International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 8 Issue 7 July - 2024, Pages: 71-79

Geospatial Network Analysis Methods and Renewable Energy Applications

Taha Alfadul Taha Ali,

Associate Professor of Information Technology (**Geospatial Data Science**)
Computer Science & Information Technology, Alzaiem Alazhari University, Tahapilot13@gmail.com, https://orcid.org/0000-0003-1906-0110

Abstract: *This paper* ***is*** *to illustrate Methodology and application and technology for renewable energy of the types of Network analysis: Find Nearest, Shortest Distance, Fastest route, Finding Coverage, Service Areas , Optimize Fleet, Select Optimal Site, Origin-Destination – OD Cost Matrix, and Huff Model. to support the decision makers. There are five methodology: analysis GIS Network Analysis , Design GIS Network Analysis, Develop GIS Network Analysis, Implementation GIS Network Analysis, Evaluations GIS Network Analysis. There are many applications for GIS Network analysis for renewable energy such as Finding the Nearest Locations, Determining Shortest Distance Routes, Identifying Fastest Routes, Finding Coverage Areas, Determining Service Areas, Optimizing Fleet Management, Selecting Optimal Site Locations, Origin-Destination (OD) Cost Matrix Analysis, and Utilizing the Huff Model for Spatial Interaction Analysis. In Conclusion, the utilization of GIS Network Analysis technology for renewable energy has been instrumental in revolutionizing transportation network analysis and offering valuable insights for decision-making. The effective design of GIS data renewable energy has empowered industry professionals to optimize networks, plan routes efficiently, and make data-driven decisions, leading to substantial cost savings and improvements in efficiency. By leveraging the power of GIS technology, transportation professionals can unlock valuable insights to optimize traffic management and promote sustainable transportation solutions for renewable energy, setting the stage for a more connected and sustainable future. The strategic GIS data design has transformed the transportation industry by allowing companies and cities to develop future-proof mobility solutions that enhance efficiency, reduce costs, and improve safety. Through the efficient application of geographic information systems (GIS) for renewable energy, planners can extract valuable insights, optimize transportation networks, and make informed decisions that positively impact both efficiency and user experience. As cities continue to evolve, incorporating GIS data design will become increasingly crucial for staying ahead of the curve. The future research integrated the geospatial network analysis with IoT, cloud data, AI, Cyber Security.*

Keywords: Geoinformatics, Network analysis algorithm, Spatial Analysis, Geocoding, geoereferences.

1. Introduction

The realm of GIS network analysis delves into the exploration of geographic networks or real-world networks to comprehend the patterns of flows within and around such networks. By employing mathematical sub-disciplines like graph theory and topology, GIS network analysis concentrates on edge-node topology to depict real-life information networks. This type of analysis is crucial for identifying optimal service locations, such as determining the fastest or most direct route between locations based on specific travel costs. The use of GIS technology in solving transportation issues is particularly vital in today's context, necessitating new data structures to represent the intricacies of transportation networks and execute various network algorithms. This includes addressing challenges in road networks that require analysis to enhance the movement of people, goods, services, and resources. GIS technology has become a fundamental component in supporting transportation network analysis or planning, enabling database expansion through integration with attribute and spatial data. For instance, it plays a pivotal role in comprehensive urban development by serving as a lifeline for the urban economy and society. Additionally, GIS provides valuable insights for planners regarding areas that have insufficient services from healthcare institutions and helps determine the most appropriate locations to build new facilities. As a digital computer application designed for capturing, storing, manipulating, analyzing, and displaying geographic information, GIS relies on location as its defining element. Location serves as the foundation for many benefits of GIS such as mapping display and distance measurement. GIS-T represents one of the most crucial application areas of GIS technology today due to its ability to fulfill potential in logistics and distribution logistics by utilizing advanced network analysis techniques[1][2][3]. The utilization of GIS Network Analysis technology has played a pivotal role in revolutionizing transportation network analysis and offering valuable insights for decision-making. The design of GIS data involves the use of geospatial data, analysis, and visualization tools to interpret and optimize transportation networks. By integrating various information sources such as GPS data, road networks, traffic volumes, and land use data, GIS data design provides a comprehensive view of transportation systems. GIS technology empowers transportation planners to accurately visualize complex networks, aiding in the identification of problem areas and potential routes for improvement. It also enables detailed analysis of various network parameters such as traffic volumes, travel times, and congestion levels. The integration of multiple data sources like traffic counts, demographic data, and land-use data offers a holistic understanding of network dynamics. Real-time data analysis is another vital feature of GIS technology, allowing for the incorporation of live traffic

feeds to analyze current network conditions. This capability enables transportation authorities to respond swiftly to incidents and adjust traffic signal timings accordingly. The use of predictive modeling with historical data and statistical models assists in predicting future traffic flows, congestion patterns, and travel behavior. This proactive planning approach enables the identification of potential issues before they materialize. GIS technology also facilitates data-driven decision-making by providing concrete evidence for resource allocation and improving network performance. In summary, GIS Network Analysis technology has significantly transformed transportation network analysis by providing valuable insights, enhancing decision-making processes, reducing traffic congestion, improving efficiency, and leading to substantial cost savings [4][5]. There are many research discuss the geospatial analysis and applications [6] [7][8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24],[25],[26],[27],[28],[29],[30],[31],[32],[33],[34],[35],[36].[37]. [38],[39],[40],[41],[42].[43],[44],[45],[46],[47],[48],[49], [50],[51],[52].

2. Methodology

There are many GIS Network Analysis Methods: Analysis, Design, Development, Implementation, and Evaluations.

2.1. Phase (1):Analyze of GIS Network Analysis: in this phase we should analyze requirement for GIS Network Analysis: Hardware, Software, Users, Data, and Methods. Furthermore, technology plays a critical role in GIS Network Analysis by utilizing Network Analysis (NA) services such as route optimization, determining closest facilities, estimating service areas, conducting location-allocation analysis, computing origin-destination cost matrices, and solving vehicle routing problems through GIS Software Online or customized enterprise services. This ensures accurate results suitable for realistic road networks. In summary, the analysis of GIS Network Analysis underscores its significance in geographic information science and its potential to address a wide array of network-based challenges. With advancements in methodology and technology integration, there are opportunities for further growth and innovative applications across various domains[53]

2.2. Phase (2): Design of GIS Network Analysis: in this phase we should design network. The process of designing GIS Network Analysis involves the gathering, arrangement, and interpretation of geographical data for the purpose of transportation planning. This provides valuable information on transportation networks, traffic patterns, and the best routes to take. Through the use of specialized software and algorithms, GIS data design enables planners to make well-informed decisions based on precise and comprehensive geospatial data. This comprehensive approach allows for more accurate analysis and decision-making. Additionally, GIS data design empowers transport planners to accurately analyze the spatial relationships within a transportation network, identify areas of traffic congestion, assess road conditions, and determine the most efficient routes. By integrating various data sources such as road networks, traffic volume, population density, and public transportation routes, GIS data design offers a comprehensive view of the transportation network. Furthermore, GIS data design allows for the visual representation of intricate transportation networks. By creating interactive maps and visualizations, transport planners can easily identify patterns, bottlenecks, and areas that require improvement. This visualization capability assists decision-makers in gaining valuable insights for infrastructure planning, expansion, and resource allocation. Additionally, real-time monitoring of the transportation network enables proactive decision-making and swift responses to traffic issues. In summary, effective GIS Network Analysis Design is crucial for transportation network analysis as it provides several key benefits: improving data visualization to identify transportation network patterns and problem areas; determining optimal routes to reduce travel time and fuel consumption; empowering decision-makers by providing valuable insights for infrastructure planning; enabling efficient management in emergency situations[54].

2.3. Phase (3): Develop of GIS Network Analysis: in this phase we should implement network through Route Network Analysis, Route Network Performing, and Route Network Results. The process of developing GIS Network Analysis entails the establishment of network data structures and the utilization of network analysis tools. These data structures are rooted in graph theory and topology, leading to significant advancements in GIS data structures. The initial step involves constructing network topology to ensure accuracy in road network data, followed by creating a network dataset for representing traffic data. The application of the Network analyst extension in GIS Software for Desktop facilitates the creation of a network dataset that models transportation networks, allowing for dynamic modeling of factors such as turn restrictions, speed limits, and traffic conditions. This extension employs Dijkstra's algorithm to calculate the least accumulated cost between destination nodes and other nodes in the network. Best route analysis and closest facilities analysis are two types of network analyses that can be applied. Moreover, the development of GIS Network Analysis also entails using attribute data to establish a database of road networks and identifying optimal routes based on specific travel expenses. This process aids in identifying ideal locations for service provision by enhancing resource movement and flow in complex road networks. Additionally, technological advancements in GIS have revolutionized transportation network analysis by providing professionals with valuable insights into commuter patterns, traffic flow, and infrastructure efficiency through diverse data sources. The integration of multiple data sources allows for a comprehensive understanding and informed decision-making regarding transportation systems. In conclusion, the development of GIS Network Analysis involves leveraging theoretical foundations in graph theory and topology to create advanced network data structures, as well as utilizing GIS technology to analyze transportation networks and optimize their efficiency[55].

2.4. Phase (4): implement of GIS Network Analysis : Expanding on the preceding stages of the GIS Network Analysis process, the execution phase represents a critical juncture where all the preparatory work culminates. First and foremost, the creation of a network dataset is imperative for modeling traffic data, necessitating a line feature class and tables for traffic data. This dataset consists of edges that represent travel links and junctions that facilitate navigation, enabling the modeling of realistic road network elements such as turn restrictions, speed limits, and varying traffic conditions. Subsequently, this dataset forms the foundation for subsequent spatial analyses based on network data. The GIS Software Network Analyst Extension serves as a robust tool for conducting route analysis, providing travel directions, performing closest facility analysis, and analyzing service areas. This extension utilizes Dijkstra's algorithm to calculate the minimum accumulated cost between destination nodes within the network. Best route analysis and closest facilities analysis are two common types of network analyses that yield valuable insights into optimizing transportation routes and identifying nearby facilities based on specific criteria such as distance or time. Furthermore, leveraging GIS Data Design can revolutionize transportation planning by employing advanced techniques like aerial imagery and GPS tracking to gather real-time and accurate data about road networks and traffic patterns. This data is then organized and optimized to create meaningful maps and models for analysis. In summary, the effective implementation of GIS Network Analysis methods plays a pivotal role in enhancing mobility, connectivity, and transportation efficiency. By harnessing the power of GIS technology, transportation planners can make informed decisions, optimize routes, identify bottlenecks, improve system performance, reduce congestion, and promote sustainable development[56].

2.5. Phase (5): Evaluate of GIS Network Analysis: When delving into GIS Network Analysis, it is crucial to take into account the rapid advancements in both geographic information systems (GIS) and network analysis from a methodological and scientific standpoint. GIS is specifically designed for the capture, storage, manipulation, analysis, and visualization of geographic information, with location serving as the foundation for its advantages. The application of GIS in addressing transportation issues stands out as one of its most significant areas of impact today. This involves the development of new data structures to represent the complexities of transportation networks and to execute various network algorithms. These enhancements encompass turn-tables, dynamic segmentation, linear referencing, traffic lines, and non-planar networks. Its usage has been increasingly prevalent in the private sector to aid logistics overall and distribution and production logistics in particular. Regarding applications of network analysis, GIS can be utilized for diverse purposes such as locating nearest sites, determining shortest distance routes, identifying fastest routes, establishing coverage areas, defining service areas, optimizing fleet management, selecting optimal site locations, and conducting origin-destination (OD) cost matrix analysis. It can also be applied for spatial interaction analysis through methods like kriging and spline. When evaluating accessibility using GIS technology based on network analysis techniques, service networks computed by the Network Analyst can surmount limitations by identifying accessible streets within a specific distance via the road network. In summary, GIS Network Analysis has evolved into an indispensable tool across various fields including transportation planning and management. Technological progress has enabled the execution of complex analyses that significantly contribute to decision-making processes across different sectors [57].

3. Discussions

Here we can discuss The GIS Network Analysis Applications for Renewable Energy

3.1. Finding the Nearest Locations

The utilization of GIS Network Analysis in locating of renewable energy resources (Solar, wind, and Biomass energy) the closest sites is a crucial component of spatial examination for renewable energy resources (Solar, wind, and Biomass energy). The incorporation of GIS technology empowers the creation of effective travel paths for renewable energy resources (Solar, wind, and Biomass energy), generation of travel guidance for renewable energy resources (Solar, wind, and Biomass energy), and definition of service areas based on travel time and distance covered for renewable energy resources (Solar, wind, and Biomass energy). This strategy aims to enhance renewable energy development by facilitating efficient visitation to various renewable energy resources (Solar, wind, and Biomass energy) sites with informed decision-making. The fusion of sustainable development (Society, Environment, and Economic) infrastructure with existing road transportation systems has been explored. we devised an indicator using a multi-criteria decision analysis approach to determine the nearest facilities renewable energy resources (Solar, wind, and Biomass energy), This illustrates how network analysis can contribute to lifestyle enhancements and transportation planning by considering road criteria essential for sustainable development (Society, Environment, and Economic) of renewable energy resources (Solar, wind, and Biomass energy). Moreover, network analysis techniques have demonstrated near real-time problem-solving capabilities through various GIS environment conceptual models. These models enable the determination of routes, closest facilities, estimation of service areas, and OD Cost-Matrix analysis among other applications. Additionally, non-planar network models have garnered interest due to their ability to represent complex network structures more effectively than planar models. In conclusion, GIS Network Analysis methods for renewable energy resources (Solar, wind, and Biomass energy) offer valuable insights into locating the closest sites through efficient route planning, allocation of facilities, and optimization of transportation networks [58].

3.2. Determining Shortest Distance Routes

Locating the most efficient travel paths is a fundamental aspect of GIS network analysis for renewable energy resources (Solar, wind, and Biomass energy), particularly in the realm of transportation for renewable energy resources (Solar, wind, and Biomass energy), logistics renewable energy resources (Solar, wind, and Biomass energy), and route optimization renewable energy resources (Solar, wind, and Biomass energy). When using network analysis with any GIS software, determining the shortest path involves finding the most optimal route that requires the minimal distance, time, or resources to travel from a specific starting point to a specific endpoint for renewable energy resources (Solar, wind, and Biomass energy). This takes into consideration constraints within the network such as distances, speed limits, one-way streets, and other road attributes. The analysis has applications in fields such as transport planning, logistics, and navigation. GIS software provides various algorithms like Dijkstra and A* (A-star) for calculating the shortest path by utilizing spatial data to determine the most efficient route for renewable energy resources (Solar, wind, and Biomass energy). Moreover, network analysis can be utilized to define service areas covered by specific transportation or distribution networks. This allows for mapping and analyzing the areas covered by a particular network, providing insights into service accessibility and coverage. Furthermore, it aids in decision-making for urban planning, transport management, and regional development. In renewable energy settings, GIS-based network analysis can be leveraged to establish the ideal route for visiting renewable energy resources (Solar, wind, and Biomass energy) destinations. In summary, GIS network analysis methods for renewable energy resources (Solar, wind, and Biomass energy) for determining the shortest distance routes offer valuable insights for optimizing transportation systems and improving logistical operations across various industries[59].

3.3. Identifying Fastest Routes

GIS Network Analysis provides techniques for finding efficient routes between locations for renewable energy resources (Solar, wind, and Biomass energy), including point-to-point analysis to determine the nearest destination and quickest route based on travel time. It considers factors like speed limits and road classification and allows for different modes of transportation. Integrating renewable energy resources data sources such as road networks and traffic patterns empowers professionals to identify efficient routes, leading to reduced travel time and fuel consumption. GIS data design is crucial for analyzing transportation networks and visualizing them through interactive maps. Real-time data feeds enable proactive decision-making and improve overall efficiency. Network Analysis using GIS can determine optimal locations for services renewable energy resources (Solar, wind, and Biomass energy) by calculating the quickest or shortest routes based on specific travel expenses. Overall, GIS Network Analysis plays a vital role in enhancing transportation systems by reducing travel time, lowering costs, and improving emergency management for renewable energy resources (Solar, wind, and Biomass energy)[60].

3.4. Finding Coverage Areas

GIS Network Analysis Methods and Applications renewable energy resources (Solar, wind, and Biomass energy): Uncovering Coverage Areas. In the realm of GIS Network Analysis, uncovering coverage areas is a fundamental aspect that involves determining which locations fall within a specified impedance from a particular point. This type of network analysis is particularly valuable for various applications, such as identifying service areas for facilities renewable energy resources (Solar, wind, and Biomass energy), pinpointing the nearest locations for renewable energy resources (Solar, wind, and Biomass energy), and optimizing fleet management renewable energy resources (Solar, wind, and Biomass energy). One of the primary applications of uncovering coverage areas is in service area analysis renewable energy resources (Solar, wind, and Biomass energy), where it is crucial to identify which residences or businesses are within a certain distance from a specific facility. For instance, establishing the 10-minute service area for renewable energy resources (Solar, wind, and Biomass energy) can provide insight into which areas are covered within a specified time frame. This type of analysis takes into consideration the street network and can offer valuable insights into accessibility and coverage for renewable energy resources (Solar, wind, and Biomass energy). Furthermore, uncovering coverage areas is also utilized in optimizing fleet management by determining the range of vehicles within a specified impedance. This can be particularly beneficial for logistics and delivery companies looking to optimize their operations by identifying the most efficient routes based on accessibility and coverage. Moreover, network analysis methods for uncovering coverage areas play a critical role in selecting optimal site locations by analyzing the accessibility and reach from potential locations to desired destinations. By comprehending the coverage areas, organizations can make informed decisions about where to locate new facilities based on proximity to customers or other crucial factors. Overall, uncovering coverage areas for renewable energy resources (Solar, wind, and Biomass energy) through GIS network analysis methods is an important tool for understanding accessibility, reach, and service coverage in various applications such as emergency services, transportation planning, and infrastructure development for renewable energy resources (Solar, wind, and Biomass energy)[61].

3.5. Determining Service Areas

Mapping and analyzing the areas covered by a specific network in GIS is a vital method for service area analysis. This type of analysis is crucial for making informed decisions about planning, equipment location, and service accessibility for renewable energy resources (Solar, wind, and Biomass energy). It allows users to visualize and quantify the geographical reach of a given network, which can facilitate decision-making in urban planning, transport, and regional development for renewable energy

resources (Solar, wind, and Biomass energy). One straightforward way to assess accessibility for renewable energy resources (Solar, wind, and Biomass energy) is by using a buffer distance around a point. However, since people travel by road, this method may not accurately reflect the actual accessibility to the site. Service networks computed by Network Analyst can overcome this limitation by identifying the accessible streets within a specified impedance from a site via the road network. This makes it possible to see what is alongside the accessible streets, such as finding competing businesses within a specific drive time. Additionally, service area analysis is valuable for logistics and delivery companies seeking to optimize their operations by identifying efficient routes based on specific impedance criteria. This type of analysis enables them to accurately predict traffic flows and anticipate congestion hotspots while designing road networks and traffic management systems. In summary, service area analysis for renewable energy resources (Solar, wind, and Biomass energy) in GIS plays a critical role in identifying optimal locations for service delivery and improving accessibility. By leveraging the capabilities of geographic information systems and network analysis tools, it provides valuable insights into traffic patterns, congestion hotspots, and optimization strategies for renewable energy resources (Solar, wind, and Biomass energy)[62].

3.6. Optimizing Fleet Management

Efficient fleet management for renewable energy resources (Solar, wind, and Biomass energy) is a key application of GIS network analysis, allowing transportation professionals to effectively allocate resources and reduce operating costs. Through the use of GIS renewable energy resources data design, organizations can identify inefficiencies in fleet operations and optimize routes, resulting in significant cost savings and increased efficiency. Effective route planning is essential for optimizing transportation networks, and GIS data design provides access to spatial data such as road networks for renewable energy resources (Solar, wind, and Biomass energy), traffic patterns for renewable energy resources (Solar, wind, and Biomass energy), and historical traffic data for renewable energy resources (Solar, wind, and Biomass energy). This information enables transportation professionals to identify the most efficient routes, reduce travel time, and minimize fuel consumption. Additionally, GIS technology supports real-time monitoring of the transportation network, enabling proactive decision-making and quick responses to traffic issues. Improved emergency response is another crucial aspect of fleet management, with GIS renewable energy data design aiding in identifying accident-prone areas and high-risk zones within transportation networks. By understanding these risk factors, transportation authorities can implement targeted safety measures to reduce accidents and enhance overall road safety. In conclusion, leveraging the potential of GIS data design in optimizing fleet management for renewable energy resources (Solar, wind, and Biomass energy) is essential for developing sustainable and efficient transportation infrastructure. By integrating GIS techniques into planning processes, cities can create smarter transportation systems that enhance residents' quality of life while promoting environmental sustainability for renewable energy resources (Solar, wind, and Biomass energy)[63].

3.7. Selecting Optimal Site Locations

GIS network analysis for renewable energy resources (Solar, wind, and Biomass energy) is crucial for identifying prime site locations for facilities or services. It considers factors like proximity, access, and travel distances, providing valuable insights through network analysis tools. In renewable energy(solar, wind, and biomass energy), it helps pinpoint areas with high demand for renewable energy resources services and strategically places new facilities for better accessibility and improved renewable energy resources (Solar, wind, and Biomass energy) outcomes. It's also useful in retail and logistics for renewable energy resources (Solar, wind, and Biomass energy), helping businesses find ideal locations for stores or warehouses based on customer demographics and transportation infrastructure, optimizing distribution efficiency and minimizing costs. GIS technology allows organizations to conduct comprehensive spatial analyses when selecting optimal site locations for renewable energy resources (Solar, wind, and Biomass energy) by considering factors such as population density, existing infrastructure, and transportation networks, leading to well-informed choices beneficial for both the organization and the community. In conclusion, GIS network analysis methods for renewable energy resources (Solar, wind, and Biomass energy) are essential for identifying optimal site locations, offering insights into spatial relationships and accessibility that lead to more efficient service provision and improved overall outcomes for renewable energy resources (Solar, wind, and Biomass energy)[64].

3.8. Origin-Destination (OD) Cost Matrix Analysis

The OD cost matrix analysis for renewable energy resources (Solar, wind, and Biomass energy) stands as a pivotal instrument in GIS network analysis, allowing for the computation of network impedance from every origin to every destination. This analysis furnishes a ranked table of destinations based on the minimum network impedance required to travel from each origin. The outcomes of this analysis hold great significance for a variety of uses, including identifying nearest locations for renewable energy resources (Solar, wind, and Biomass energy), determining shortest distance routes for renewable energy resources (Solar, wind, and Biomass energy), finding fastest routes for renewable energy resources (Solar, wind, and Biomass energy), defining coverage areas for renewable energy resources (Solar, wind, and Biomass energy), establishing service areas for renewable energy resources (Solar, wind, and Biomass energy), optimizing fleet management for renewable energy resources (Solar, wind, and Biomass energy), and selecting prime site locations for renewable energy resources (Solar, wind, and Biomass energy). The process of conducting OD cost matrix analysis entails the creation of an origin-destination (OD) cost matrix from multiple origins to multiple destinations for

renewable energy resources (Solar, wind, and Biomass energy) using Network Analyst. This matrix contains the network impedance and ranks destinations based on the minimum impedance required for travel. The best network path is identified for each origin-destination pair, and the cost is recorded in the attribute table of the output lines. One of the major advantages of OD cost matrix analysis for renewable energy resources (Solar, wind, and Biomass energy) is its capacity to identify the closest destinations from each origin, offering valuable insights for industries. Furthermore, it provides a means to determine efficient routes and service areas crucial for logistics and distribution planning for renewable energy resources (Solar, wind, and Biomass energy). Through the utilization of GIS technology, OD cost matrix analysis allows decision-makers to make informed choices regarding route optimization for renewable energy resources (Solar, wind, and Biomass energy), facility location selection for renewable energy resources (Solar, wind, and Biomass energy), and resource allocation for renewable energy resources (Solar, wind, and Biomass energy). In conclusion, OD cost matrix analysis for renewable energy resources (Solar, wind, and Biomass energy) represents a potent method within GIS network analysis with diverse applications across various sectors. Its capability to provide valuable insights into travel costs and optimal routes renders it an invaluable tool for decision-making in different industries for renewable energy resources (Solar, wind, and Biomass energy)[65].

3.9. Utilizing the Huff Model for Spatial Interaction Analysis

Spatial interaction analysis plays a vital role in GIS network analysis, and one particularly valuable model for this purpose is the Huff Model. The Huff Model serves as a spatial interaction model that enables the examination of consumer behavior and the forecasting of sales potential for different locations. It considers factors like distance, competition, and the appeal of various locations to determine the likelihood of a consumer from one location traveling to another location to make a purchase. This model can be utilized in diverse scenarios, including retail site selection, development of marketing strategies, and urban planning for renewable energy resources (Solar, wind, and Biomass energy). The underlying principle of the Huff Model is that consumer behavior is impacted by both the distance to a potential location and the attractiveness of that location. By integrating spatial data on consumer demographics, competitor locations, and other relevant factors using GIS network analysis methods, it becomes feasible to create spatial interaction models that accurately forecast consumer behavior. This can aid businesses in making well-informed decisions about where to establish new stores or run marketing campaigns, as well as help urban planners comprehend movement patterns within a city. The application of the Huff Model for spatial interaction analysis serves as just one example of how GIS network analysis methods and technology can be harnessed to gain valuable insights into geographical phenomena. By leveraging spatial data and advanced mapping techniques, it becomes possible to analyze complex systems such as transportation networks and consumer behavior in ways that were previously unattainable. This opens up new avenues for research across various disciplines and has the potential to impact decision-making processes in fields like retail, urban planning, and transportation logistics for renewable energy resources (Solar, wind, and Biomass energy)[66].

4. Conclusion

In conclusion, GIS network analysis methods for renewable energy have proven invaluable in geographic information science by providing opportunities for research across a wide range of disciplines. The ability of network analysis to represent complex systems intuitively has become increasingly important in an increasingly complex world. Additionally, as networks are fundamentally spatial, there is clear potential for research in network analysis that could prove valuable across various disciplines. In conclusion, GIS network analysis methods and applications have great potential in optimizing transportation infrastructure for sustainable development. Leveraging this technology will continue to play a critical role in transportation safety, data collection for modeling and analysis purposes, as well as the overall improvement of intelligent transportation systems (ITS) for renewable energy[67][68][69][70].

References

[1] "NETWORK ANALYSIS in GIS - Remote sensing, GIS and GPS". (Accessed Jan 13, 2024). [Online]. Available: https://ebooks.inflibnet.ac.in/geop10/chapter/network-analysis-in-gis/

[2] Manfred M. Fischer. "GIS and network analysis". Jan 2004. [Online]. Available: https://www.researchgate.net/publication/23730944_GIS_and_network_analysis

[3] "5 Types of Network Analysis in GIS - GIS Geography". Oct 2023. [Online]. Available: https://gisgeography.com/network-analysis/

[4] "Importance of GIS data design in transportation network analysis". (accessed Jan 13, 2024). [Online]. Available: https://utilitiesone.com/importance-of-gis-data-design-in-transportation-network-analysis

[5] M. Fisher. "GIS and Network Analysis". (accessed Jan 13, 2024). [Online]. Available: https://trid.trb.org/view/760235

[6] Geoinformatics Sustainable Development Goals: Consumption& Production, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 12/2023

[7] Geoinformatics Sustainable Development Goals: Sustainable Cities & Communities, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 11/2023

[8] Geoinformatics Sustainable Development Goals: inequalities, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 10/2023
[9] GIS Data Model Sustainable Renewable Energy Development for Mineral Exploration, Ministry of Mineral workshop, TAT Ali, 2023
[10] Geoinformatics Sustainable Development Goals: Industry, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 9/2023
[11] Geoinformatics Sustainable Development Goals: Economic, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 8/2023
[12] Geoinformatics Sustainable Development Goals: Energy, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 7/2023
[13] Geoinformatics Sustainable Development Goals: Water & Sanitation, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 6/2023
[14] Geoinformatics Sustainable Development Goals: Gender, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 5/2023
[15] Geoinformatics Sustainable Development Goals: Education, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 4/2023
[16] Geoinformatics Sustainable Development Goals: Health, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 3/2023
[17] Geoinformatics Sustainable Development Goals: Hunger, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 2/2023
[18] Geoinformatics Sustainable Development Goals: Poverty, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 1/2023
[19] Geoinformatics Sustainable Development Goals: Partnerships, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 12/2022
[20] Geoinformatics Sustainable Development Goals: Peace Institutions, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 11/2022
[21] Geoinformatics Sustainable Development Goals: Life on land, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 10/2022
[22] Geoinformatics Sustainable Development Goals: Life below Water, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 9/2022
[23] Geoinformatics Sustainable Development Goals: Climate Actions, TAT Ali, Geo4SDG Sudan Forum, GeoFive Training & Consulting, Sudan, 8/2022
[24] Enterprise Geospatial Database Develop Coronavirus Disease (Covid-19), TAT Ali, Rihan Journal for Scientific Publishing, 2022.
[25] Museum Tourism in Khartoum, Analysis and Decision Sudan: A Geoinformatics Support System, TAT Ali, S Subair, H AlEisa, Proceedings of the International Conference on Image Processing, Computer , 2017
[26] Geospatial Economic Crisis Response Gas Station, TAT Ali, Asian Research Journal of Current Science 4 (1), 197-204, 2022
[27] Geospatial Technology Renewable Energy Trends & Opportunities & Futures Research, TAT Ali, Asian Basic and Applied Research Journal 5 (4), 12-15, 2022
[28] GIS-based Model: 5A's Business Tourisms Attractions Tourism, Accommodations, Access Transportation, Amenity Service, Awareness, TAT Ali, Asian Research Journal of Current Science, Indian 4 (1), 188-196, 2022
[29] GeoSpatial Technology Documental Historical Tourism Site: Turkey in Khartoum, TAT Ali, JCCO Joint International Conference on ICT in Education and Training,2018
[30] Geospatial-Enable Hotels Call Center in sudan, TAT Ali, Sudanese Journal of Computing and Geoinformatics, 2018t
[31] Business Hotels Tourism Sites in Khartoum, TAT Ali, GIS Web-based,Sudan (1-5), 2018
[32] Geoinformatics distribution Reality Analysis For Sustainable Business Tourism Development, TAT Ali, Gadarif University Journal Of Humanity Science(ISSN:1858-8840) 3 (1), 2017
[33] Space Technology and Development (Social, Economic and Environment), TAT Ali, Digital Transformation Towards Efficiency and Excellence 1 (1), 1-13, 2023

[34] GIS UML-based Business Object Modelling: Renewable Energy, TAT Ali, International Journal of Engineering and Information Systems (IJEAIS), 2022
[35]Sudanese Enterprise Museum System - SEMS, TAT Ali, Algulzum Scientific Journal(ISSN:1858-9766) 1 (11), 55-74
[36] GIS-based Analysis : Water & wastewater Distribution Network, (2022) TAT Ali, M Daleel, Algulzum Scientific & Security& Strategy Journal, 8 (1), 133-148, March 2022
https://www.researchgate.net/publication/373328395_GIS-based_Analysis_Water_wastewater_Distribution_Network

[37] Geoinformatics Tourism Optimal Site Selection Analysis, Khartoum, Sudan, TAT Ali, Academic Journal of Research and Scientific Publishing| AJRSP, 2020
[38] GIS-based DSS Data Model Business Tourism in Sudan, TAT Ali, Sudanese Journal of Computing and Geoinformatics , 2017.
[39]Data Model Business Tourism in Sudan, TAT Ali, DSS GIS-based
Sudanese Journal of Computing and Geoinformatics, Geoinformatics Center, 2017

[40] GIS Data Model Solar Energy Development, TAT Ali, R Saeed, G Hayder, 1st Science Engineering Technology and Sustainability International , 2021
[41] Geospatial Big Data Analytics Applications Trends, Challenges & Opportunities.TAT Ali, Asian Basic and Applied Research Journal, India 5 (3), 1-5, 2022
[42] Geoinformatics Technology Distributed Geospatial Database Development for Economic Crisis Management and Natural Disasters, TAT Ali, Academic Journal of Research and Scientific Publishing| AJRSP(2706-6495) 35, 2022
[43] Geoinformatics Applications : Tourisms Applications System,(2022), TAT Ali, M Daleel, Algulzum Scientific Journal, 17 (1), April 2022
https://www.researchgate.net/publication/359175974_Geoinformatics_Applications_Tourisms_Applications_System_Gulzum_Science_Journal_17_Apr_2022

[44] Geospatial Technology Archaeologies: Gari Region, TAT Ali, Academic Journal of Research and Scientific Publishing| AJRSP, 34 , 2022
[45] Spatial Statistics Nearest Neighbor Distribution Analysis For Tourism& Archaeology In Khartoum, Sudan, TAT Ali, Journal of The Faculty of Science and Technology (JFST),2019
[46] GIS & RS-Based Archaeologies Site Documents: Gari Region, Khartoum, Sudan, TAT Ali, JCCO Joint International Conference on ICT in Education and Training. 2018
[47]GIS-based E-Promotion: Prehistoric Sudan: The Mesolithic and Neolithic Periods, TAT Ali, GIS&Geospace Applications Journal.
[48] GIS-based Reality Analysis: Business Hotels Tourism In Khartoum State, TAT Ali, Red Sea University Journal of Basic and Applied Science, 2017
[49] GMGD: Geospatial Measuring Geographic Distributions Cellular Phone Towers, TAT Ali, International Journal of Engineering and Information Systems (IJEAIS), 6 ,4 , 2022
[50] GIS-based web Application Marketing: Turkey Historical Site in Khartoum, TAT Ali, Rihan Journal for Scientific Publishing, 2022
[51] Enterprise GeoSpatial Database Development : Strategic Affairs in Sudan, TAT Ali, Journal of science & Space Technology,5, 56-64, 2019
[52] Agile Enterprise Geographic Information System (AEGIS) from design and development perspective, TAT Ali, RA Saeed, OO Khalifa, ES Ali, N Odeh, G Hayder, AA Hashim, 8th International Conference on Mechatronics Engineering (ICOM 2022), 26-31, 2022
[53] "Guide to Network Analysis (Part 1 - Network Dataset and Network Analysis) | GIS Software API for Python". Jan 2024. [Online]. Available: https://developers.arcgis.com/python/guide/part1-introduction-to-network-analysis/
[54]] A. K. Singh, K. Mohan, P. Kumar and P. K. Singh. "Network Analysis Using GIS". Oct 2013. [Online]. Available: https://www.researchgate.net/publication/259572597_Network_Analysis_Using_GIS
[55] "Network Analysis in Geographic Information Science: Review, Assessment, and Projections". Mar 2010. [Online]. Available: https://locationscience.ua.edu/People/Curtin/NetworksCAGIS.pdf
[56] Sayed. "GIS-Based Network Analysis for the Roads Network of the Greater Cairo Area". Mar 2018. [Online]. Available: https://ceur-ws.org/Vol-2144/paper2.pdf
[57] "Geographic Information System (GIS) in Network Analysis - 1986 Words | Book Review Example". (accessed Jan 13, 2024). [Online]. Available: https://ivypanda.com/essays/geographic-information-system-gis-in-network-analysis/
[58] K. Mohan. "Network Analysis Using GIS". (accessed Jan 13, 2024). [Online]. Available: https://www.academia.edu/59621933/Network_Analysis_Using_GIS
[59]] "QGis shortest path network analysis tools | Blog GIS & Territories". Jul 2023. [Online]. Available: https://www.sigterritoires.fr/index.php/en/qgis-shortest-path-network-analysis-tools/

[60] ADMIN. "Content Writer Prof. R.K. Kohli Prof. V.K. Garg & Prof. Ashok Dhawan". Feb 2018. [Online]. Available: http://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/S000014ER/P000276/M027498/ET/1519197866Paper-06_Module_27_etext.pdf
[61] "Types of network analysis layers-ArcMap | Documentation". Sep 2021. [Online]. Available: https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/types-of-network-analyses.htm
[62] Fischer, Manfred M.. "GIS and Network Analysis". Apr 2003. [Online]. Available: https://www.econstor.eu/bitstream/10419/116172/1/ERSA2003_433.pdf

[63]] Manfred M. Fischer. "GIS and Network Analysis". Aug 2003. [Online]. Available: https://ideas.repec.org/p/wiw/wiwrsa/ersa03p433.html
[64] M. Eleiche. "Network Analysis Methods for Mobile GIS". (accessed Jan 13, 2024). [Online]. Available: https://www.academia.edu/677437/Network_Analysis_Methods_for_Mobile_GIS
[65] "Network Analysis - GIS Wiki | The GIS Encyclopedia". Apr 2021. [Online]. Available: http://wiki.gis.com/wiki/index.php/Network_Analysis
[66] "Microsoft Word - EESE10891035.docx". (accessed Jan 13, 2024). [Online]. Available: https://iopscience.iop.org/article/10.1088/1755-1315/1089/1/012035/pdf
[67] S. Czapiewski. "28 - Bielawy, 29 - Bartodzieje, 30 - Babia Wies, 31 - Czersko Polskie, 32 - Zimne Wody, 33 - Skrzetusko, 34 - Bonie, 35 - Gorzyskowo, 36 - Srodmiescie, 37 - Szwederowo, 38 - Wzgorze Wolnosci, 39 - Kapusciska, 40 - Glinki, 41 - Wyzyny". Jun 2019. [Online]. Available: https://apcz.umk.pl/JEHS/article/download/6990/pdf/56624
[68] "Geographic information system - Wikipedia". Jan 2024. [Online]. Available: https://en.wikipedia.org/wiki/Geographic_information_system
[69] Claudia M. Viana, E. Gomes, I. Boavida-Portugal and J. Rocha. "Introductory Chapter: GIS and Spatial Analysis". Jul 2023. [Online]. Available: https://www.intechopen.com/chapters/87154
[70]] "o". May 2008. [Online]. Available: https://locationscience.ua.edu/People/Curtin/NetworkAnalysis2.pdf