevertheless, the current model remains limited to simulated and distance-based optimization. It does not include real-world accessibility variables such as slope, pavement condition, walkway width, resting points, temporary barriers, crowd movement, or visitor preferences. Therefore, the 7.8% improvement should be interpreted as an initial methodological validation of the proposed GIS-based GA-TSP framework rather than a complete representation of actual tourist behaviour.

Future studies should incorporate real-world accessibility and pedestrian movement data to further evaluate the practical effectiveness of the model for inclusive heritage tourism route planning. Overall, the results demonstrate that the GA-TSP approach performs better than the manually configured TSP-only route in terms of total distance, route sequence, and spatial movement logic. The proposed framework contributes to heritage tourism route optimization by showing how GIS-based network analysis and evolutionary optimization can be integrated to generate a more efficient and practical route sequence. This supports the potential of GIS-based GA-TSP modelling as a spatial decision-support tool for improving route planning in compact urban heritage destinations.

4. Conclusion

In conclusion, this research demonstrates a successful integration of GIS and GA with the implementation of TSP to optimize the heritage tourism routes, particularly within the compact of urban heritage zone line Ipoh's old town. By comparing a manually designed TSP route to an automated GA-TSP method, the findings highlight the major benefits of algorithmic route optimization in terms of both spatial practicality and overall travel efficiency. The GA-TSP model which was created using Python scripting and visualised using ArcGIS Pro has produced a more logical and efficient path resulting in approximately 7.8% reduction in the total distance compared to the TSP route. More importantly, it helps avoid and eliminate any irrational spatial sequences such as redundant path that existed in the TSP model. This not only improves route efficiency but may also enhance visitor convenience by reducing unnecessary travel distances.

The proposed framework has practical value for tourism planning and route management. This method supports tourism planning by providing more efficient and logically organized routes which provides an excellent and better opportunity for various of tourist agencies, city planners, and local governments to create a better heritage route that meet a variety of user preferences and demands. The GA-TSP route optimization serves as a decision support tool that can contribute significantly to the data-driven tourism planning, especially in the development of a smart tourism city.

The main strength of this study lies in the integration of GIS and GA-TSP for spatial route optimization, enabling the evaluation of multiple route permutations and producing more efficient and spatially coherent tourism routes than manually designed TSP approaches. However, this study is limited by the use of simulated data and a distance-based optimization approach without incorporating real-time, temporal, or multi-criteria accessibility factors such as transport network impedance. In addition, the model has not been validated using real-world tourist data, which may affect its applicability in urban tourism environments. Nevertheless, the tools used in this study Python for automation, ArcGIS Pro for spatial analysis, and Google Maps and Google Earth Pro for data acquisition are compatible with real-time data integration and can be adapted to diverse urban environments. The proposed framework may serve as a decision-support tool for tourism authorities to improve route efficiency and visitor circulation within heritage tourism areas. Overall, the GA-TSP approach demonstrates strong potential as a practical decision-support tool for heritage tourism route optimization and supports data-driven planning to enhance visitor experience and sustainable urban tourism management.

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6. References

Ali, E. (2020). Geographic Information System (GIS): Definition, Development, Applications & Components. *Department of Geography, Ananda Chandra College. India*, *158*.

Antosiewicz, M., Koloch, G., & Kamiński, B. (2013). Choice of Best Possible Metaheuristic Algorithm for the Travelling Salesman Problem with Limited Computational Time: Quality, Uncertainty and Speed. *Journal of Theoretical and Applied Computer Science*, *7*(1), 46–55.

Awad, A. R., & Chiban, S. O. (2015). Recent Advances in Global Optimization for Combinatorial Discrete Problems. *Applied Mathematics*, *06*(11), 1842–1856. [Crossref]

Azevedo, B. F., Rocha, A. M. A. C., & Pereira, A. I. (2024). Hybrid Approaches to Optimization and Machine Learning Methods: A Systematic Literature Review. *Machine Learning*, *113*(7), 4055–4097. [Crossref]

Benchekroun, Y., Senba, H., Haddouch, K., & El Moutaouakil, K. (2024). Tourist Route Optimization with a Combined A* Algorithm and Genetic Algorithm. *Mathematical Modeling and Computing*, *11*(4), 966–977. [Crossref]

Bitušíková, A. (2021). Cultural Heritage as a Means of Heritage Tourism Development. *Muzeológia a Kultúrne Dedičstvo*, *9*(1), 81–95. [Crossref]

Cao, S. (2022). An Optimal Round-Trip Route Planning Method for Tourism Based on Improved Genetic Algorithm. *Computational Intelligence and Neuroscience*, *2022*, 1–8. [Crossref]

Choi, K.-C., Li, S., Lam, C.-T., Wong, A., Lei, P., Ng, B., & Siu, K.-M. (2022). Genetic Algorithm For Tourism Route Planning Considering Time Constrains. *International Journal of Engineering Trends and Technology*, *70*(1), 171–179. [Crossref]

Costa, F., Brito, M., Louro, P., & Gama, S. (2025). Genetic Algorithm Optimization of Sales Routes with Time and Workload Objectives. *AppliedMath*, *5*(3), 103. [Crossref]

Damos, M. A., Zhu, J., Li, W., Hassan, A., & Khalifa, E. (2021). A Novel Urban Tourism Path Planning Approach Based on a Multiobjective Genetic Algorithm. *ISPRS International Journal of Geo-Information*, *10*(8), 530. [Crossref]

Du, P., & Hu, H. (2018). Optimization of Tourism Route Planning Algorithm for Forest Wetland Based on GIS. *Journal of Discrete Mathematical Sciences and Cryptography*, *21*(2), 283–288. [Crossref]

Dumitrașcu, A. V., Teodorescu, C., & Cioclu, A. (2023). Accessibility and Tourist Satisfaction—Influencing Factors for Tourism in Dobrogea, Romania. *Sustainability*, *15*(9), 7525. [Crossref]

Economic Planning Unit. (2021). *Twelfth Malaysia Plan, 2021--2025: A Prosperous, Inclusive, Sustainable Malaysia*. Prime Minister's Department of Malaysia. https://rmke12.ekonomi.gov.my

Feizizadeh, B., Fathi, S., Ghasmeizad Gonbad, Z., Ghasmei, M., & Makki, M. (2023). A Multiple Geospatial Approach for Intangible Cultural Heritage Tourism Potentiality Mapping in Iran. *Sustainability*, *15*(24), 16659. [Crossref]

Gill, N., & Bobba, B. (2013). *Identification of Optimum Path for Tourist Places Using GIS based Network Analysis: A Case Study of New Delhi.*

Goldberg, D. E. (1989). *Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wealey.*

Gomez-Heras, M., González Soutelo, S., Castelo Ruano, R., & García Juan, L. (2023). The Challenge of Accessibility to Heritage around the Via Francigena: The Potential of Thermal Heritage for Accessible Tourism. *Heritage*, *6*(11), 7115–7125. [Crossref]

Holland, J. H. (1975). *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control, and Artificial Intelligence.* University of Michigan Press.

Hooi, P. M., & Yaacob, N. M. (2019). Accessibility for physically challenged persons in heritage buildings. *Journal of Design and Built Environment*, *19*(1), 24–39.

Huang, B., Yao, L., & Raguraman, K. (2006). Bi-level GA and GIS for Multi-objective TSP Route Planning. *Transportation Planning and Technology*, *29*(2), 105–124. [Crossref]

Isa, F. M., Ariffin, W. N. M., Jusoh, M. S., & Putri, E. P. (2024). A Review of Genetic Algorithm: Operations and Applications. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *40*(1), 1–34. [Crossref]

Ishaya, J., Ibrahim, A., & Lo, N. (2019). A Comparative Analysis of the Travelling Salesman Problem: Exact and Machine Learning Techniques. *Open Journal of Discrete Applied Mathematics*, *2*(3), 23–37. [Crossref]

Ismail, N., Masron, T., & Ahmad, A. (2014). Cultural Heritage Tourism in Malaysia: Issues and Challenges. *SHS Web of Conferences*, *12*, 01059. [Crossref]

Jankowski, P. (1995). Integrating Geographical Information Systems and Multiple Criteria Decision-Making Methods. *International Journal of Geographical Information Systems*, *9*(3), 251–273. [Crossref]

Kowalik, P., Sobecki, G., Bawoł, P., & Muzolf, P. (2023). A Flow-Based Formulation of the Travelling Salesman Problem with Penalties on Nodes. *Sustainability*, *15*(5), 4330. [Crossref]

Li, S., Luo, T., Wang, L., Xing, L., & Ren, T. (2022). Tourism Route Optimization Based on Improved Knowledge Ant Colony Algorithm. *Complex & Intelligent Systems*, *8*(5), 3973–3988. [Crossref]

Liu, Z., Zhang, M., & Osmani, M. (2023). Building Information Modelling (BIM) Driven Sustainable Cultural Heritage Tourism. *Buildings*, *13*(8), 1925. [Crossref]

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information science and systems*. John Wiley & Sons.

Mahmoudinazlou, S., & Kwon, C. (2024). A Hybrid Genetic Algorithm for the Min–Max Multiple Traveling Salesman Problem. *Computers & Operations Research*, *162*, 106455. [Crossref]

Malashin, I. P., Tynchenko, V. S., Masich, I. S., Sukhanov, D. A., Ageev, D. A., Nelyub, V. A., Gantimurov, A. P., & Borodulin, A. S. (2024). Two-Stage Genetic Algorithm for Optimization Logistics Network for Groupage Delivery. *Applied Sciences*, *14*(24), 12005. [Crossref]

Mondal, M., & Srivastava, D. (2023). A Genetic Algorithm-Based Approach to Solve a New Time-Limited Travelling Salesman Problem. *International Journal of Distributed Systems and Technologies*, *14*(2), 1–14. [Crossref]

Nasir, O., Kamal, M. A., & Agrawal, R. (2022). Exploring the Tangible Conservation of Architectural Heritage and History: Bringing Past into the Future. *American Journal of Civil Engineering and Architecture*, *10*(3), 147–156.

Nocca, F. (2017). The Role of Cultural Heritage in Sustainable Development: Multidimensional Indicators as Decision-Making Tool. *Sustainability*, *9*(10), 1882. [Crossref]

Ochelska-Mierzejewska, J., Poniszewska-Marańda, A., & Marańda, W. (2021). Selected Genetic Algorithms for Vehicle Routing Problem Solving. *Electronics*, *10*(24), 3147. [Crossref]

Pei, Q., Wang, L., Du, P., & Wang, Z. (2022). Optimization of Tourism Routes in Lushunkou District based on ArcGIS. *PLOS ONE*, *17*(3), e0264526. [Crossref]

Pop, P. C., Cosma, O., Sabo, C., & Sitar, C. P. (2024). A Comprehensive Survey on the Generalized Traveling Salesman Problem. *European Journal of Operational Research*, *314*(3), 819–835. [Crossref]

Prameshwori, T., J, W., Surjit, L., & Ramananda, L. (2021). GIS Based Route Network Analysis for Tourist Places : A Case Study Of Greater Imphal. *International Journal of Scientific Research in Science and Technology*, 233–238. [Crossref]

Sanmargaraja, S. (2015). Accessible Tourism Destinations in Malaysia: Disabled Tourists' Requirements. *Australian Journal of Basic and Applied Sciences*. https://www.researchgate.net/publication/317036802

Sathya, N., & Muthukumaravel, A. (2015). A Review of the Optimization Algorithms on Traveling Salesman Problem. *Indian Journal of Science and Technology*, *8*(29). [Crossref]

Sharma, A., Khan, F., Sharma, D., Gupta, S., & Student, F. Y. (2020). Python: the Programming Language of Future. *International Journal of Innovative Research in Technology*, *6*(12), 115–118.

Sumida, B. H., Houston, A. I., McNamara, J. M., & Hamilton, W. D. (1990). Genetic Algorithms and Evolution. *Journal of Theoretical Biology*, *147*(1), 59–84. [Crossref]

Vallone, R., Moscatelli, M., & Grünner, R. (2013). *GIS as Tool for Cultural Heritage Management*. https://www.researchgate.net/publication/236256617

Xiao, W., Mills, J., Guidi, G., Rodríguez-Gonzálvez, P., Gonizzi Barsanti, S., & González-Aguilera, D. (2018). Geoinformatics for the Conservation and Promotion of Cultural Heritage in Support of the UN Sustainable Development Goals. *ISPRS Journal of Photogrammetry and Remote Sensing*, *142*, 389–406. [Crossref]

Yan, J., Zlatanova, S., Lee, J. (Brian), & Liu, Q. (2021). Indoor Traveling Salesman Problem (ITSP) Path Planning. *ISPRS International Journal of Geo-Information*, *10*(9), 616. [Crossref]

Yfantidou, G., Ntakou, K., Balaska, P., & Spyridopoulou, E. (2020). The Issue of Universal Design and the Factors of Accessible Accommodation and Sport Facilities at Hotels for the People with Disabilities. *EURAM 2020 Conference Proceedings*. https://www.researchgate.net/publication/360849673_The_issue_of_universal_design_and_the_factors_of_accessible_accommodation_and_sport_facilities_at_hotels_for_the_people_with_disabilities

Youssef, H., M. Sait, S., & Adiche, H. (2001). Evolutionary Algorithms, Simulated Annealing and Tabu Search: A Comparative Study. *Engineering Applications of Artificial Intelligence*, *14*(2), 167–181. [Crossref]

Yousuf, I., Anwer, I., & Ali, H. (2025). *Application of the Travelling Salesman Problem in Optimizing Logistic Routes*. [Crossref]

Yu, H., & Lu, F. (2012). A Multi-Modal Route Planning Approach with an Improved Genetic Algorithm. *Advances in Geo-Spatial Information Science*, *193*.

Zahari, N. F., Ani, I. C., & Rashid, R. A. (2020). Profiling Disabled Facilities and Accessibility Provided in National Heritage Buildings in Malaysia. *Journal of Critical Reviews*, *7*(05). [Crossref]

Zahari, Nurul Fadzila, Kamarudin, H., Ahmad Zawawi, Z., Abdul Rashid, R., & Mohd Bahari, M. (2023). Heritage Tourism: A Disabled Person's Rights to Engage in Social Activity. *Planning Malaysia*, *21*. [Crossref]

Zakaria, Z., & Hua, A. K. (2024). Exploring the Cultural Tourism of Malaysia: A Comprehensive Review. *Sustainable Environmental Insight*, *1*(2), 96–107. [Crossref]