Hindawi
Mathematical Problems in Engineering
Volume 2024, Article ID 1029499, 10 pages
https://doi.org/10.1155/2024/1029499

Research Article

Optimized Distance-Based Algorithm for Cloud Space—Tourist Route Recommendation for Heritage Town, Pondicherry, India

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Received 23 January 2023; Revised 4 October 2023; Accepted 7 February 2024; Published 7 March 2024

Academic Editor: Juan C. Jauregui-Correa

Architecture, often regarded as a three-dimensional art form, relies on a multitude of abstractions during the design process. In this context, architectural elements are effectively represented through vector-based data processing techniques, offering a canvas for creative exploration. To further our understanding of spatial configurations and generate multiple design insights, mathematical structures known as graphs come into play. Graph theory, a fundamental component of this process, it is a mathematical field that studies relationships and connections between objects using vertices and edges, finding applications in computer science, network analysis, and more finds application in architectural design. This study delves into the application of graph theory in the analytical exploration of urban networks, with a focus on tourism parameters in the picturesque town of Pondicherry, Tamil Nadu, India. Traditionally, urban network analysis seeks to determine the shortest distance between origin and destination, a metric rooted in accessibility. However, in leisure destinations, a novel approach involving an optimized distance-based algorithm is introduced. This innovative methodology aims to facilitate efficient access to all tourist destinations within the spatial extent while minimizing discrete physical distances. To illustrate this concept, we take the iconic French Quarters in the White Town of Pondicherry as a case study. By applying the optimized distance-based algorithm, we endeavor to uncover the most efficient route for tourists to navigate and leisurely explore the area. The outcome of this analysis reveals a path graph structure, which, when compared to a circular graph structure, demonstrates superior efficiency in guiding tourists through the space. The implications of this tourist route extend beyond the realm of tourism itself. It has the potential to enhance the organization of tourist activities, allowing stakeholders to manage and regulate the flow of visitors. Additionally, it presents an opportunity to promote and develop the region's often-underestimated tourist destinations, which can, in turn, have a positive impact on the local economy. In summary, the integration of graph theory into architectural and urban design methodologies enriches the approach to tourism and offers a holistic perspective on spatial optimization.

1. Introduction

Architecture, as a discipline, embodies the essence of three-dimensional artistry, and it grapples with intricate challenges that demand the utilization of diverse abstractions as tools for creative problem-solving. These complexities inherent to architectural design necessitate a process of abstraction to simplify, analyze, and transform them into dynamic design possibilities. The multifaceted intricacies of architectural design can be approached and comprehended through the lens of architectural abstraction. This method of abstraction allows designers to deconstruct complex architectural problems, making them more manageable and facilitating a deeper exploration of potential solutions. It is essential to note that architectural complexity can be defined in numerous ways, depending on the context and objectives of the design. In this context, we choose to represent architectural design intricacy through a graph–theoretical approach. Graph theory, a branch of mathematics, offers a powerful framework for modeling and understanding spatial configurations. By utilizing graphs, architectural intricacies can be efficiently translated into a structured and visual representation, enabling designers to analyze spatial relationships, connectivity, and functional aspects within the architectural context. The practice of architecture thrives on the dynamic interplay between artistic creativity and technical problem-solving. Architectural abstraction, particularly when harnessed through graph theory, serves as a valuable tool to navigate the intricacies of architectural design, allowing designers to transform complexity into innovation and realize their creative visions.

Graph theory, a branch of discrete mathematics, has witnessed a significant surge in relevance over the past two decades, particularly in the realms of engineering and technology, owing to advancements in computational techniques [1]. Among its many applications, the field of architectural design stands out as an area where graph theory plays a pivotal role. This research venture delves into the nuanced applications of graph theory within the domain of spatial network analysis, specifically focusing on a heritage tourist town. By leveraging graph theory as a foundational design tool, this study aims to unravel the underlying principles of architectural design, offering insights into the intricate urban planning aspects that are integral to fostering sustainability. Notably, the promotion of walkability emerges as a critical concern, not only for the betterment of public health but also for nurturing environmentally conscious and socially engaged communities.

Urban design research discovered a relationship between urban form and active transportation. Urban pattern structure has a subtle duality of interpretation. Spatial configuration affects travel behavior, accessibility influences the social aspects, and the pair is recognizable by humans as well by computers once modeled as a graph (networks) [2]. And about the structural facet of urban systems, there are various traditional methods to carry out a quantitative analysis. Discrete network-based spatial representations work better for urban studies, especially those involving human life as it enables the consideration of actual network distance [3]. Much of the built environment design literature focuses on walkable space variables such as design, density, diversity, and accessibility. There is an evident gap in understanding the surrounding spaces and their accessibility from the user's view in algorithmic design while traversing from origin to destination. This intense process proposes an alternative approach for route structuring for historic towns principally in the case of leisure purposes also for other instances to prove the effectiveness of the accessibility parameter not only in terms of discrete relations. The general objective is to contribute primarily to the network navigation possibilities through a graph–theoretical approach that focuses on spatial structures and their effect on parameters such as proximity, accessibility, and connectivity.

The word "tour" is borrowed from the Latin term tornus, meaning "a tool for making a circle" indirectly means a circuit structure. Tourism is described as the peoples' movement from their usual place of residence to another space (to return) for a minimum period of 24 hr to a maximum of 6 months for leisure and pleasure [4]. Tourist route is the influential element of tourist products even long before the concept of tourism came into play. First travel routes were components of trading systems or religious practices. Inventions of automobiles lead to incredible possibilities of travel. During the last two decades, tourist routes came into a larger lens worldwide especially the themed itinerary. Tourism and travel are research arenas not based on a single theory but relatively depend on the circuit drawn by the tourist from when leaves the home navigates through the path and ends the travel by reaching home [5].

The tourism industry is itself a complex entity comprising of independent providers that focus on the consumer. The tourism system is explained by five elements—a traveler-generating region, a destination region, a transit region, travel, and the tourism industry with the external environment [6]. These five domains function when there is an efficient connection between them and hence have a considerable impact on accessibility [6, 7]. Connectivity in the built environment design literature focuses on walkable space variables such as design, density, diversity, and destination accessibility [8]. From the facet of tourism, accessibility in diverse dimensions at divergent geographic levels is the macro, meso, and micro levels. Each one is based distinctly on the physical connection, approach to information, or social activities and services [9]. Three perspectives of access are physical access, sensory access, and communication access, provision of access becomes an inclusive marketing process for the exploration of tourism products and services for the broad client database [10]. Physical access here means the users flow through networks to reach the destination [11]. There is an evident gap in understanding the importance of adjacent spatial features and their accessibility in the tourist town from the users' point of view. Adjacent spatial features here in the case of tourist cities means the tourist attracted destinations as such. Recent research methods focus on subjective measures to analyze urban fabric through surveys or objective measures through computer-aided design software GIS [12]. Network accessibility eventually over lays itself on urban design as an essential parameter.

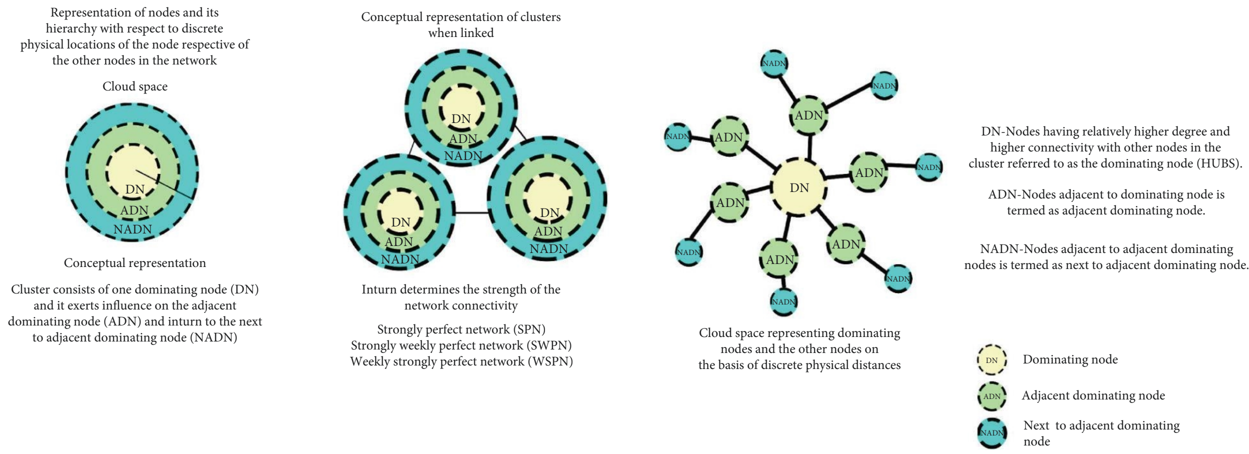

Figure 1: Conceptual representation of cloud network.

The spatial analysis could bridge between the space and ultimate users through the configurational properties [13]. Analytical urban design is made possible through a configurational approach based on theoretical foundations, analytical methods, and modeling techniques such as space syntax [14].

In the application arena, since there is "n" number of components in multiple layers in a particular domain that would involve interpretation, it is better to adopt an algorithmic design that would process data, manipulate, analyze, and automate results following the conditions assigned. The algorithmic structure for determining accessibility always finds the shortest path to reach, between the origin and the destination or any two nodes in the network wherein the immediate surrounding context is hardly considered. The shortest path problem is one of the classical algorithmic issues in graph theory. Dijkstra's Shortest Path First (SPF) algorithm works well in numerous cases. Widely used in solving path search problems includes network routing algorithm, artificial intelligence, game design [15]. Not only fit to find the shortest distance in the general geographical complication. But it is also used in finding the most reliable path for the communication networks and the critical path problem as well utilized in comparing and analyzing the time and cost complexity [16].

Accessibility through the lens of an analytical approach has been explored only in terms of shortest distance. But the shortest path problem does not work efficiently for leisure places in case of visiting multiple tourist destinations. This paper tries to derive the efficient relationship between the urban design parameters and the urban network through the analytical graph–theoretical approach to seek new interventions about the reachability in tourist towns by solving the network accessibility and is explored in the case of Pondicherry city in Tamil Nadu.

2. Graph Theoretical Aspect

Examining the inherent characteristics of network nodes and their hierarchical arrangement, particularly in relation to their discrete physical distances from other nodes within the network, emerges as a pivotal consideration [17]. To address the secure transmission of voluminous data in wireless cloud networks, this study introduces an innovative approach: the deg-greedy algorithm, grounded in the principles of graph theory [18]. This algorithm revolves around the selection of a dominating node (DN) through a degree-based evaluation of the cloud network. Elevating the efficiency of the network, a dominating-node-based broadcasting algorithm prioritizes nodes with the highest degree [19]. Additionally, if global positioning system (GPS) data are accessible for periodic updates, the maintenance of DNs is seamlessly integrated into the location variable, enhancing the network's adaptability and robustness. Conceptual illustration of novel deg-greedy algorithm represents the nature of DN, adjacent dominating node (ADN), next to adjacent dominating node (NADN) based on degree distribution and its connectivity to the related nodes (Figure 1).

3. Architectural Perspective

In the context of urban fabric (Table 1) any architectural feature, a monument, a building is contemplated as a NODE (Vertex). The element which connects the nodes is described as LINKS (Edges). The neighborhood is assumed as a district. The district is an important element of the city that holds itself by a character/nature [20]. Nodes attributed as DN based on the degree distribution (higher degree priority in the cloud space). In such a case, the nodes (building or the spaces which adapt to the context) adjacent to the DN is named ADN, and the node farther to the DN and adjacent to ADN assigned as NADN. A set that contains three types of nodes DN, ADN, and NADN can constitute a cloud space interlinked by street networks (edges) in urban cape. Several cloud networks together form a Neighborhood. Overlooking the mapping of tourist destinations in Pondicherry, it is evident that the White Town is flooded with multiple tourist destinations.

4. Optimised Distance-Based Algorithm

Analyzing the French Quarters in White Town in detail (Figure 2), overlaying with the analytical graph–theoretical concept. Consider the tourist destinations as nodes (Vertices)

Table 1: Correlation aspect: graph theory and architecture.

S. No	Architectural perspective	Graph–theoretical interpretations
1	Destination	Node
2	Street networks	Edges
3	Adjacency-based approach	Degree-based approach
4	No. of streets connecting to the destination	Node degree
5	Spatial extent	Cloud network
6	Accessibility	Connectivity
7	Efficient destination coverage	Optimized route

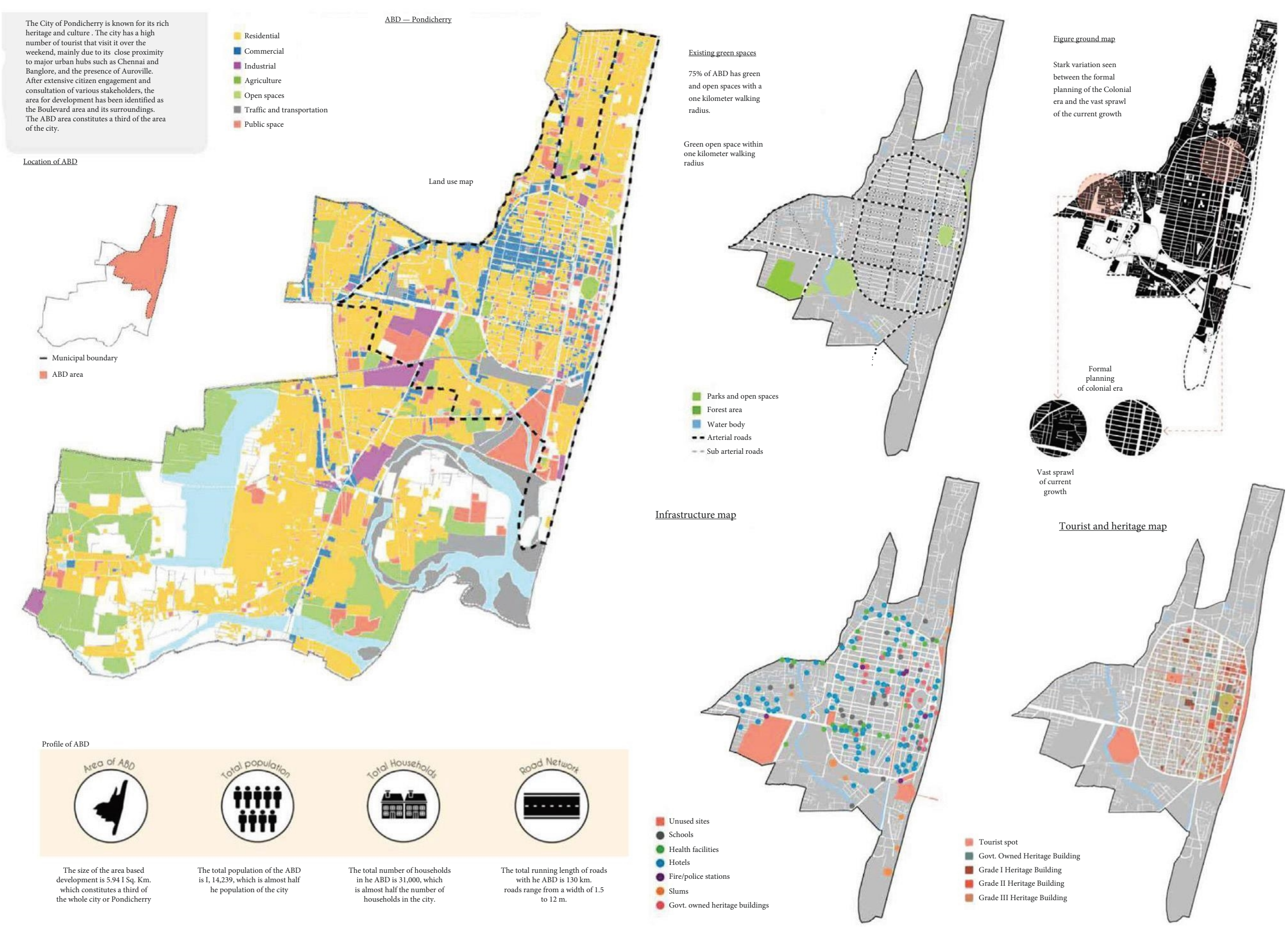

Figure 2: Area-based development—Pondicherry (smart city proposal).

of the urban fabric and the road network that links nodes are edges where people commute. Here the physical distance between the nodes is appropriated as a critical parameter of concern in the analytical approach.

In geospatial technology, the vector line data represents the geographic center of road rights-of-way on transportation networks. Delayering the urban fabric—the building block layer, the urban network layer, the axial line map (Figure 3), plan showing tourist destinations as nodes, sketch plan showcasing the number of streets network leading to the destinations, plan to portray the assigned degree distribution based on the number of edges leading to the destination (possible number of ways leading to the node; Figure 4). Plot the node based on the higher priority degree from the spatial extent and assigned as source node for the route structure analysis in the tourist user perspective. For instance, in a real-time situation, the google map application happens to be doing this for a long time identifying the shortest distance between the origin and the destination for the user, say it any purpose. Most times it works based on calculating the shortest discrete physical distance between destinations assigned, where time (a component of accessibility, reachability) is given

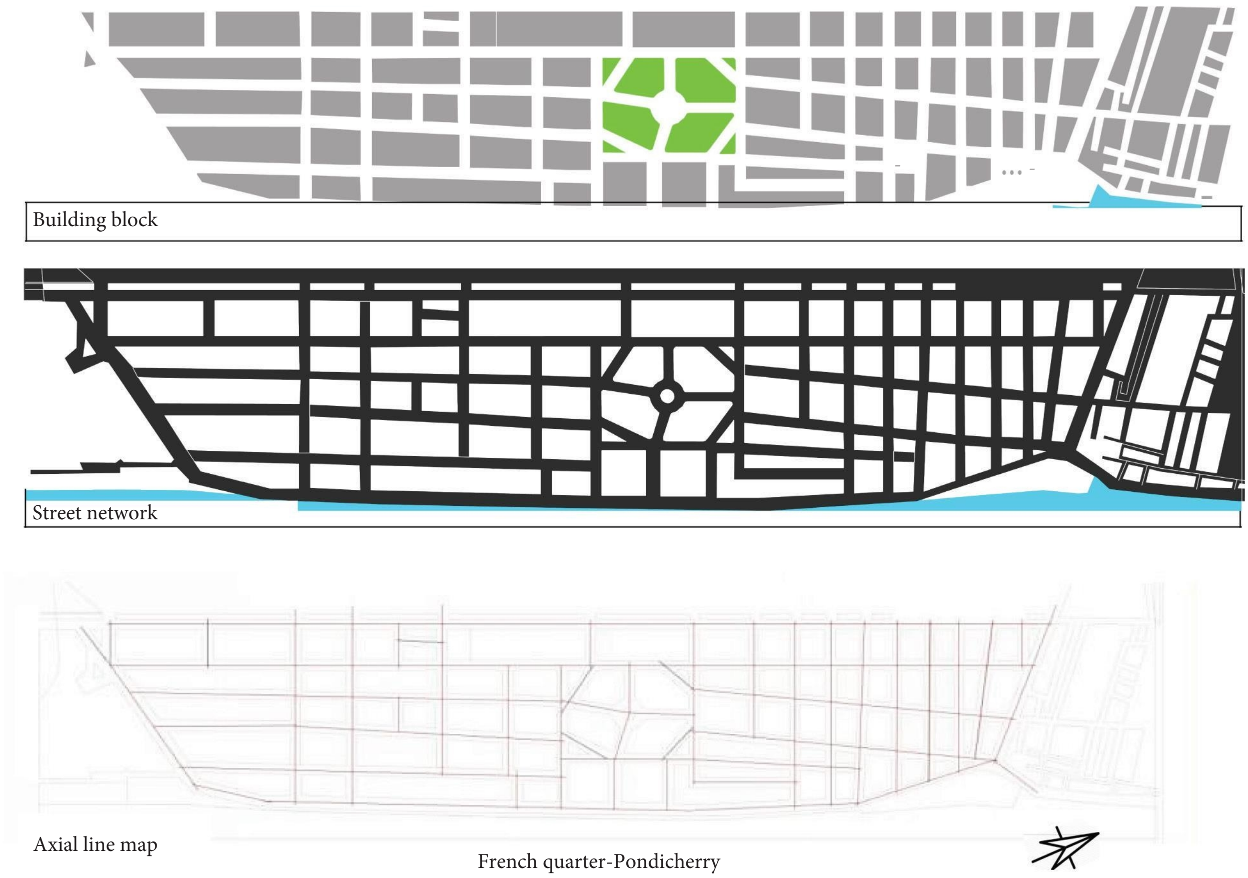

Figure 3: French town, Pondicherry—building block, street network, and axial line maps.

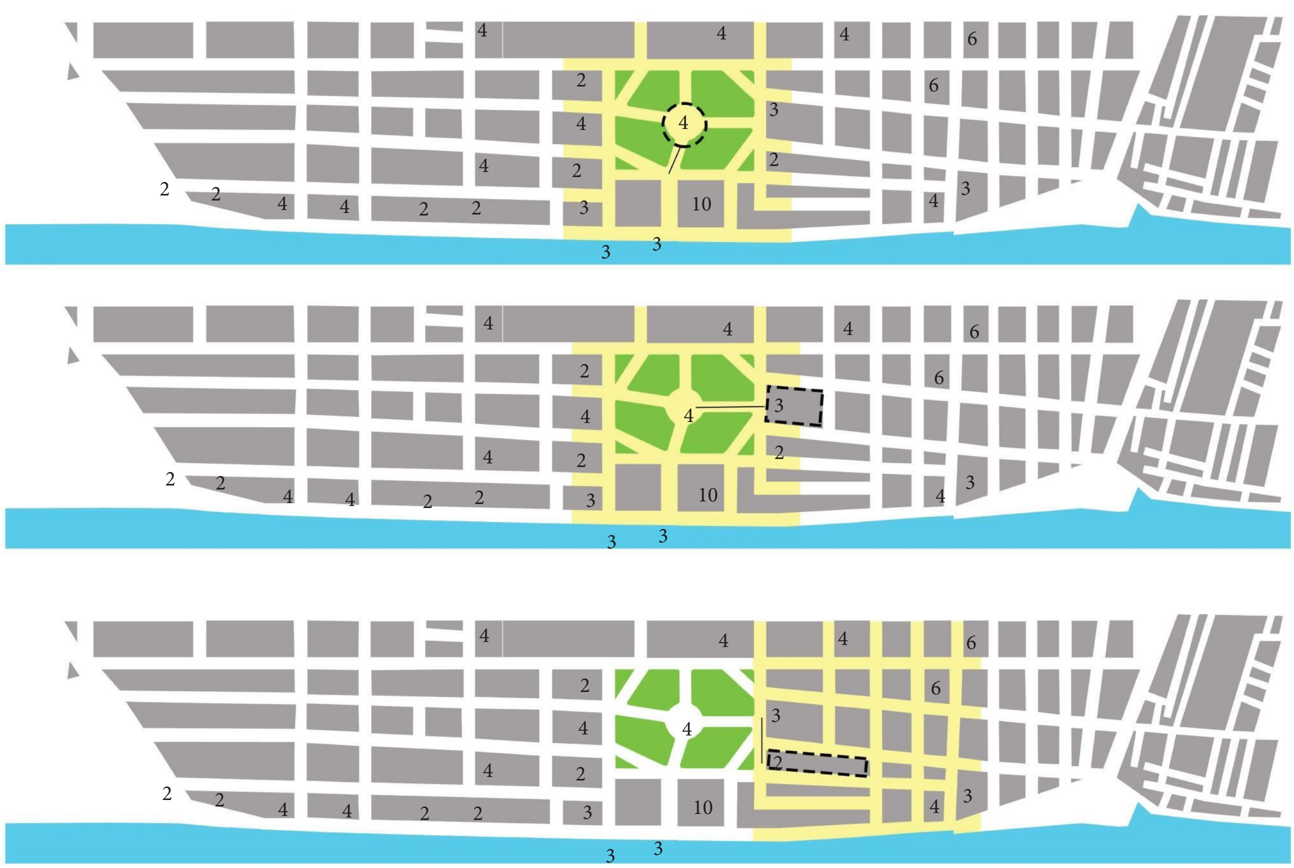

Figure 4: French town, Pondicherry—other cloud network illustration.

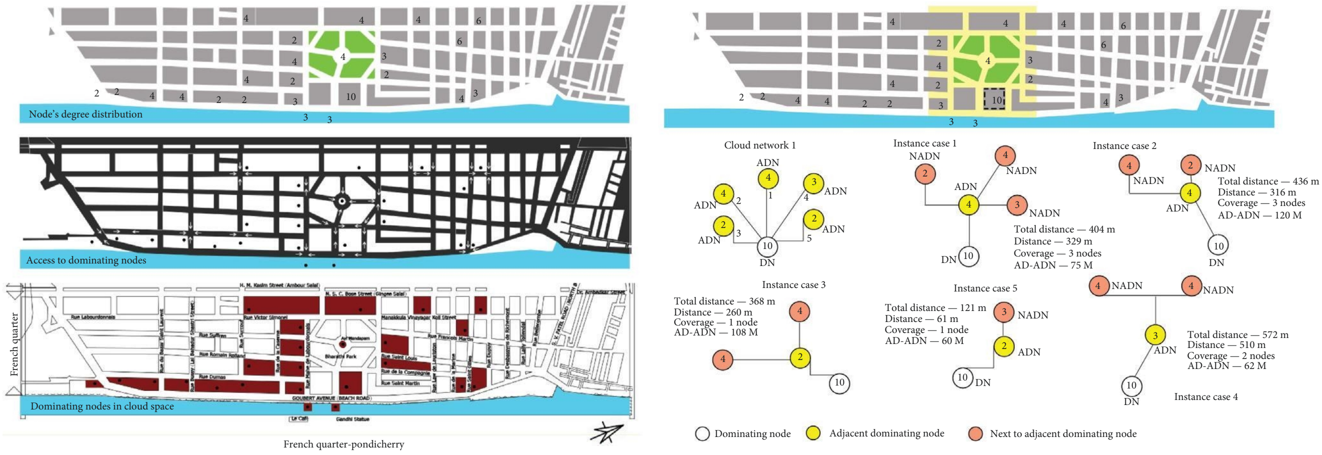

FIGURE 5: French town, Pondicherry—cloud network illustration of one case.

utmost importance [21]. But in the case of a tourist accessing the space, reachability and the maximum coverage of tourist spots between origin and destinations becomes an equal component of consideration in this algorithm. To pitch the leisure time in this research problem in the right sense, the algorithm clearly defines that the tourist user is beneficial and convincing only when it is directly proportional to the number of tourist spots viewed with minimal discrete physical distance as well to cover the entire existing destinations in the confined spatial extent planned effectively. Higher the number of tourist destinations visited higher is the social value added to space and its live ability and indirectly reflects in economic growth and related aspects.

A user standing in a space can navigate along with the road networks only in any of the directions that lie between 0° and 180° [20]. Hence, here the point of consideration in navigation concerning the orientation of the person is considered as 180°. Route structuring algorithm is examined as the multiobjective optimization model, wherein it involves multiple criteria and multiple attribute optimizations to find the optimized route for the tourist users in the French quarters of the Old Town, Pondicherry (Figure 5). Node with a higher degree within the spatial extent is selected as the source node for navigation represented as DN of the cloud for an instance of analysis. In such a case, the cloud network is illustrated with DN, ADN, and NADN and the edges leading to them with discrete physical distance. Manipulation of DN and each ADN with the respective physical distance and the number of NADN nodes interlinked is studied.

To navigate from DN–ADN = maximum number of nodes ADN is connected with (i), and minimum discrete distance between DN and ADN (ii; Figure 5). Based on these criteria, the successive node is chosen to navigate from the source DN. At present, the active node is selected as the DN for the next cloud network, and the cloud network is illustrated by mapping the respective ADN and NADN (Figure 4). In a similar case, the same process is followed to select the next node to navigate. This methodology is looped until all the nodes in the chosen network are visited (Figure 6). Hence, this algorithmic procedure at the end of complete functioning finds the best optimal route for navigation in the case of leisure places solving all the complexities ranging from finding the shortest path between the origin and the destination to visiting all the tourist destinations considered in the spatial extent SE (Figure 6).

5. Flowchart

The algorithm is demonstrated in a precise flowchart (Figure 7) with the terminator, input, process, decision, and statements for clear understanding. The function terminates and is followed by input statements: (i) input geographical maps and (ii) input each tourist destination as a Node. Follows the process statements: (i) assign each node with Degree D, (ii) calculate Degree D, (iii) assign highest degree node as S, (iv) consider S as DN, (v) label adjacent nodes as ADN and NADN, (vi) if no nodes; end, (vii) if nodes present continue to construct cloud network with DN, ADN, and NADN, (viii) navigate 360° from DN, (ix) fix user orientation direction as 180° from DN, (x) find Nx, (xi) calculate d, and (xii) find total d. The decision statements: (i) if (Max Nx, Min d), (ii) if yes, assign as NSNy, (iii) if no, (iv) if (Max Nx, Max d), and (v) if yes, assign as NSNy. Repeat process statements: (i) exclude the previous node as VNx, (ii) assign NSNy as S, (iii) consider S as DN, and (iv) repeat the process till the end. Output statement: (i) store the best solution (tourist route is outlined). Terminator statement indicates the end of the program functioning (Algorithm 1).

6. Results and Discussions

Pondicherry, despite its inherent tourist appeal, has often fallen short of being recognized as a premier tourist destination over an extended period. This shortfall can be attributed to the absence of a well-structured link connecting the various tourist destinations within the region. In the context of a tourist town, the concept of reachability and the comprehensive coverage of tourist attractions between the origin and destination assumes equal importance compared to merely finding the shortest path between these two points, especially when the surrounding context is given limited consideration.

Figure 6: French town, Pondicherry—existing route and proposed route.

The algorithm, we propose offers a clear perspective on the optimal utilization of a tourist's time and experience. It emphasizes that the tourist can derive maximum benefit when they manage to visit all the designated tourist destinations within a specified timeframe, taking into account the leisure aspect of their journey. In essence, the algorithm recognizes that the extent to which a tourist can explore and experience the various spaces within a region is directly proportional to the social value added to that place. This, in turn, has indirect implications for the region's economic growth and related socioeconomic aspects. In summary, Pondicherry's potential as a top-tier tourist destination can be fully realized by not just considering the shortest path between points but also by strategically optimizing the coverage of its attractions, thereby enhancing the overall appeal and contributing to the region's economic prosperity and social well-being.

Taking an analytical approach to establish a clear relationship between urban design parameters and the urban network is instrumental in identifying the most optimal routes within a city. This analytical process plays a pivotal role in determining a key factor that can elevate a heritage town to the status of a global tourist destination. The routing algorithm employed in this analysis results in a path structure, a concept derived from graph theory, which has proven to be superior to a circular or cyclic structure when viewed from a tourist's perspective. The very nature of tourism implies a journey that typically begins and ends at the traveler's place of residence. Therefore, if the tourism network also exhibits a circular structure, it can be understood as a graph–theoretical concept, where the resulting graph effectively becomes a "pseudo graph" comprising two loops converging at the same point.

In the case of a city with a linear grid–pattern layout, particularly one influenced by a water edge, it becomes possible to efficiently connect all the tourist destinations along this linear axis. This arrangement not only piques the interest of tourists but also aligns with the development of an active network designed for people to leisurely stroll along. Consequently, the path planning of urban infrastructure facilities seamlessly integrates with the network, leveraging the interconnected nature of the tourist destinations. The advantages of adopting a path structure approach extend beyond tourism. They provide opportunities for the network to evolve in various directions, fostering growth, connectivity, and accessibility throughout the city. This, in turn, contributes to the overall enhancement of the urban environment, making it more appealing and functional for both residents and tourists alike.

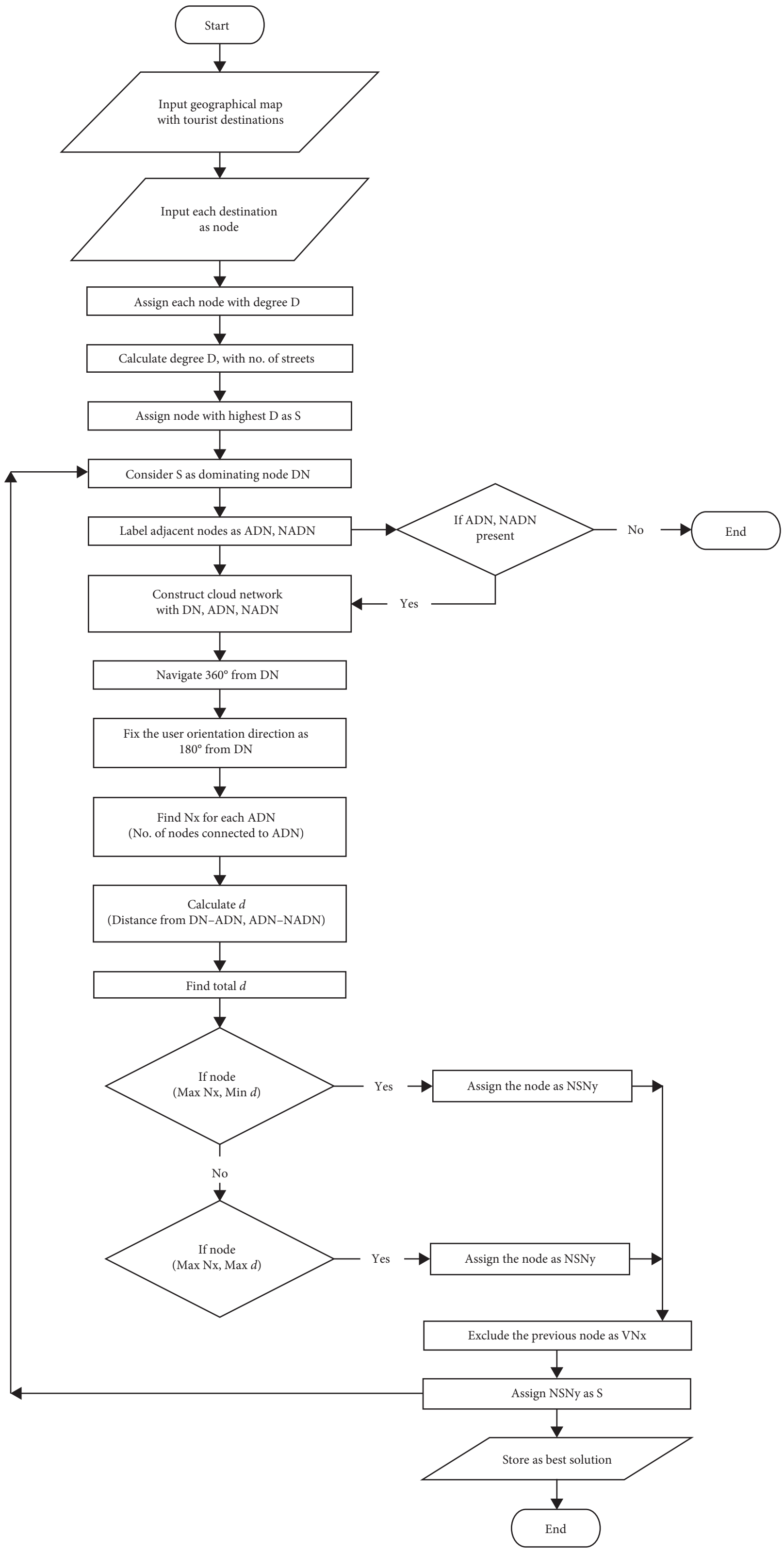

Figure 7: Algorithmic flowchart—route structure.

Input:
Geographical map of the spatial extent SE with tourist destinations.
Output:
Optimized path for tourists to visit various destinations in SE.
Procedure:
1. Start
2. Input geographical map of the spatial extent SE with tourist destinations.
3. Create an empty list for nodes.
4. For each tourist destination in SE:
   a. Create a node for the tourist destination.
   b. Assign a Degree D to the node.
   c. Calculate Degree D as the number of streets leading to the destination.
5. Find the node with the highest Degree D and assign it as the Source Node (S).
6. Consider S as the Dominating Node (DN).
7. Create two empty lists for Adjacent Dominating Nodes (ADN) and Non-Adjacent Dominating Nodes (NADN).
8. Construct a Cloud Network with DN, ADN, and NADN.
9. Set the initial orientation direction as 360° from DN.
10. Fix the user orientation direction as 180° from DN.
11. For each ADN in the list:
   a. Find Nx for the ADN.
   b. Calculate the distances:
      i. Distance (*d*) from DN to ADN.
      ii. Distance (*d*) from ADN to NADN.
   c. Calculate the total distance (Total *d*).
12. Check the ADN node with the maximum Nx and minimum total *d*.
13. Assign the selected node as NSNy (next stop node).
14. Alternatively, check the ADN node with the maximum Nx and maximum total *d*.
15. Assign the selected node as NSNy.
16. Exclude the previous node (if any) as VNx (visited node).
17. Assign NSNy as S, as the new dominating node DN.
18. Repeat steps 7–17 until all nodes are visited or the desired path is complete.
19. Stop.

Algorithm 1: Optimized tourist pathfinding algorithm.

7. Conclusion

The optimized distance-based algorithm represents a versatile solution applicable across various leisure contexts, effectively tackling pathfinding complexities within intricate urban networks, regardless of the number of facilities involved. This algorithm operates in real-time, enabling dynamic mapping of multidimensional user preferences to ensure the determination of the most optimized and efficient routes between tourist destinations. It incorporates a holistic evaluation of the surrounding context, allowing it to guide tourists through spaces in an organized manner. This, in turn, facilitates the structured flow of people, contributing to easier monitoring for assessment teams. Moreover, this algorithm plays a pivotal role in identifying and highlighting the often overlooked, yet promising tourist destinations within a region. By connecting these hidden gems, it establishes a robust tourist link, which has a significant indirect impact on the local economy. As such, future endeavors will focus on expanding the application of this optimized distance-based algorithm to encompass all potential tourist districts, further enhancing the overall tourism experience and its positive socioeconomic implications.

Notations

SE:	Spatial extent
D:	Node degree
S:	Source node
DNx:	Dominating node
Cx:	Cloud network
ADNx:	Adjacent dominating node
NADNx:	Next to adjacent dominating node
Nj:	Number of NADN connected to ADN
d:	Distance
NSNy:	New source node
VNx:	Visited node.

Data Availability

This real time optimization study input data was available from the corresponding author upon request. Due to the fact the data were collected from different tourist heritage places. It is used for research purpose only.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] O. I. Abiodun, A. Jantan, A. E. Omolara, K. V. Dada, N. A. E. Mohamed, and H. Arshad, "State-of-the-art in artificial neural network applications: a survey," *Heliyon*, vol. 4, no. 11, Article ID e00938, 2018.

[2] R. Askarizad and H. Safari, "The influence of social interactions on the behavioral patterns of the people in urban spaces (case study: the pedestrian zone of Rasht Municipality Square, Iran)," *Cities*, vol. 101, Article ID 102687, 2020.

[3] G. Boeing, "Planarity and street network representation in urban form analysis," *SSRN Electronic Journal*, 2018.

[4] M. A. Camilleri, *Travel Marketing, Tourism Economics and the Airline Product*, Springer, 2018, 1st edition, 2017.

[5] T. Flognfeldt jr, "The tourist route system–models of travelling patterns," *Belgeo*, vol. 1-2, pp. 35–58, 2005.

[6] N. Leiper, "Tourist attraction systems," *Annals of Tourism Research*, vol. 17, no. 3, pp. 367–384, 1990.

[7] D. Buhalis and A. Amaranggana, "Smart tourism destinations," in *Information and Communication Technologies in Tourism*, pp. 553–564, Springer, Cham, Germany, 2014.

[8] B. Saelens and S. Handy, "Built environment correlates of walking," *Medicine & Science in Sports & Exercise*, vol. 40, no. 7, pp. S550–S566, 2008.

[9] S. Iwarsson and A. Ståhl, "Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships," *Disability and Rehabilitation*, vol. 25, no. 2, pp. 57–66, 2003.

[10] S. Darcy, *Anxiety to Access: Tourism Patterns and Experiences of New South Wales People With a Physical Disability*, Tourism New South Wales, Sydney, 1998.

[11] V. Eichhorn and D. Buhalis, "Accessibility: a key objective for the tourism industry," in *Accessible Tourism: Concepts and Issues*, pp. 46–61, Channel View Publications, 2011.

[12] G. Fancello, T. Congiu, and A. Tsoukiàs, "Mapping walkability. A subjective value theory approach," *Socio-Economic Planning Sciences*, vol. 72, Article ID 100923, 2020.

[13] S. Marshall, *Streets and Patterns*, Routledge, 1st edition, 2005.

[14] K. Karimi, "A configurational approach to analytical urban design: 'Space syntax' methodology," *Urban Design International*, vol. 17, no. 4, pp. 297–318, 2012.

[15] N. A. Ojekudo and N. P. Akpan, "An application of Dijkstra's algorithm to shortest route problem," *IOSR Journal of Mathematics (IOSR-JM)*, vol. 13, no. 3, pp. 20–32, 2017.

[16] X. Z. Wang, "The comparison of three algorithms in shortest path issue," *Journal of Physics: Conference Series*, vol. 1087, no. 2, Article ID 022011, 2018.

[17] C. Mao and W. Xiao, "A comprehensive algorithm for evaluating node influences in social networks based on preference analysis and random walk," *Complexity*, vol. 2018, Article ID 1528341, 16 pages, 2018.

[18] K. Thiagarajan, R. S. Babu, and K. Saranya, "Analysis on secure big data capturing and transmission in cloud storage through novel deg-greedy algorithm," *Indian Journal of Science and Technology*, vol. 9, no. 48, pp. 1–9, 2016.

[19] M. A. Spohn and J. J. Garcia-Luna-Aceves, "Improving route discovery in on-demand routing protocols using two-hop connected dominating sets," *Ad Hoc Networks*, vol. 4, no. 4, pp. 509–531, 2006.

[20] K. Lynch, *The Image of the City*, MIT Press, 1964.

[21] Z. Yin, Z. Jin, S. Ying, S. Li, and Q. Liu, "A spatial data model for urban spatial–temporal accessibility analysis," *Journal of Geographical Systems*, vol. 22, no. 4, pp. 447–468, 2020.