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RESEARCH ARTICLE

Mapping Vulnerabilities: A Geospatial Approach to Post-Covid-19 Tourism Planning in Ile-Ife

Oluwadare Caleb Olutayo[1], Abidoye Ayodeji Iyanu[1], Abiri Anthony Olatunbosun[1], Onimhawo Oswald Ekpemhi [1] and Ataman Efesoa Faith[1]

[1]Department of Surveying and Geoinformatics, Obafemi Awolowo University, Ile-Ife, Nigeria.

Corresponding email: faithataman@gmail.com

Abstract

The COVID-19 pandemic significantly impacted the tourism sector in Ile-Ife, Nigeria, exposing vulnerabilities in emergency preparedness and response. This research investigates the spatial relationships between tourist centres and essential service facilities (healthcare, fire services, police stations), and COVID-19 incidence using geospatial techniques by mapping the location of tourism centres, service facilities and COVID-19 incidences in the study area. The study also designed a geodatabase of tourist centres and the service facilities and analysed the spatial distribution and relationship of the tourist centres and service facilities for emergency response planning. Primary data on facility locations and secondary data on COVID-19 cases were integrated into a GIS database. Nearest Neighbour Analysis revealed a random distribution of tourist centres and dispersed patterns for emergency service facilities, indicating a potential gap in accessibility. Route analysis also identified specific tourist centres with limited access to emergency services within a 2km radius. The study also highlights the potential for spatial overlap between tourist activity and COVID-19 hotspots. These findings inform recommendations for post-COVID-19 tourism planning, emphasizing the strategic use of GIS for improved emergency response, resource allocation, and risk management to ensure a safer and more resilient tourism experience in Ile-Ife.

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1.0 INTRODUCTION

1.1 Background to the Study

Tourism is a significant contributor to global income and is considered to be a vital export industry and major source of foreign exchange earnings in countries like the United States, the United Kingdom, Germany, China, and Austria. Fadahunsi (2003) opined that tourism encompasses the interactions between the tourist and host communities during the attraction and hosting of visitors. This implies that tourism is an interactive experience that involves both tourists and the local and immediate community. The study of the types, forms, patterns and relationships that exist between the tourist centers and the local communities will provide useful information for tourism planning and management practice. Ile-Ife, an ancient city in south-western Nigeria, holds a prominent place in Yoruba history and culture, attracting tourists from around the globe.

Tourism plays a vital role in the city's economy and social development. Several historical sites and cultural festival celebrations have provided economic benefits to the ancient city through the provision of services relating to transportation, health, communication, recreation and hospitality among others. This justifies the possibility for spatial interaction between the tourists and the immediate environment;, implying that the interaction of tourists is not limited to the tourist centers only but with other facilities that provide essential services for a smooth tourist tour. These tourism service facilities revolve around, transportation,

communication, health, security, hospitality, recreation and sports, etc. However, during the pandemic, the Ile-Ife tourism industry experienced an unprecedented downturn in revenue generation as a result of physical control measures relating to limited social contact and social distancing so as to reduce the risk of infection and to minimize the spread of the virus. The general experience that impacted tourism sector in Nigeria during the pandemic is a wake-up call for a systematic approach and planning for responding to health-related emergencies in the tourism sector in the country.

At present, there exists no evidence of serious scientific planning approach from the government on management strategies especially regarding problems of contact tracing and emergence response services that emanated during Pandemic that ravaged the entire globe; whereas, efficient diseases tracking and control will require a systematic with spatially integrated tools for spatial contact tracing and spatially enabled emergency responses services. Furthermore, the COVID-19 pandemic presented significant challenges including difficulties in contact tracing and emergency response, highlighting the need for improved spatial planning and management to Ile-Ife's tourism sector. The pandemic highlighted the need for a spatially informed approach to tourism planning, one that considers the distribution of tourist attractions, accessibility to essential services and potential health risk mapping for tourists, particularly in managing health crises and ensuring tourist safety.

This study is developed on the premise of related theories and concepts, the framework converges on spatial interaction theory, accessibility theory, risk management theory and sustainable development theory. This study integrated these frameworks for a more resilient post-COVID-19 tourism recovery planning that is capable of fostering a sustainable tourism sector and capable of handling future occurrences in Ile-Ife. The framework allows identification of variables regarding public health, location of tourism attractions, and location of service facilities, population as well as location and count of COVID-19 incidence. The integration of these variables ensures an efficient approach to post-COVID-19 tourism planning. This research focuses on the analysis of the spatial distribution of tourist centers, healthcare facilities, fire services, police stations, and COVID-19 incidence in Ile-Ife. It further identified vulnerabilities by examining the spatial relationships and highlighted the critical need for improved spatial planning and a more resilient and sustainable post-COVID-19 tourism in the city.

2.0 LITERATURE REVIEW

Tourism is a multisectoral phenomenon whose activity goes beyond travelling; it is an important sector that contributes globally to socio-economic, fiscal and physical development by increasing revenue, improving standards of living for individual income earners and creating job opportunity (UNWTO 2023, Johnson, etal. 1994 and Mason, 2003) and hence, contributes substantially to foreign exchange earned by developed and developing countries. With several complex relationships existing between tourism and host communities, the critical need for strategic planning and management of the complexities cannot be overemphasised.
Studies on the Osun state tourism sector have adopted a mixed methodology to determine factors responsible for local tourism participation in the state. Studies indicated that local tourism participation is significantly influenced by factors such as accessibility, education, income, occupation, and age. Ogunsusi and Boluwaji (2020); Olatunji and Ezenagu (2016); and Lebana and Sati (2017) presented several tourism attractions within the state with their potential economic benefits. This underscores the necessity of adopting a comprehensive approach to sustainable tourism development and management. Celebration of cultural festivals coupled with the presence of several prominent historical sites of great significance to Yoruba history has given Ile-Ife a prominent position as a tourism city in Osun state (See figure 1. a, b, c and d). These sites and festivals often attract visitors from both locally and international terrain providing substantial benefits in terms of economic and physical development of the city.

The tourism sector in Ile-Ife is currently faced with the lack of a spatial database that contains relevant information about visitors, tourism sites, tourism infrastructure as well and tourism activities. This is a potential challenge that has continued to hinder the adoption of a more scientific approach to spatial planning on matters relating to risk management, emergency response services and resource allocation to the tourism sector of the city. Essentially, these problems can be addressed by leveraging GIS technology effectively with the capability to precisely define locations, and analyze spatial interactions using diverse data sources to establish the interplay that exists between essential service facilities, and other relevant factors operating within the tourism landscape.

In the tourism sector, the disruption experienced during the pandemic was the consequence of the decision of governments of many countries to restrict movement in public health interest harmed the global tourism sector. This exemplifies the relationships between tourism and other sector of the economy and the vulnerability of the tourism sector as an interdependent sector as opined by ECLAC, (2020); Sigala, (2020); Rahman et al., (2019) and Fadahunsi, (2011). In Ile-Ife, the pandemic exposes the vulnerability of the tourism industry regarding contact tracing, emergency preparedness and poor allocation of resources for tourism and management. For a post-COVID-19 tourism recovery, the UNWTO (2023) advocated for a holistic understanding of the complex relationships between tourism and other sectors that provide support services for tourism. This can be determined by having a broad conceptualization of the tourism value chain, understanding the dynamic connectedness between tourism and locations, and identifying of factors and causalities that influence sustainable tourism development. Though several studies have provided global and regional thoughts on COVID-19 management using geospatial techniques, a localized study is important in culturally significant locations like in Ile-Ife within the context of post-COVID-19 tourism planning and management. By adopting GIS technology, effective disease monitoring, tracking and prompt emergency response services can be provided by integrating geo-data with spatial tools and technologies. By integrating locations of tourist attractions and other relevant tourism service facilities with COVID-19 hotspot locations in Ile-Ife, a framework for addressing the identified problems can be developed. This will provide accurate information to decision makers on the degree of vulnerability through spatial analysis. This spatial analysis will provide decision-makers with accurate vulnerability information, enabling them to make informed decisions regarding support and interventions (Khalifa et al., 2020; Mimi Li et al., 2015; Najmeh et al., 2021; Karaye, 2020; Ciro et al., 2022 and Rakibul et al., 2022). Consequently, GIS can support proactive risk mitigation and enhance the resilience of Ile-Ife's tourism sector.

Ahasan, et al. (2022) in a systematic manner reviewed GIS and spatial analysis in COVID-19 research, the study revealed that GIS has played a crucial role in visualizing COVID-19 spread and providing accurate information to the public. Several studies have shown that spatial analyses such as hotspot detection and autocorrelation have significant contributions to understanding transmission patterns of the pandemic. Global and regional studies have also explored the combination of qualitative and quantitative data integrated with GIS to express vulnerability in this regard.

Primarily focusing on the potential benefits of GIS solutions to post-COVID-19, Neysani et al., (2022) provided an overview of ten (10) important areas, giving examples of their uses in real-world scenarios where the GIS system can be applied to manage and control the COVID-19 pandemic. The categorization included spatiotemporal analysis, spatial decision support system, public participatory GIS, location-based service, web mapping, medical waste collections, geo business, spatial decision support, Internet of Things (OIT) among others. The study provided a clear framework for understanding the diverse uses of GIS. However, in a localized tourism context like Ile-Ife, the digital divide may pose a significant threat to the effectiveness of GIS-based pandemic planning and response;, particularly in the interventions to empower marginalized communities through a participatory GIS (PGIS).

GIS is quite a useful spatial decision support system that offers efficient and effective solutions to solve different problems with promising evidence in tourism. It is a system that offers a wide range of capabilities through spatial analysis and data visualization. Fadahunsi (2011) underscores that adopting GIS system to promote sustainable tourism growth and development cannot be overemphasized. Oliver (2017) also highlighted the potential of GIS to integrate different forms of tourism information. The duo suggested the necessity for a unified and user-friendly system that will provide accessibility to tourism information for all stakeholders in the tourism industry. However, the study focused on visualization and lacked consideration for spatial relationships and patterns.

More importantly, the ability to integrate demographic, geographic, ecological, environmental, social, economic and cultural data into GIS can facilitate effective Environmental Impact Assessments (EIAs) that will allow informed decisions to mitigate the environmental footprint of tourism activities. Sustainable tourism development has immensely benefited from the application of GIS by harnessing its capacity for economic and land resource allocation, optimum route determination, and suitability analysis to enhance tourist satisfaction and to promote destination competitiveness within tourism landscape as demonstrated by Min-Seong et al. (2017) and Altinay et al. (2016).

Furthermore, sustainable tourism practices depend on efficient resource allocation, which underscores the necessity of understanding spatial relationships between geographic objects and the forms of spatial interactions between them. As highlighted by Farsari (2004), tourism resources comprise different elements, including tourist infrastructure (historical locations), demographic data, and natural/cultural locations. Further on this, Rahman (2010) expresses the potential of GIS for ecotourism planning; the study specifically highlighted the crucial role of GIS in the process to monitor land-use changes and assess environmental impacts for effective and efficient resource allocation.

Jurkus et al. (2021) explored the intersection of tourism sustainability and competitiveness in seaside and marine resorts of Karklė, Lithuania. Within the context of SDGs, the study employed a mixed-methods approach by combining the Delphi technique, remote sensing and GIS spatial analysis. To balance tourism development with environmental sustainability, GIS was able to identify deficiencies and propose solutions for marine spatial planning. The integration of local knowledge and values with spatial analysis makes the methodology highly relevant to localized cultural settings like Ile-Ife for sustainable tourism planning. The study of Mărgărit-Mircea et al. (2020) emphasized the need for spatially enabled strategies for emergency preparedness in tourism. The spatial enhanced emergency preparedness provides understanding for responses by mapping risk zones, analyzing accessibility, modelling evacuation, real-time monitoring and resource allocation. Though Mărgărit-Mircea et al. (2020) mentioned tourism infrastructure and tourism services as key factors, the GIS analysis does not consider the relationships.

Furthermore, post-pandemic tourism planning for the localized area of Ile-Ife necessitates risk zone mapping and accessibility to facilities as important elements for post-COVID-19 tourism planning. Studies have successful tracked the spatiotemporal progression of COVID-19, demonstrating its spread from one location to another by exploring multiple geospatial models for analysis and visualization. Mărgărit-Mircea and Alexandru-Sabin (2021) explored GIS to model transnational tourism flows by documenting all tourist origins and destinations. Similarly, Kang et al. (2022), Zheng et al. (2022), Sihala (2020), and Tsai et al. (2021) employed spatial analysis tools, such as Moran's I and Getis-Ord Gi statistic, to analyze tourism hotspots and assess vulnerability for emergency response. Moreover, the research from Muhammad et al. (2022) used spatial autocorrelation methods to map the distribution of COVID-19 in Afghanistan, the study showcases the application of GIS to disease spread analysis and informs public health interventions. Similarly, an assessment of COVID-19 Spread was presented over Oman by Al-Kindi et al. (2020), The study employed multiple GIS models, such as Weighted Mean Centre (WMC), Standard Deviational Ellipses (SDE), Moran's I, Getis-Ord General-G, and Getis-Ord G*i. to analyze the spatial distribution of the COVID-19 cases.

Nadeem et al. (2021) explored the potential of digital technologies, such as virtual and augmented reality, for post-COVID-19 tourism recovery. However, these digital solutions require integration with spatial analysis to address localized challenges and emergency response planning. The integration of digital tourism with spatial analysis will allow for better resource allocation, crowd management, and emergency routing, enhancing the overall tourist experience and ensuring safety. The findings of studies by Kang et al. (2022), Muhammad *et al.,* (2022), Al-Kindi et al. (2020), Kang et al. (2022), Zheng et al. (2022), Sihala (2020), and Tsai et al. (2021) have offered valuable insight into the spatial dynamics of COVID-19; the exploration of time series data by these studies also provides understanding into the spatiotemporal transmission of the disease across several countries and locations. Consequently, insight can be gained into relevant information for future preparation on identifying vulnerable demography and location as well as the development of healthcare infrastructure, and control measures for future spread of pandemic by taking into account the COVID-19 hotspots.

The existing literature further underscores the critical role of spatial analysis in tourism planning and emergency response, particularly in the context of the COVID-19 pandemic. GIS offers a powerful framework for analyzing spatial relationships, identifying vulnerabilities, and informing evidence-based decision-making. However, there is a notable gap in the literature regarding the application of geospatial techniques to localized cultural tourism settings, such as Ile-Ife. While studies have addressed tourism planning and pandemic response separately, few have integrated these aspects within a comprehensive spatial framework tailored to specific cultural tourism destinations.

This research aims to bridge this critical gap by conducting a comprehensive spatial analysis of tourist centers, essential service facilities, and COVID-19 incidence in Ile-Ife. By employing a suite of GIS

techniques, including nearest neighbor analysis, route analysis, and hotspot detection, this study will identify spatial patterns and relationships that inform post-COVID-19 tourism planning and emergency response strategies. This research will contribute to a more resilient and sustainable tourism experience in Ile-Ife by providing actionable insights for resource allocation, infrastructure development, risk management, and the enhancement of public safety. Furthermore, it will develop a geospatial database that can be used for future research and planning in the region.

(a) Ile-Ife Freedom Tower

(b) Oduduwa Ancestral home

(C) Oke-mogun Shrine

(d) Oranmiyan Staff

Figure 1: Some tourism attraction sites in Ile-Ife

3.0 METHODOLOGY

3.1 Study Area

The Study Area is Ile-Ife situated in the south-western Nigerian state of Osun (See figure 2), is approximately 22.96 km^2. It is located at an altitude of roughly 270 meters above mean sea level. Ife Central and Ife East Local Government Areas are the two local government areas that make up the Town. The community is situated in the nation's tropical rainforest region. The community is located between longitudes 4°30′ and 4°34′E and latitudes 7°28′ and 7°45′ north. The Opa River is present and a reservoir, which serves as a water treatment facility for OAU College. There are a total of twenty-one (21) electoral wards spread round both Local Government. The population of Ile-Ife was last recorded at approximately 331,000 people in 2015 (NPC, 2015). This accounted for approximately 0.182% of the total population of Nigeria at that time. Based on a population growth rate of 0.61% per year from 2006 to 2015, it is projected that the population of Ile-Ife would reach 395,392 by the year 2025; this study underscores the need to investigate spatial interactions and relationships between tourism and other facilities to document potential vulnerability. From the ancient sacred groves and palaces to foremost educational institutions and contemporary art galleries, the population, cultural significance and urbanization, this study presents a complex phenomenon of investigation.

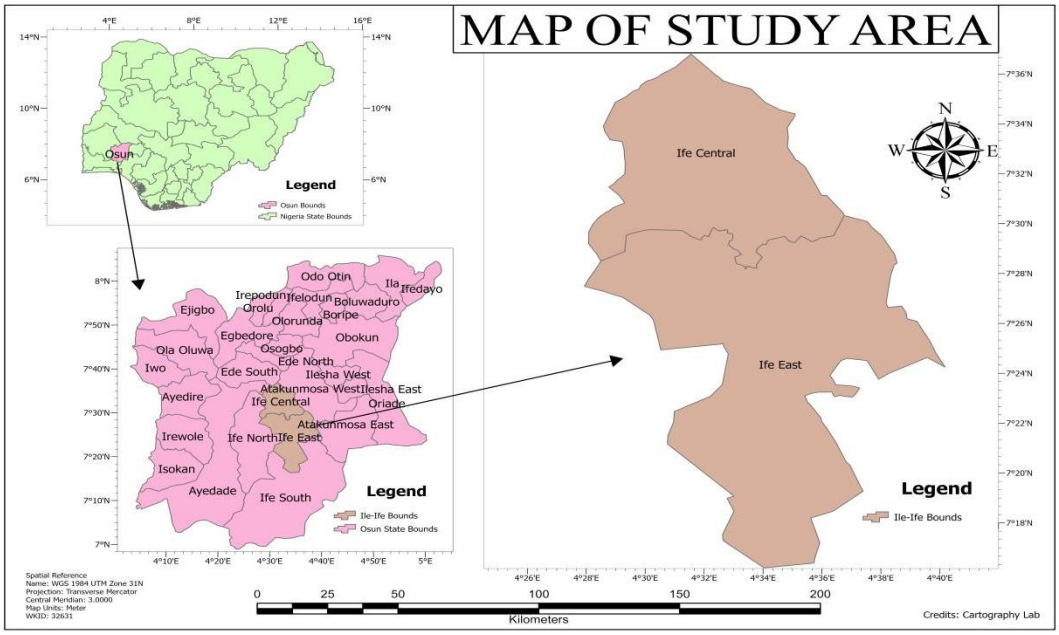


Figure 2: Map of Study Area.
Source: Cartography Lab

3.2 Materials and Methods

This research adopted a mixed-method research technique that combined qualitative data and quantitative spatial analysis using Nearest Neighbourhood Analysis (NNA) and road network analysis for the determine spatial patterns and relationships using GIS software. Relationships between tourist centers, service facilities, and confirmed COVID-19 cases were examined in the study area, with a focus on identifying spatial distributions and patterns of occurrence of the pandemic. This methodological framework provided valuable insights for future planning and development in the study area (See figure 3).

3.2.1 Data Types and Sources

Combinations of primary and secondary data were used (Figure 3). Primary data involves the locations of tourist centers and service facilities in the study area were accurately determined using hand-held GPS (Global Positioning System) devices and the relevant attribute data of mapped objects obtained through a field survey. The secondary data were datasets obtained from already existing data which includes as existing base map of the study area, a political ward map of the study area obtained from the Independent National Electoral Commission (INEC) and the count for COVID-19 confirmed cases based on political wards in the study area.

The count of confirmed cases in the study area was obtained from the Nigeria Centre for Disease Control and Prevention (NCDC) report for the year 2024. NCDC is the government agency that was responsible for the management of the pandemic in Nigeria. Other secondary data includes Google Earth imagery of the study area, Satellite imagery of the study area, Information for a literature study from journals, magazines, books, and the internet.

3.2.2 Instrument Requirement

Both hardware and software were used to conduct this study (See table 1). The hardware includes an Intel ® Core i5-6200U computer with a 500 GB hard drive, 8.00 GB of RAM with a 2.40 GHz clock speed, a 15-inch display, a digital Camera, and a Garmin GNSS handheld receiver. The required software used for processing was ArcMap 10.7.1 version and Google Earth pro 7.3.4 version.

Table 1: Data Requirement

S/N	Data	Source	Purpose
1	Google earth imagery	Google earth	For digitizing road network
2	Digital imagery	Digital camera	For visual representation of Features
3	Handheld GPS coordinates of spatial data in the study area	Field Survey	Input to WPS excel sheet, convert to database table, set spatial reference, convert to points map.
4	Existing base map of the study area	GIS Laboratory	For boundary mapping
5	COVID-19 cases in the study area	NCDC	Input ward incidence cases to the database and convert to points map
6	Attribute data of service facilities	Field survey and online	Input to WPS Excel sheet, convert to a database table, set spatial reference, and convert to points map.
7	Wards in local Government areas	Independent National Electoral Commission (INEC)	To delineate the political ward and to obtain attribute data to input into the database

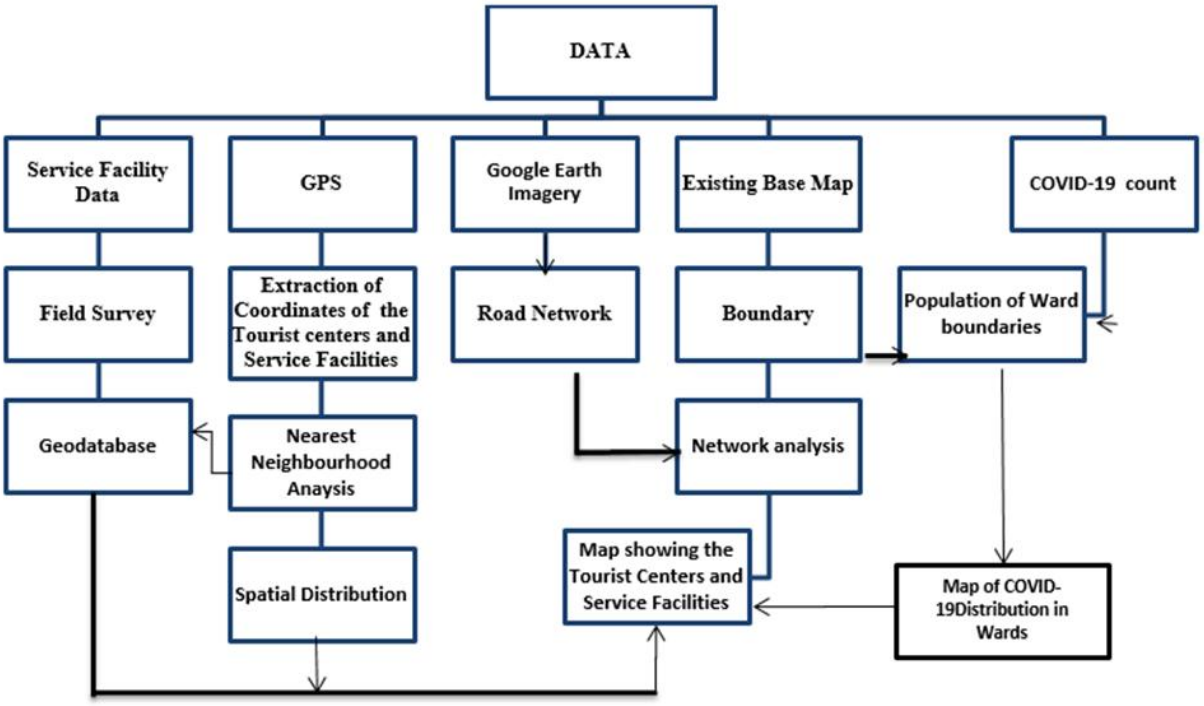
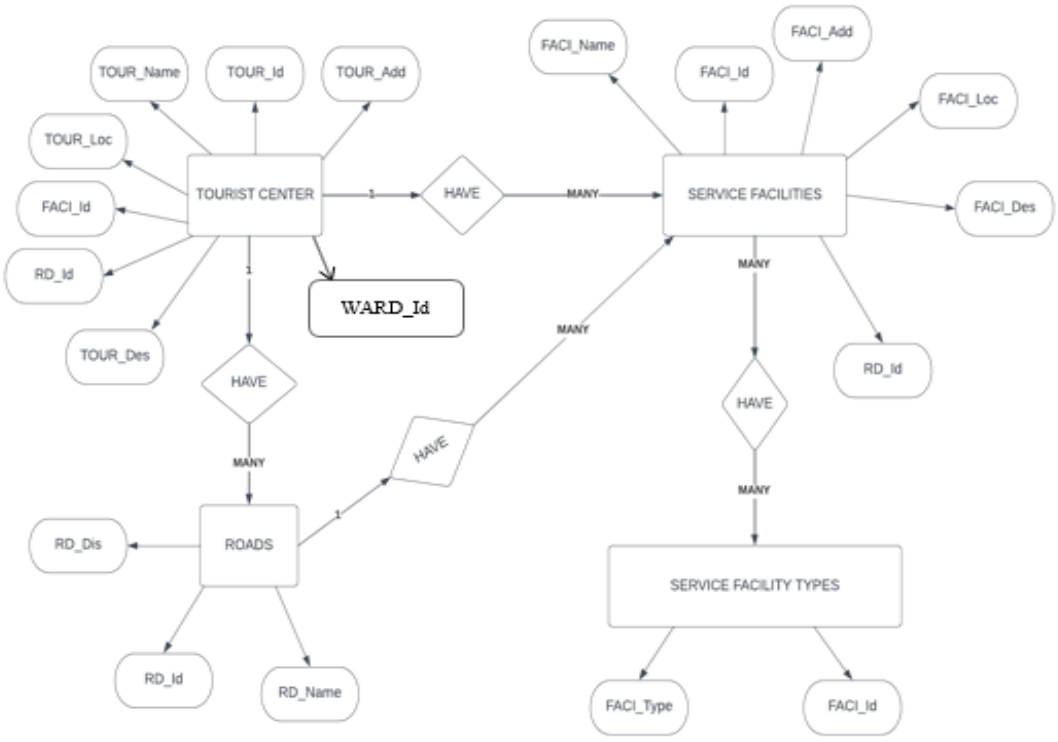


Figure 3: Methodology framework
Source: Author's (2025)

3.2.3. Procedure for data collection and processing

The primary and secondary data were processed using ArcMap (10.7) software, which enabled the digitization of the existing base map, representation of road networks, and study area boundary. Shape files were employed to visualize these features. For tourist centers and service facilities, precise coordinate data (Eastings and Northings) were gathered and organized into separate Excel sheets. These sheets were then integrated into ArcGIS, converted into point layers, and saved as shape files. These shape files were utilized to create a comprehensive map showcasing the study area boundary, tourist centers, road networks, and service facilities, both as points and polygons. The database was created using attribute and demographic data of the entities (See table 2 and figure 3, respectively). The primary data file for modifying and managing data in ArcGIS was the geodatabase, which is a native data structure. It included information

about support buildings and tourist attractions. The Tourist centers and service facility geodatabase was structured to follow a relational database model format (See figure 4).



Source: Author's (2025)
Figure 4: Entity-Relational Model

Table 2: Relational schema of the entities

S/N	Field Name	Field Attribute
1.	Tourist Center	(TOUR_Id, TOUR_name, TOUR_add, TOUR_loc,TOUR_des, TOUR_ser , WARD_Id, FACI_Id, RD_Id)
2.	Service Facilities	(FACI_Id,FACI_name, FACI_loc, FACI_add, FACI_des, FACI_ser, RD_Id)
3.	Service Facility types	(FACI_type, FACI_Id)
4.	Roads	(RD_Id, RD_name, RD_dis)

3.2.4. Nearest Neighborhood Analysis for Determination of Spatial Distribution

The spatial distributions of tourist centers and emergency service facilities were analyzed through a Nearest Neighborhood Analysis, allowing the identification of potential hotspots or clusters in the study area. The closest neighbor index was determined by this tool based on the average distance between each tourism destination and its nearby support facility. The formula for nearest neighbor is expressed as:

$$Rn = 2d/n/a \quad (1)$$

Where Rn is the nearest neighbour value, d = the mean distance of the nearest neighbor in kilometers where a = area of study in kilometers and n = total number of features to be studied. If the Nearest Neighbour Ratio (index) is less than 1, the pattern will exhibit clustering; if the index is greater than 1, it will exhibit of a dispersed pattern. If the index is equal to 1, then it will be that of a random pattern. The NNA was adopted because analysis is based on proximity; all data points were numeric (coordinate values) and were accurately determined on Euclidean space with GPS, ensuring that no outliers are present.

3.2.5. Route Network Analysis

Road network analysis was done using the Network Analysis tool in ArcGIS was used to define the topological relationship between all objects of consideration. This analysis is important to determine the behavior of flow within and around the selected locations. The analysis also determines the minimum travel time between tourist centres and service facilities.

Travel time(m) = Road length / speed limit / 60 (2)

The road network analysis produced the most efficient routes within 2km of tourist centers to emergency service facilities in case of viral infection symptoms. The system requirement for this analysis is as presented in Table 3.

Table 3: Requirement for analyzing road network

S/N	System requirements	Data requirements
1.	Real time	Accurate
2.	Compact	Up to date
3.	Address conversion function	Topologically correct
4.	Output by visual display or synthetic voice	Attributes
5.	Road conditions	One-way streets, classification, speed limitations, turning restrictions, width and height restrictions, interchanges, roundabouts, and reference landmarks

4.0: RESULTS AND DISCUSSION

4.1. Spatial Distribution of COVID-19 and Relationships with Tourist Centers and Service Facilities

The study's findings showed that sixteen (16) tourist destinations in the study area are sixteen (16) tourist destinations in the study area are sixteen (16) tourist destinations in the study area are either institutionally oriented or focused on promoting and developing art and culture. Table 4 shows the location of these destinations determined using a handheld GPS receiver. With a large number of cultural sites, this result generally indicates the cultural prominence of Ile Ife's tourism potential with a very significant number of cultural sites. The result serves as the basic input for route network analysis using GIS network analysis. The clustered distribution pattern of cultural sites can be inferred around the central area with the coordinate approximate value of 671000m to 673000m in Eastings and 826000m to 828000m in Northings.

However, the institution-based tourist centres with the Art and cultural sites show a dispersed pattern as indicated by their location in different parts of the city. For instance, the OAU locations are in the western area and the Ife Grand Resort is in the far west. In the result, the distribution of cultural tourist centres was clustered in nature, which shows the historical prominence of the city in Yoruba history. Meanwhile, for other sites, the distributions were noticed to be dispersed in nature, which suggests the impact of modernization within the city. However, tourism sites within OAU show some activities of educational tourism while the art studios and galleries indicate the diversification of tourism offerings beyond the rich historical measures.

Table 4: Tourist Centers in Ile-Ife with Location and Coordinates

Tourist center	Eastings (m)	Northings (m)	Remarks
OAU Zoo	668299.000	832008.550	Institutional based
A. G. Leventis Museum of Natural History, OAU	668668.690	831167.910	Institutional based
OAU library	668040.110	831458.560	Institutional based
Oduduwa Groove and Shrine	672154.870	827637.540	Cultural
Tower of Independence	672293.460	827488.590	Cultural
Oduduwa Afewonro Park	672240.000	827440.000	Cultural
National Museum Ife	672117.310	827420.230	Cultural
Opa Oranmiyan	671867.710	826724.470	Cultural
Obalufon Shrine	671032.840	827954.150	Cultural
Okemogun shrine	672375.040	827563.870	Cultural
Yemo Pottery Museum	673023.390	828675.800	Cultural
Dotun Popoola Studios	664783.00	830327.000	Art and culture
Moremi statue of liberty	671938.940	827251.780	Cultural
Ooni Palace	672180.840	827401.370	Cultural
Omidiran Art Gallery	668745.920	828464.860	Art and culture
Ife Grand Resort	663683.530	828409.780	Art and culture

Having determined the location of tourist centres and service facilities under consideration, the database was created for existing roads, tourist centres and service facilities in the study area. This was carried out by populating the attributes data of all entities (tourist centres and service facilities) on ArcGIS. This study revealed that there are a total of sixteen (16) tourist centers, amongst a total of over one hundred (100) service facilities in the study area. The location of tourist centers in the study area is presented in Table 4 and Figure 6 (a and b) as well. The COVID-19 incidence data were then mapped against the ward datasets, which was used to generate a Dot density map of COVID-19 incidence around the political wards in figure 6a and the location of the tourist centre with the incidence locations in figure 6b as presented.

The result shows confirmed cases of COVID-19 occurrence across the political ward amounted to 389. The ward with the highest is Ilare Ward II with 41 reported cases, followed by Okerewe Ward II, Ilode Ward II, Iremo ward IV with 35, 28 and 27 reported cases respectively. Okerewe Ward and Iremo Ward II reported the lowest cases with 9 persons infested while Iremo Ward III, Iremo Ward V and Modakeke Ward III had confirmed cases of infested persons with 10, 10 and 11 persons respectively. This data projects Ilare Ward II as the most vulnerable, followed by Okerewe Ward II, Ilode Ward II, Iremo Ward IV, Ilare Ward I, Ilare Ward IV, and Akarababta Ward, likely due to the clustering of cultural sites and dense population in the city's core.

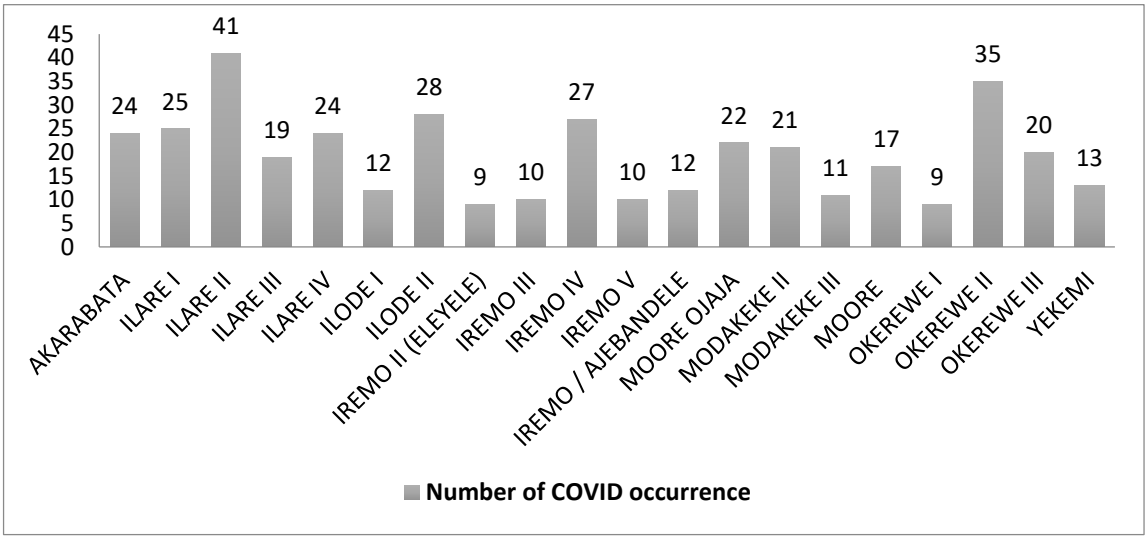
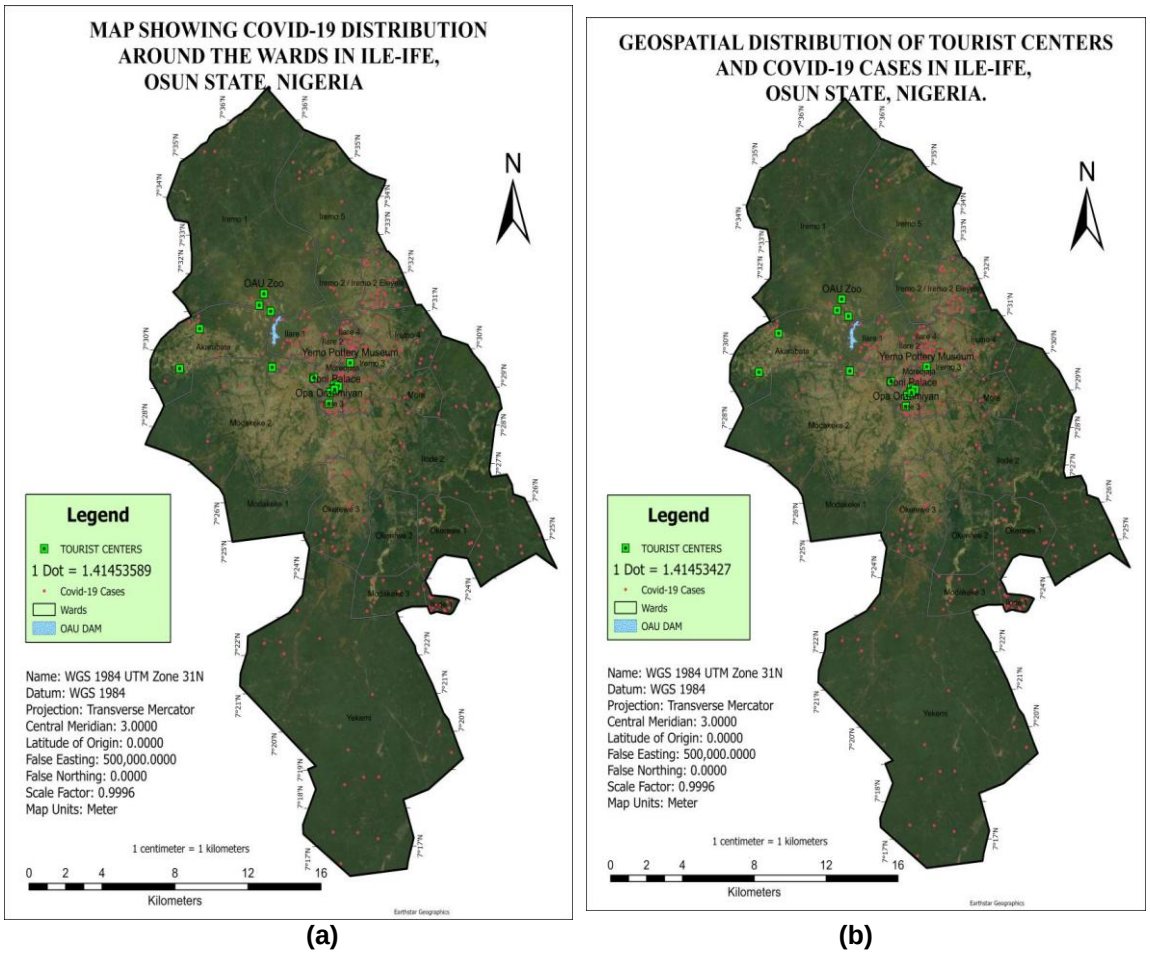


Figure 5: COVID-19 counts per ward in Ile-Ife
Source: NCDC report (2024)



(a) **(b)**

Figure 6 : (a) Spatial distribution of COVID-19 incidence across political wards
(b) spatial overlap of tourist centers and covid-19 incidence.

4.2 Spatial Distribution Analysis

Spatial distribution of tourist centers and emergency service facilities in Ile-Ife was determined to understand their geographical patterns and identifying potential areas of concern for post-COVID-19 tourism planning and management. This analysis was done using the spatial statistical tool of ArcGIS. The results of the spatial analysis indicated that tourist centers and emergency service facilities were randomly located or in clusters in specific areas, while others showed a scarcity of these facilities. This information is crucial for tourism plans and management post-COVID-19, as it highlights potential overcrowding in some areas and an under-utilization of resources in others.

The spatial distribution analysis of tourist centers in Ile-Ife shows a random pattern based on NNA ratio of 0.96; additionally, the Z-Score index of -0.244 falls within the range of critical values further affirms that the distribution of tourist centers in the study area lacks any discernible spatial clustering or systematic arrangement. Furthermore, NNA analysis of fire services in Ile-Ife reveals a dispersed pattern based on ratio value of 2.24 across the study area; similarly, the Z-Score index of 3.358 surpassing the critical value of 2.58 further confirms the dispersed nature of fire service locations. This pattern highlights potential challenges in emergency response times and resource allocation, as major paths of the community would have limited access to fire services facilities.

In the same manner, the result of NNA analysis of ratio 1.34 for healthcare facilities in the study area indicated a dispersed pattern. This signifies that the healthcare facilities are not clustered together but rather spread out across the study area. Additionally, the Z-score index of 3.358, which exceeds the critical value of 2.58, further confirms the dispersed nature of the distribution. This finding is significant for post-COVID-19 tourism planning and management in Ile-Ife. The dispersed pattern of healthcare facilities implies that access to medical services may be more equitable for both residents and tourists throughout the region. It also suggests that in the event of a pandemic outbreak or any health-related emergencies, healthcare resources are distributed in a manner that can effectively cater to various areas.

Furthermore, understanding the dispersed distribution of healthcare facilities helps in identifying potential gaps in coverage, enabling authorities to strategically plan for the allocation of resources and infrastructure development in order to strengthen the healthcare system and enhance preparedness for future health challenges in the post-pandemic tourism landscape. The result shows that the NNA analysis of police stations in Ile-Ife indicated a random pattern with a ratio value of 1.05. The result suggested a lack of significant clustering or regularity in the distribution of police stations. Additionally, the Z-score index of value 0.21 confirms that the distribution pattern is not significantly different from what would be expected in a random distribution.

4.3 Network Analysis for Service Area

Further to this study, the analysis of the road networks between tourist centers and emergency response facilities in Ile-Ife was carried out, focusing on the selected facilities. This is essential for post-COVID-19 tourism planning as it identifies opportunities to improve accessibility, safety, and preparedness in the tourism sector. In the study, the service area analysis examined healthcare facilities revealed that four (4) tourist centers, namely: Ife Grand Resort, Omidiran Art Gallery, Yemo Pottery Museum and Dotun Popoola Studios, are situated in locations where healthcare services are not available within a 2km radius (See figure 7a). These results indicated a potential challenge in accessing healthcare services by tourists in these specific areas in case of any emergency.

Similarly, the service area analysis conducted for fire service facilities revealed that four (4) tourist centers namely: OAU Library, OAU Zoo, A. G. Leventis Museum of Natural History, OAU and Yemo Pottery Museum out of the sixteen (16) tourist centers were situated in areas where fire service facilities can reach within a 2km distance (See figure 7b). The service area analysis of all the service facilities under consideration is presented in Figure 8. Further on this, the service area analysis conducted for police stations revealed that about 43.75% (seven out of sixteen) tourist centers are situated in areas where tourist and other service facilities cannot be reached by security services within 2km radius, namely: OAU Library, OAU Zoo, A. G. Leventis Museum of Natural History, OAU, Dotun Popoola Studios, Ife Grand Resort, Omidiran Art Gallery and Obalofun Shrine, as indicated in Figure 8.

The location of these police stations tends to be distributed randomly and more concentrated in the south-eastern parts of Ile-Ife. This suggests that these tourist centers might face challenges in terms of immediate police support and response within the specified distance. Post-COVID-19 tourism planning should therefore seek to address this in order to enhance safety and security for tourists visiting the centers.

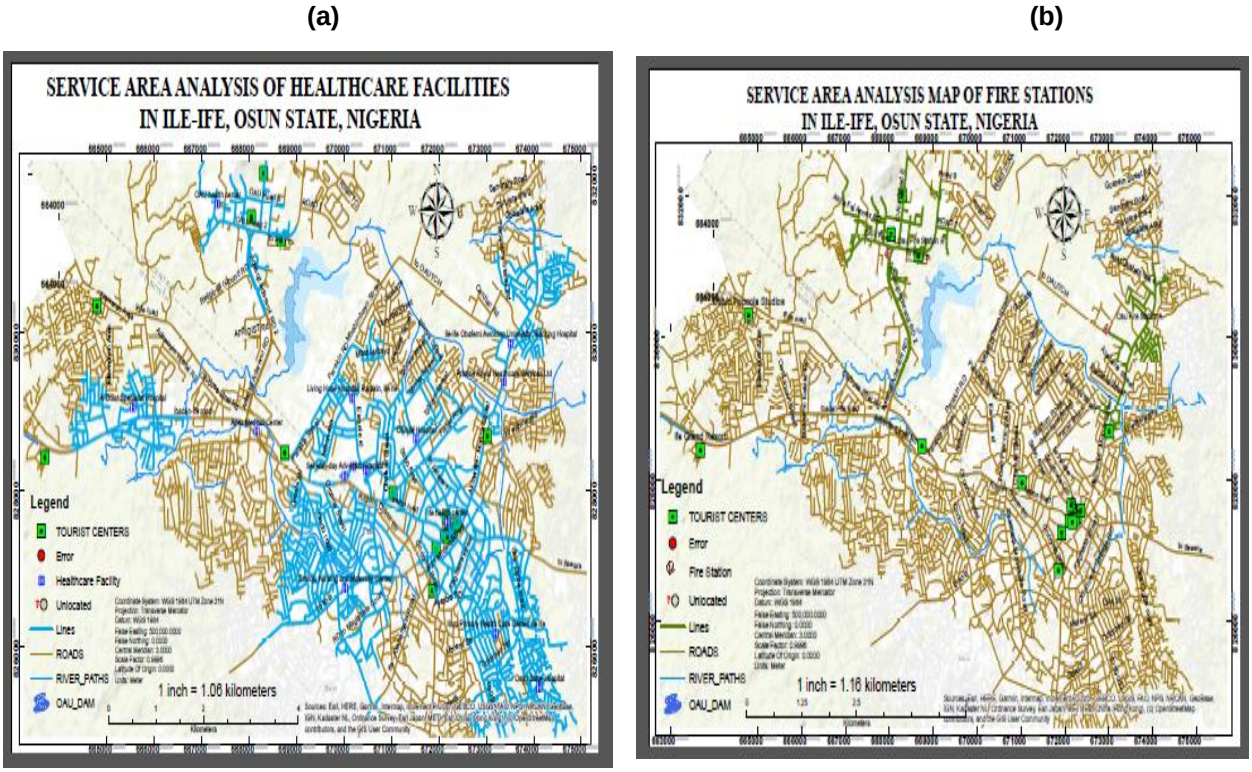
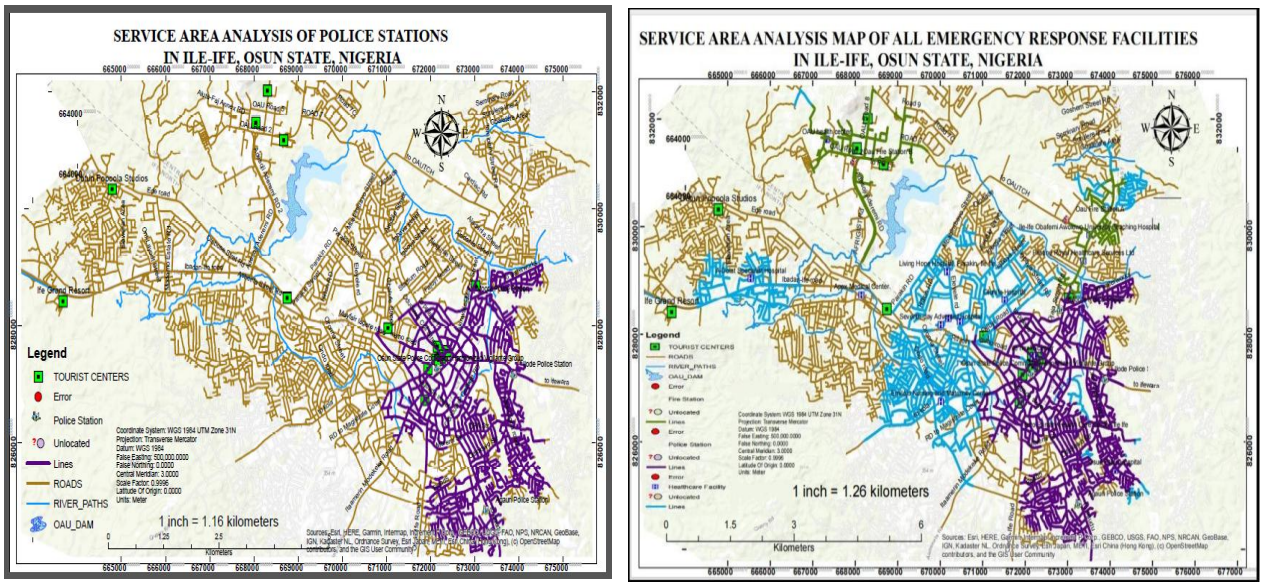


Figure 7 (a) Service area analysis of health care facilities and tourist centers at 2km radius (b) service area analysis of for fire station and tourist centers at 2km radius

The service area analysis of all emergency services that provide support to tourism in the study area (including police stations, healthcare facilities, and fire services (See figures 8a and 8b), reveals valuable insights into their general coverage and accessibility. The analysis indicates that a significant portion of the study area (87.5%) is well-served by emergency services, ensuring prompt assistance within a reasonable distance. However, the study also highlighted certain regions where there are gaps in emergency service coverage (12.5%, particularly 2 tourist centers out of the total 16, namely; Ife Grand Resort" and Dotun Popoola Studios). These areas could potentially experience longer response times, posing safety concerns for tourists and residents in a situation of alert to a viral outbreak.



(a) **(b)**

Figure 8 (a) Service area analysis of police stations facilities and tourist centers at 2km radius (b) service area analysis of emergency response facilities and tourist centers at 2km radius

The service area network analysis for accommodation facilities ascertains the serviceable healthcare facilities within a 2km distance from the accommodation facilities. The result describes that 90% of all accommodation facilities are within a serviceable distance from healthcare facilities, which is a good result in general. The thorough evaluation of road systems and emergency response infrastructure enables informed decisions to be made to enhance Ile-Ife's tourism environment and also helps to create a resilient and safer environment for visitors and local populations in the post-COVID-19 period by solving accessibility issues and maximizing emergency response services.

4.4 Discussion of Results

The description of time and distance of service facilities to tourist centers are presented in table 4; additionally, the closest facility analysis of healthcare facilities revealed that four healthcare facilities are at the closest distance to the tourist centers providing services for about nine (9) tourist centers in total, as shown in figure 10 and table 5. Whereas, areas with limited healthcare accessibility, like Ife Grand Resort and Dotun Popoola Studios, may need infrastructure development or mobile healthcare units to ensure the well-being of tourists and residents.

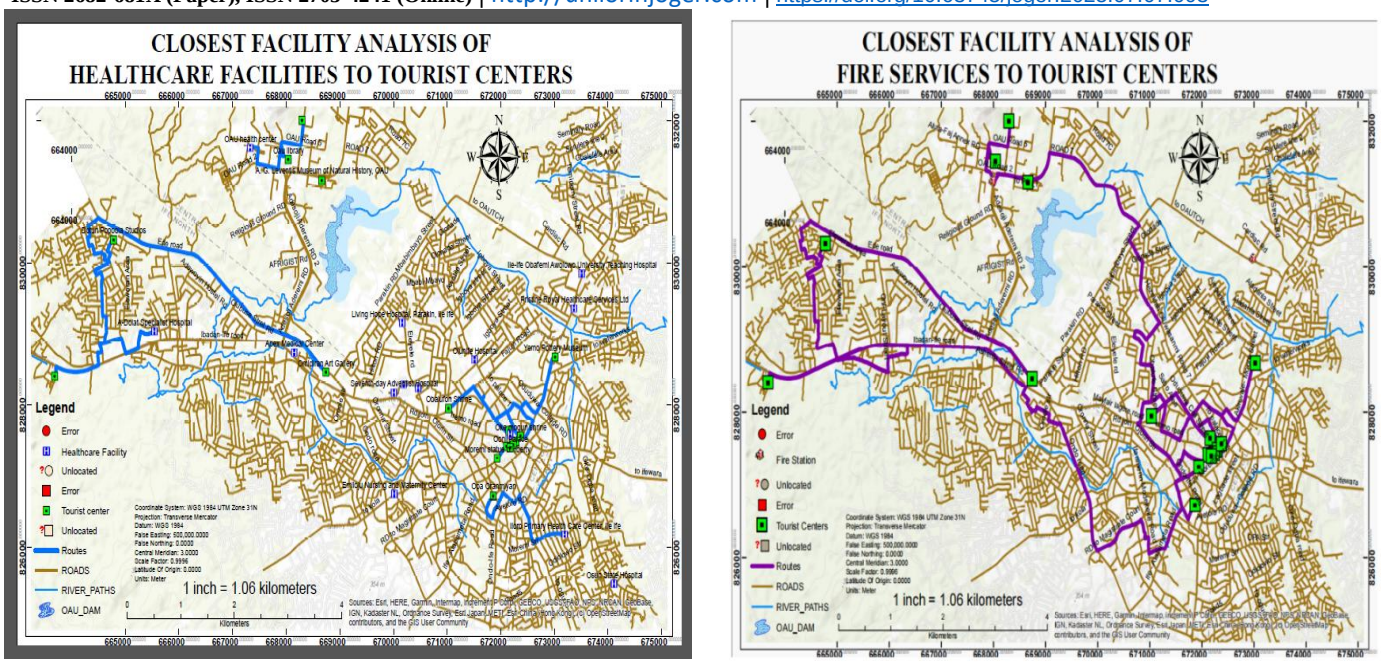
The study further revealed that OAU Fire Station B is the only fire station located close to all tourist destinations among the two accessible fire stations (See table 5 and figure 9b). The fire station should therefore have a key role in providing backup support and assistance to places where it has superior coverage.

Similarly, the closest facility analysis of police stations in the study region reveals that out of the four (4) police stations present, only the Osun State Police Command Harmonized Vigilante Group and the Moore Police Station were situated in the closest proximity to all tourist centers (See table 5). These two police stations serve as the primary law enforcement facilities nearest to the tourist destinations, potentially ensuring quicker response times and enhanced security for both visitors and local communities (See table 5). Likewise the closest facility analysis of accommodation facilities to healthcare facilities in the study region as shown in figure 9a reveals that a good number of accommodation facilities have healthcare facilities at close proximity, in a case of a visitor begins to develop symptoms of a viral disease while in the hotel, he or she can easily find the closest healthcare facility to receive medical treatment. The results of the analysis of other facilities are presented in Figures 10a and 10b respectively.

Table 5: Average travel time and average distance of service facilities to tourist centers

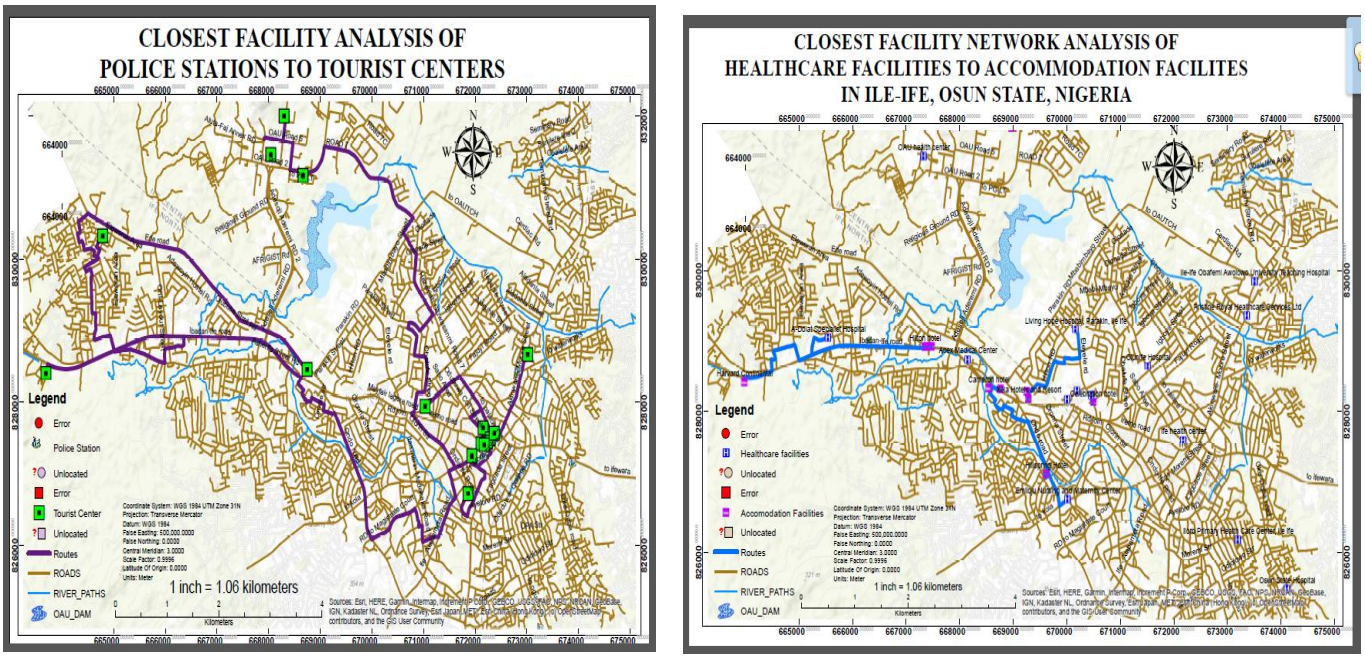
S/N	Closest Facility Details	Distance (Km)	Time (Mins)
1	Ife Health Centre To Oduduwa Groove And Shrine	0.1	0.1
2	Celebration Hotel To Comprehensive Health Centre OAUTHC Eleyele	0.1	0.2
3	Osun State Police Command Harmonized Vigilante Group To Oduduwa Afewonro Park	0.3	0.5
4	Moore Police Station To Yemo Pottery Museum	0.3	0.5
5	Osun State Police Command Harmonized Vigilante Group To Tower Of Independence Centre	0.4	0.6
6	Osun State Police Command Harmonized Vigilante Group To Moremi Statue Of Liberty	0.5	0.8
7	OAU Fire Station B To OAU Library	0.6	1
8	Osun State Police Command Harmonized Vigilante Group To Ooni Palace	0.7	1.1
9	Osun State Police Command Harmonized Vigilante Group To National Museum Ife	0.7	1.2
10	Hill Spring Hotel To Emiloju Nursing And Maternity Centre	0.8	1.3
11	Moore Police Station To OkeMogun Shrine	1	1.7
12	OAU Health Centre To OAU Library	1.1	1.8
13	Ife Health Centre To Tower Of Independence	1.1	1.8
14	Ife Health Centre To OduduwaAfewonro Park	1.2	2
15	Ife Health Centre To Ooni Palace	1.2	2
16	Ife Health Centre To National Museum Ife	1.3	2.2
17	OAU Fire Station B To OAU Zoo	1.4	2.3
18	Osun State Police Command Harmonized Vigilante Group To Oduduwa Groove And Shrine	1.4	2.4
19	Osun State Police Command Harmonized Vigilante Group To OpaOranmiyan	1.5	2.5
20	Ife Health Centre To Moremi Statue Of Liberty	1.6	2.6
21	Ife Health Centre To Obalufon Shrine	1.6	2.7
22	Ife Health Centre To OkeMogun Shrine	1.6	2.7
23	Mayfair Hotels To Living Hope Hospital, Parakin, Ile Ife	1.7	2.9
24	Xela Hotels And Resort To Living Hope Hospital, Parakin, Ile Ife	1.8	3
25	OAU Health Centre To OAU Zoo	1.9	3.1
26	Ife Health Centre To Yemo Pottery Museum	2.2	3.6
27	Osun State Police Command Harmonized Vigilante Group To Obalufon Shrine	2.3	3.8
28	Harvard Continental - A-DOLAT Specialist Hospital	2.3	3.8
29	Iloro Primary Health Care Centre, Ile Ife To OpaOranmiyan	2.6	4.4

S/N	Closest Facility Details	Distance (Km)	Time (Mins)
30	Hotel Diganga To A-DOLAT Specialist Hospital	2.7	4.4
31	Hilton Hotel To A-DOLAT Specialist Hospital	2.6	4.4
32	A-Dolat Specialist Hospital - Ife Grand Resort	2.7	4.6
33	Cameron Hotel To Emiloju Nursing And Maternity Centre	2.8	4.6
34	New Hotel Diganga To A-DOLAT Specialist Hospital	2.7	4.6
35	Hotel De Tresure To Emiloju Nursing And Maternity Centre	2.8	4.8
36	A-Dolat Specialist Hospital To DotunPopoola Studios	3.3	5.4
37	A-Dolat Specialist Hospital - Omidiran Art Gallery	8.8	14.6
38	OAU Fire Station B To Oduduwa Groove And Shrine	9	15
39	OAU Fire Station B To Moremi Statue Of Liberty	9	15.1
40	OAU Fire Station B To National Museum Ife	9.2	15.4
41	OAU Fire Station B To Ooni Palace	9.3	15.5
42	OAU Fire Station B To Tower Of Independence	9.4	15.7
43	OAU Fire Station B To OduduwaAfewonro Park	9.5	15.8
44	OAU Fire Station B To Obalufon Shrine	9.6	16
45	OAU Fire Station B To OpaOranmiyan	9.6	16
46	Osun State Police Command Harmonized Vigilante Group To OAU Zoo	9.8	16.3
47	Osun State Police Command Harmonized Vigilante Group To OAU Library	9.8	16.4
48	OAU Fire Station B To OkeMogun Shrine	9.9	16.5
49	OAU Fire Station B To Yemo Pottery Museum	10.5	17.5
50	Osun State Police Command Harmonized Vigilante Group To Ife Grand Resort	12.5	20.8
51	Osun State Police Command Harmonized Vigilante Group To DotunPopoola Studios	13.1	21.9
52	Osun State Police Command Harmonized Vigilante Group To Omidiran Art Gallery	18.7	31.2
53	OAU Fire Station B To Ife Grand Resort	20.4	34.1
54	OAU Fire Station B To DotunPopoola Studios	21.1	35.2
55	OAU Fire Station B To Omidiran Art Gallery	26.6	44.5



(a) **(b)**

Figure 9 (a) Closest facility analysis of health care facilities to tourism centers
(b) Closest facility analysis of fire service facilities to tourism centers



(a) **(b)**

Figure 10 (a) Closest facility analysis of police station facilities to tourism centers
(b) Closest facility analysis of healthcare facilities to accommodation facilities

This study has provided important insights into the potential of geospatial technologies in reviving the tourism industry despite the difficulties caused by the pandemic. According to this study, a sizable fraction of tourist attractions exactly seven (7) out of sixteen (16) are situated in wards with a high frequency of COVID-19 occurrence (See figure 5). This underscores the significance of a thorough comprehension of the spatial interaction between tourist amenities and regions of high transmission in order to offer safe

tourism experiences and guarantee the welfare of both visitors and the local population. The result of this study shows the uncertainty of having a responsive emergency response service within the study area that will effectively and efficiently respond to the distress calls on issues relating to security, emergency health calls, fire outbreak, arm robbery or even natural disasters and hazard post COVID.

The spatial relationships between the present service facilities and tourist centers in Ile-Ife currently only shows a fairly promising opportunity for quick responses to future outbreaks of pandemic and other emergencies associated with tourism and tourists in this regard. With a growing population and physical development, the result of this study shows a lack of an organised, rapid response emergency system.

Currently, in the study area, between one minute's drive to ten minutes' drive, 65.45% of all mapped facilities have inter-facility accessibility, while 23.63% inter-accessibility exists within eleven to twenty minutes' drive in the study area. Whereas, 3.63% of facilities have inter-facility access within a twenty-one to 30 minute drive, while 5.45% of the mapped facilities have a time drive between 31 minutes to 50 minutes. Similarly, 1.8% of mapped facilities have a travel time within forty-one to fifty minutes' drive. Based on this record (See table 5), facilities with less than one minute to ten minutes were considered to have poor inter-facility accessibility (See tables 5 and 6) and thus required that all the lacking service facilities be provided within a ten-minute drive, as the case may be.

Table 6: Evaluation of approximate Inter-facility accessibility between mapped facilities

Travel time (mins)	Inter-facility accessibility	Number of facilities	Percentage
0 to 9	**Good**	**36**	**65.45**
10-19	**Fair**	**13**	**23.63**
20-29	**Poor**	**2**	**3.63**
30-39	**Very poor**	**3**	**5.45**
40-49	**Very poor**	**1**	**1.81**

4.5 Implications of Results for Post-COVID-19 Tourism Planning in Ile-Ife

Ile-Ife's significant global tourist patronage presents a risk of introducing new diseases and transmission chains that can potentially escalate any future pandemics. This research suggested a framework for post COIVID-19 tourism planning in the study area. This research indicates that political wards hosting major tourist attractions experienced higher COVID-19 case counts, likely due to increased mobility and interaction between residents and visitors (See figure 6b). In this context, the accessibility of health centers from tourist locations is crucial; this is because travel times to healthcare facilities can potentially pose a significant challenge for tourists needing urgent medical attention during outbreaks.

The substantial variability in travel times across Ile-Ife highlights spatial disparities in service accessibility, emphasizing the need to incorporate spatial considerations into future public health planning (See figure 11). Prioritizing citizens with longer travel times and limited access when locating new health centers or improving existing transportation infrastructure is essential. Notably, areas with high COVID-19 case counts are particularly vulnerable to future disease and pandemic spread; this research suggests, therefore, that future pandemic surges may strain existing health facilities, especially in densely populated wards, due to increased interpersonal contact.

Sustainable post-COVID-19 tourism requires a strategic reallocation of resources to address potential overcrowding and resource depletion while simultaneously strengthening healthcare systems to prevent future crises. Improving access to routine healthcare services is also essential for reducing health disparities. The capacity and preparedness of existing health infrastructure, including testing facilities, isolation wards, intensive care units, and adequately spaced layouts, are critical for effective pandemic response, enabling early detection and efficient vaccination programs (Abdulraheem et al., 2011; Adeyemi et al., 2022).

Furthermore, an under-equipped or overcrowded facility offers limited benefit; therefore, strengthening Ile-Ife's healthcare system requires deliberate investments and interventions in healthcare infrastructure that serve the entire population, particularly in underserved areas. An immediate COVID-19 outbreak response and public health protection demands that stakeholders take responsibility to address the critical need to

increase the number of capable health facilities beyond the existing numbers, this is very critical for establishing and maintaining improved health data collection and analysis especially for disease tracking and outbreak controls.

Moreover, the need for spatially optimized emergency response is very critical to support sustainable tourism in this post-COVID era. To achieve this, emergency response facilities need to be strategically placed in a way that will optimize and improve the use of the existing road network efficiency. To this end, the need for the development of a real-time emergency response system that will integrate a GPS tracking system and GIS data is critically essential to providing mobile emergency healthcare units for sustainable and resilient tourism service delivery in Ile-Ife (Figure 11). Though most tourism infrastructure in Ile-Ife is culturally based, the development of future tourism infrastructure must consider spatial distribution and accessibility. This will enable the integration of public health data into tourism planning and will provide a spatially enabled early warning system for any disease outbreaks and spread across the study area.

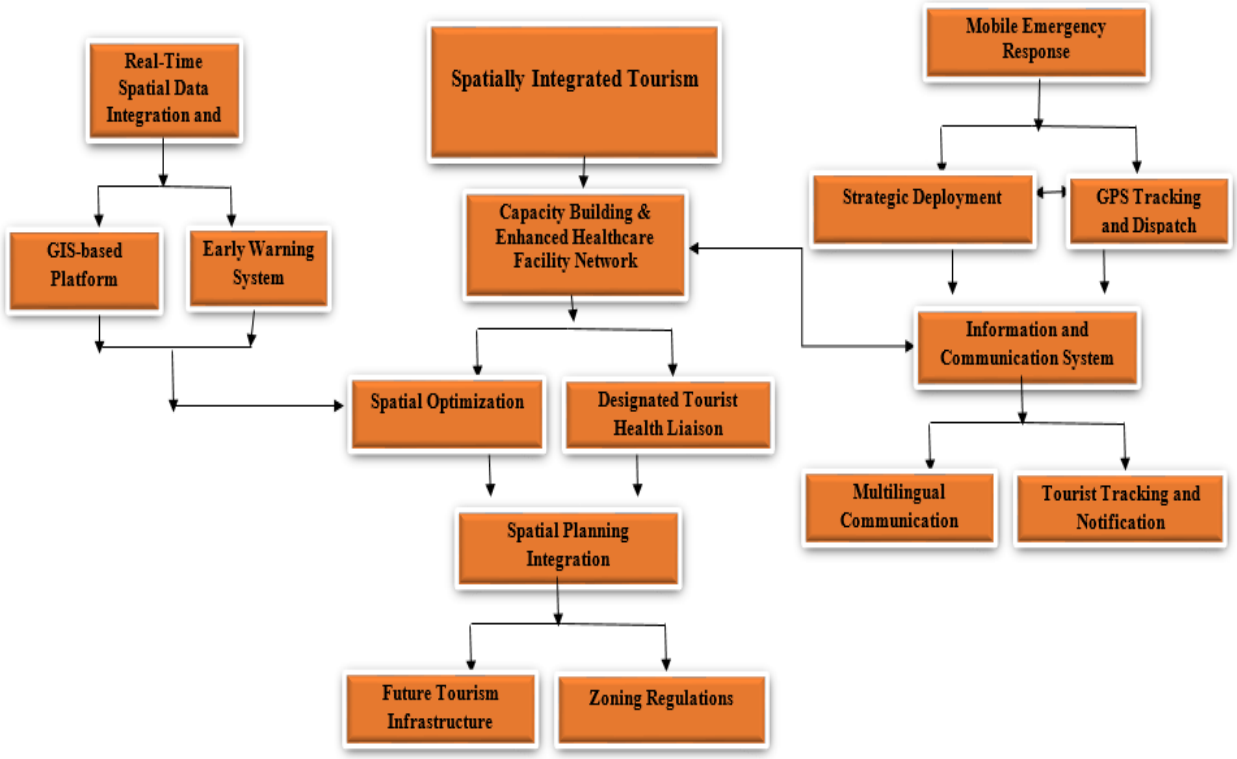


Figure 11: Proposed framework for Post-COVID-19 Tourism Planning in Ile-Ife

5.0 CONCLUSION

The COVID-19 epidemic had a significant negative influence on Ile-Ife's tourism industry in 2020, leading to the closure of tourist attractions and enterprises. However, geospatial methods provide a remedy for this problem. These techniques has shown possibilities for visualization of identified tourist centers as well as to map out the distribution of COVID-19 cases. In order to establish strategies that encourage safe travel experiences and protecting the welfare of tourists and the local community, tourism stakeholders can benefit from an understanding of the spatial relationships between tourist amenities and regions of high transmission. Geospatial tools can help with resource allocation, risk analysis, and crisis management by integrating them into tourism planning.

This study adds to the body of knowledge on post-COVID-19 tourism recovery and shows how geospatial approaches may be used in the sector practically in future occurrences. This work has successfully built a strong database and navigational maps, which is a noteworthy accomplishment. These resources can be very helpful in assisting visitors navigate the township while avoiding the wards with the most documented incidences of COVID-19. By providing travelers with useful information, we may anticipate a rise in visitor confidence and a surge in tourism activities, both of which are essential for both local and regional economic recovery.

Finally, the random distribution of tourist attractions in the study area suggests the possibility of a more balanced and sustainable tourism growth. Likewise the spatial distribution of emergency response services in the township is poor. This is a vital part of the research and policy makers or town planners should take the appropriate initiative so as to remedy this problem in the township. This study emphasizes the significance of effective resource allocation, risk assessment, and crisis management for a resilient and adaptive tourist industry by utilizing geospatial approaches in tourism planning and management. This study therefore recommends that tourism planners, managers, and policymakers, employ the findings of this research in providing valuable guidance for efficient and safe tourism in the post-COVID-19 era. Research into visitor attitudes and actions related to the use of geospatial data should be carried out, this may reveal how these tools affect decision-making.

6.0 LIMITATION OF THE STUDY

The potential limit of this work is the use ward-based data for COVID-19 incidence, and this may not capture the precise location of the reported incidence. Tourism patterns and disease spread are dynamic; future studies for Ile-Ife may consider spatiotemporal changes and time series analysis. Since the scope of this study focused on spatial interaction, future studies may consider integrating economic, social, cultural, and other relevant data for a more robust analysis. Future research in the area of geospatial approaches for post-COVID-19 tourism planning has a lot of promising directions, including collaborating with local communities and stakeholders, carrying out comparative studies in various settings, integrating real-time data, evaluating socioeconomic impacts, and incorporating qualitative research. These efforts will ultimately result in more resilient, sustainable, and visitor-friendly tourist destinations.

Longitudinal studies that chart the development of tourist patterns and COVID-19 cases through time can be another fruitful area of research. Future researchers may examine the efficiency of geographical measures in minimizing the pandemic's impact on tourism using this longitudinal method and make the required corrections for a more resilient, sustainable, and visitor-friendly tourism.

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