APPLICATION OF GEOSPATIAL TOOLS IN EVALUATING THE CONFORMITY OF FILLING STATIONS TO APPROVED PLANNING STANDARDS

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Abstract

The location of filling stations in urban and suburban regions has become commonplace due to increase in urbanization and rising energy demands. Given the possible environmental, safety, and aesthetic effects, it is now more important than ever to ensure these enterprises adhere to the approved planning standard. This study's goal is to evaluates filling station compliance with planning requirements using geospatial tools, consisting of Geographic Information Systems (GIS), remote sensing, and spatial analysis methods. These tools play a critical role in this assessment by offering comprehensive insights into spatial linkages, conformity rate, and environmental implications based on the spatial data gathered and planning regulations. As a way to assess whether filling stations correspond to predetermined planning requirements, this study employed the practical application of geospatial technology which include geospatial data and regulatory requirements in this system, this improves assessment accuracy while streamlining decision-making procedures and promoting sustainable urban development. The results highlight the value of utilizing geospatial techniques to assess factors including spatial organization, safety, and accessibility in filling station setups. In view of this strategy, having 65% of filling stations complied with the requisite 400-meter distance from neighboring stations and 35% filling stations do not adhere to the required 9-meter buffer from highways out of other results, potentially posing safety risks and causing accidents. This will help to maximize urban planning effectiveness, resulting in safer and more sustainable urban environments.

***Keywords**: Filling stations, Geospatial tools, planning standard and Urbanization*

Introduction

The most obvious sign of changes in worldwide human settlement patterns is the phenomenon of urbanization. Insights into the complex dynamics of urbanization can be gained from the increase in migratory movements that occurred throughout the globalization era, which spans the 20th and 21st centuries (Zhang 2016). Many people migrate daily to urban areas around the world in quest of better life opportunities. Our lifestyles and work routines are significantly impacted by this widespread migration from rural areas to urban centers. Urbanization is underlined as the distinguishing characteristic of our modern era in recent studies from the United Nations Department of Economic and Social Affairs and the United Nations Population Fund (Zhang 2016). Suburbanization refers to the movement of urban populations and employment possibilities out of core cities and towards less populated suburban areas. This effect causes urban population and jobs to be dispersed over a larger geographic area. Currently, emerging countries are mostly affected by the issues brought on by growing urbanization. Only 17.8% of people in the developing world lived in urban areas in the middle of the 20th century, but over the succeeding five decades since 1950, this number has risen to more than 40%. According to projections, by 2030, approximately 60% of the people in emerging countries will live in urban settings (Zhang 2016). Several Nigerian cities, including Ilaro, which is also seeing this rapid growth, display this tendency. This rising urbanization and industrialization of developing nations has increased the demand for petroleum products, which has led to an increase in the number of gas stations. In Nigeria, filling stations operations started prior to independence; the production and distribution of petroleum products which did not gain much popularity until independence in 1960 as a result of the fact that the mileage of motor able roads rarely increased and are few vehicles plying these roads. However, with the independence in1960, Construction of more roads, schools, and factories started and consumption of Petroleum Products increased. Demands for all grades of Petroleum Products started to overtake the supply and this became more manifested after the civil war leading to opening of many filling stations across the country (Mohammed, 2020).

With respect to fuel storage, Nigeria has seven main storage facilities located at cross river, delta, Lagos and Rivers with a total capacity of almost 80,000 metric tonnes in Nigeria. There is only one of the depots functioning which is located at Ejigbo- Lagos State Nigeria.

In terms of retail activities, there are presently 3450 petrol stations across (as of August 2022), with 156 available filling stations in Nigeria recently approved for construction (Olubanwo and Bada 2018). The Government plans to expand and upgrade the storage facilities from a capacity of 30 million liters currently to 250 million liters by 2020 (Oni, Akinola, and Salami 2017). Other small-scale retailers are involved in the sale of lubricants and Liquefied petroleum gas (LPG).

Filling Station otherwise known as Petrol station, Gas Station, Refueling Station, or Service Station across the world is a facility which sells fuel and lubricants for motor vehicles, generators and other machine. The most common fuel products sold is Premium Motor Spirit (PMS) known as petrol, Automotive Gas Oil (AGO) and Dual-Purpose Kerosene (DPK) known as kerosene demands are on the high increase. Geospatial tools can aid locating filling stations where there are less congestion and danger to the community as much as possible and should conform to the guidelines of the regulating bodies.

Geospatial technologies include a variety of modern instruments necessary for mapping and analyzing the geography of the Earth and human societies. Since the initial types of mapping were created in earlier times, these technologies have developed with time. Environmental monitoring, rapid disaster response mapping, climate modeling, census and political cartography, remote sensing, logistics, and urban planning are among the many thematic and scientific sectors that geospatial data supports (Mcinerney 2015). Making a digital replica of the physical world is the primary goal of geospatial data. Akinyemi, Owolabi, and Adewale (2017), examine the geographic distribution of gas stations and their effects on traffic safety in Lagos. GIS is used as a potent tool in this study to collect, manage, and analyze geographical data about gas stations and road safety. The researcher utilized geographic data layers that included information on road networks, the locations of gas stations, patterns of traffic, accident data, and potentially other pertinent statistics. Then found patterns, correlations, and insights by combining these many data sources that assisted in explaining how the distribution of gas stations affects traffic safety in Lagos. Jimoh, Ibrahim, and Durodola (2020), also employed kernel density estimation to model the spatial distribution of petrol filling stations in Abeokuta, providing insights into the clustering pattern and suggests strategies for balanced distribution.

Another research use Geographic Information Systems (GIS) to obtain and analyze geospatial data linked to the locations of fuel filling stations in Ilaro through the application of spatial analytic methods. In order to get knowledge about how these stations are dispersed throughout the urban environment, the researchers sought to identify patterns, densities, and probable clustering of these stations. This research have an impact on urban planning strategies, analyzing how Ilaro's gas stations affect the environment, paying close attention to issues including soil contamination, air and water pollution, and health concerns (Adelaja, Ayanlade, and Ojo 2019; Ajayi and Abiodun 2017).

Nevertheless, the dispersed and unplanned placement of these stations may have a negative impact on urban aesthetics, aggravate traffic congestion, jeopardize public safety, and add to environmental pollution. With the aid of geospatial tools, this study aims to evaluate the spatial distribution of filling stations within Ilaro, Ogun State, as well as the degree to which each filling station adheres to specified planning requirements. By updating with newly created filling stations as well as validating those that are currently under construction, this study broadens the scope of earlier research by building on it.

The permitted planning criteria include A petrol filling station should be built on ground that is at least 33 x 33 square meters, or the size of two plots of land, to allow for unrestricted traffic movement. The distance between one gas station and the next should be 400 meters. To create a buffer zone for the residential home, a gas station should be placed 50 meters away from all sides of the built-up areas. The buffer zone can be used for any non-residential land use. A maximum of 15 meters should separate the edge of the road from the closest pump. Additionally, including the one that is under construction, there should not be more than four (4) stations in a 2-kilometer radius of the site. The distance between a filling station and a school, hospital, theater, clinic, or other public or semi-public building should not be less than 100 meters. Also, the location of a filling station should not be adjacent to NNPC/PPMC pipelines, PHCN transmission lines, or railroad tracks (Mohammed and Jeb 2014; Olasunkanmi and Farotimi 2017).

Study Area

Ilaro Metropolis in Ogun State, Nigeria, is the research area. The seat of the Yewa South Local Government, also known as Yewa Land, is located in Ilaro Town. This local government superseded the Egbado division of the previous Western State and eventually joined Nigeria's Ogun State. Ilaro town is located 50 kilometers from Abeokuta, the capital of Ogun State, and 100 kilometers from Ikeja, the capital of Lagos State. Ajilete, Oke-Odan, Owode, Ibese, Oja Odan, Pahayi, Idogo-Ipaja, Papa-Alanto, and Imasayi are towns that serve as boundary town for Ilaro (Sowole, 2016). Additionally, there are some political elements; the town is home to both the state's high court and magistrate courts. Ilaro's average low temperature is 23 °C, and its maximum temperature is 34 °C (Alausa et al. 2021). Pre-primary, primary, secondary, and postsecondary education are all available at the schools that make up Ilaro's educational system. The federal polytechnic Ilaro, established in September 1979, as well as the Egbado Teachers Training College are examples of higher education institutions.46,999 people call Ilaro town in Ogun state home. Ilaro, Nigeria is located at latitude 6° 53' 20.44" N and longitude 3° 00' 50.98" E on the map. (31N 501564.35318786 mE, 761479.3580395 mN) are the UTM coordinates.

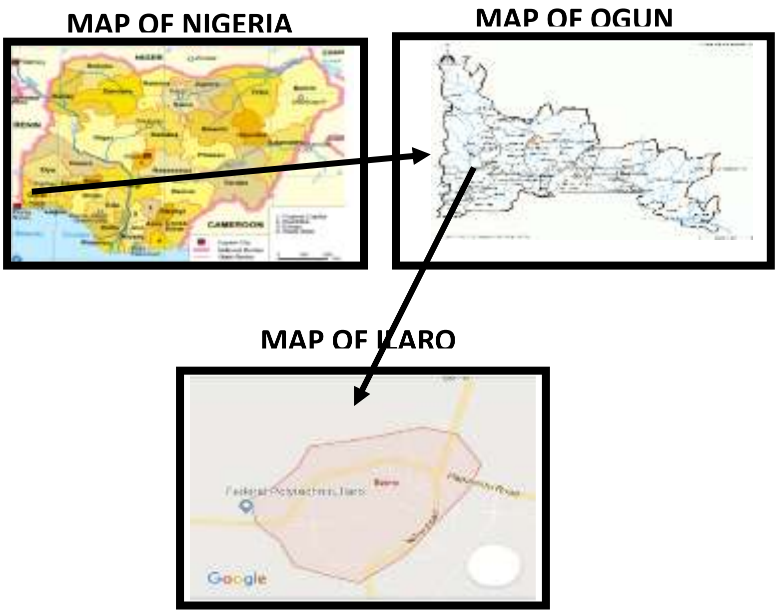

Figure 1: Study Area Map (Source Google Earth, 2023)

Materials and Method

Geospatial tools were adopted which included data acquisition through ground method and the use of GIS for the creation of database. The spatial data and attribute data were acquired, sorted and manipulated. Microsoft Excel was used, while the ArcGIS 10.6.1 was used for data processing, data visualization, database creation, and analysis.

Data Gathering

The process of gathering primary data began with planning, which entailed locating the existing filling station within the study area. Next, ground truthing for the validation of downloaded data was performed, and at the same time as collecting the spatial data, a social survey (interview) was conducted to gather attribute data.

The data acquisition process includes the following:

- Site visitation to identify filling stations.

- List station names, study area locations, and coordinates for those locations.
- Downloaded Google Earth imagery of Ilaro town (2022).

Data Sorting and Manipulation using Microsoft excel

The acquired attribute and spatial data during the social survey and field data acquisition respectively were typed into the Microsoft Excel 2016 environment, sorted, and arranged in a format acceptable by the ArcMap for further processing as shown in table 1 below.

Table 1: The Geographic Coordinates and attribute data of Petrol Filling Stations

S/N	OBJECT	LONGITUDE	LATITUDE	Area (m²)	Address
1	Fpi	499223.150	761147.2574	2067.403088	Along Ilaro Oja Odan Road
2	Arolat	503655.8919	761424.8545	1437.888214	Leslie Road
3	Ephraim Lana Akintan	512164.4327	762117.9363	1602.711098	Along Ilaro Papalantoro Road
4	Hashabi	499960.545	762081.3575	2125.815875	Along Express
5	Kaolas	509581.9894	762841.3107	3994.188757	Along Ilaro Papalantoro Road
6	Matglobus	506486.0275	766516.59	1257.578034	Ilaro - Ibese Road
7	Total	502329.6972	763777.8273	877.326343	Along Express
8	Under Construction	505568.2985	763878.6714	6026.091533	New Garage Ilaro
9	Ultimate	505951.5681	764653.9196	1145.018658	Ilaro - Ibese Road
10	Honeywell	498973.1863	761036.0771	2057.683204	Along Ilaro Oja Odan Road
11	John Folu	499573.7917	761030.7854	1532.141849	Ibikunle Amosun road
12	Ifotech	499580.0639	761412.446	509.801938	Along Express
13	Afariogun	508506.456	762801.6231	8817.711025	Along Ilaro Papalantoro Road
14	Arolat	503744.0314	758718.5666	1437.888214	Saabo
15	Toyse	502146.9739	763608.1249	3111.342739	Along Express
16	Arolat	501699.0439	761226.4187	886.090067	Along Ibikunle Amosun road
17	Buksol	502064.5337	763583.5227	2202.887779	Along Express
18	Under Construction	498494.2895	761046.6604	3266.71521	Ita Waya Along Ilaro Oja Odan Road
19	Conoil	502978.1217	763946.0245	2682.516376	Along Express
20	Afariogun	499869.428	761801.5001	3135.282686	Along Express
21	Awo	500642.8207	763052.0297	1507.791619	Along Express
22	Gaboma	500162.8515	762341.5158	3718.916349	Along Express
23	Olufela	500414.5256	762565.1057	1591.63591	Along Express
24	ATINSOLA Nig LTD	501992.3815	758642.656	1300.698431	Sawmill
25	Iab	502618.2877	763745.4699	1840.989783	Along Express
26	Himra	504362.1345	761765.2912	645.676412	Along Ilaro Oja Odan Road

27	Ifeoluwa	499866.0885	761961.501	1887.34078	Along Express
28	Total	505680.2175	761557.1464	3188.372941	Igboro
29	Gdm	499986.9218	761119.2622	1774.956296	Along Ibikunle Amosun road
30	Joase Filling Station	503786.0815	756565.9306	1112.909869	Along Ilaro - Owode Road
31	Ascon	503953.4109	758748.721	2090.461005	Saabo
32	Tpg	503730.5189	757338.5155	2074.20614	Along Ilaro - Owode Road
33	Under Construction	500789.6692	761104.4455	3336.722826	Along Ibikunle Amosun road, Orita
34	Yaad	501161.1449	761008.137	2477.435974	Along Ibikunle Amosun road
35	Elak	505102.5449	759756.0094	1885.094871	Along Ilaro - Owode Road
36	Himbab	502739.7625	761428.8254	920.823	Igboro
37	Isbra	500750.5108	760527.1236	444.077525	Orita - Saabo Road

Data Processing

- Used a map-to-image georeferencing technique to georeferenced the imagery after importing it into ArcGIS 10.6.1.
- Two shapefiles for roads and filling stations were created in the Arc Catalog environment.
- Created fields for the name, kind, and calculated length in meters of the road.
- Created a checklist to gather thorough data about gas stations.
- The gathered data was exported to ArcGIS 10.6.1 and saved in a project folder on the C disk.
- Create shapefiles from the data so that it may be analyzed later.
- Mapped the positions of the filling stations using a variety of symbols.
- Created Excel tables and graphs to display the inventory data.
- The first goal of locating and mapping out the filling stations was accomplished.
- To determine adherence to planning standards:
- Used ArcGIS to do proximity and buffering analyses.
- To monitor adherence to road setbacks, a 9-meter buffer was established along roads near gas stations.
- To find sites inside the 9-meter road safety zone, use query by location.
- Based on the Ogun State Government's 300-meter standard (2022), I calculated the distance between gas stations.
- Used query operations to find stations that were 300 meters or less apart from other stations.
- In accordance with DPR requirements, the distance between filling stations and public institutions (such as hospitals and schools) was calculated using a 100-meter radius.
- executed a location-based query in ArcGIS using the database of public facilities to find close-by stations.
- To identify gas filling station distributional patterns:
- To determine if the distribution of the stations was random, clustered, or regular, closest neighbour analysis was used.
- Determined the separation between each filling station's nearest neighbours.

Results and Analysis

Spatial distribution

The outcomes of this study are visually represented by a spatial distribution image as shown in figure 2 below. As a way to shed light on potential compliance patterns and spatial trends, this image showed how filling stations were arranged within the built-up area. This image serves as platform to determine whether the filling stations under study have a spatial distribution that complies with planning rules or not. This visual representation will aid in developing well-informed recommendations for urban planning and land use management in the study area and in providing a greater understanding of the implications of the study's findings**.**

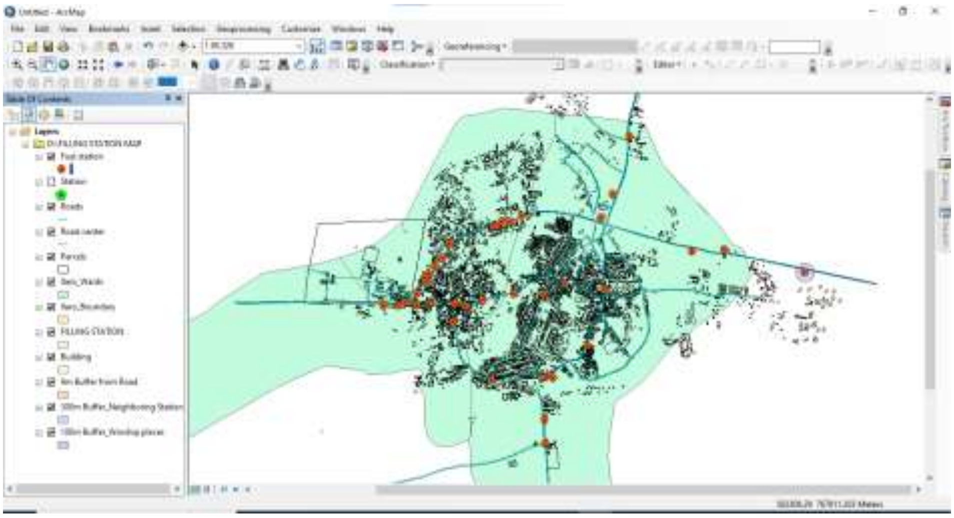

Figure 2: Image showing distribution of the Filling Station as shown with red colour

Adherence to Planning Criteria

A thorough analysis of the spatial distribution of the filling stations throughout the research area was done to determine how well they adhered to planning criteria. This study required a tactical strategy combining two core analytical methods:

Buffering Analysis

Buffering techniques were used to create predetermined spaces around important structures including roadways, communication masts, filling stations and residential areas. Applying buffer zones as spatial reference areas allowed for the delineation of required proximity and specified distances as required by planning standards.

This buffering method made it possible to directly evaluate compliance with predetermined standards and offered a concrete depiction of allowable distances.

Figure 3: Image showing 100m Buffer setbacks from worship centers

Figure 4: image showing 400m Buffer setback of nearest neighbor filling station from either side of the road

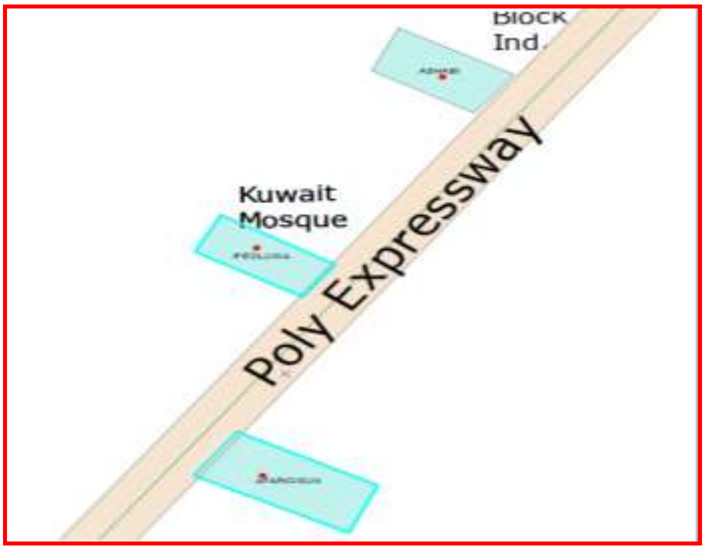

Figure 5: Image showing some filling stations defying the 9m Town planning setback from the road

Querying Analysis

carried out querying procedures to extract data points that fell within the specified buffer zones. Through searches, the qualities and characteristics of filling stations, communication masts, and their relative spatial linkages were painstakingly investigated.

By making these queries, the study could identify instances where the placement of filling stations either agreed with or varied from the prescribed planning criteria.

The foundation of the assessment procedure for figuring out if filling stations are in compliance with regulatory requirements was these analytical methodologies, which included both buffering and querying techniques. The research got profound understandings of the degree of conformance displayed by filling stations in terms of their geographical distribution, proximity to communication masts, and location related residential areas within the study territory by using a methodical strategy. This thorough analysis made it possible to conduct a thorough assessment of compliance with planning requirements, which improved the study.

The queries performed in this work gave answers to certain generic questions asked from the database. Two query criteria were adopted in this work;

i. Single criteria

ii. Multiple criteria

Figure 6: Query result of Filling stations whose area coverage sizes are not in conformity with planning standards

Figure 7: Query result of Filling stations whose 100m setbacks from worship centers are not in conformity with planning standards.

Figure 8: Query result of Filling stations whose 400m radius from the nearest neighbor filling station on either side of the road are not in conformity with planning standards.

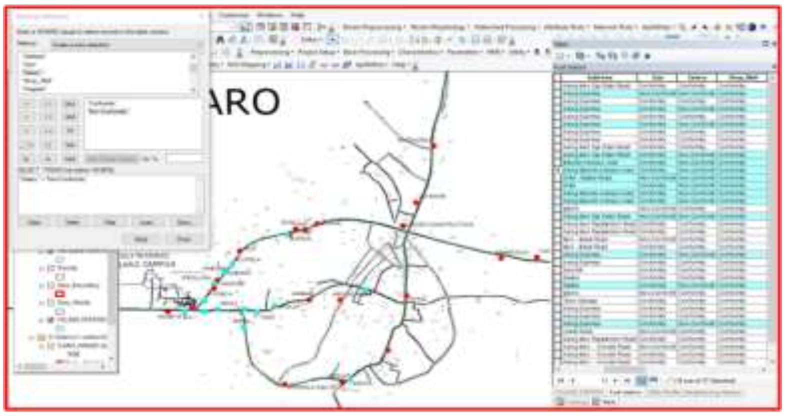

Figure 9: Query result of Filling stations whose 100m setbacks from Eateries are not in conformity with planning standards

Figure 10: Query result of Filling stations whose 100m setbacks from Hospitals are not in conformity with planning standards.

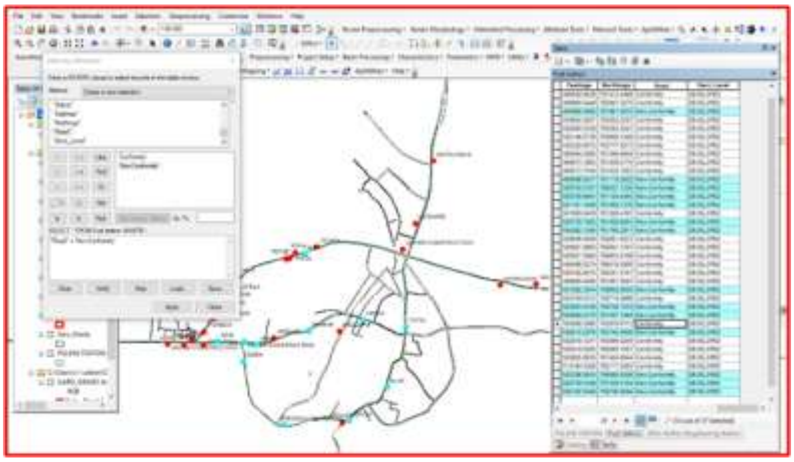

Figure 11: Query result of Filling stations whose 9m setbacks from Roads are not in conformity with planning standards

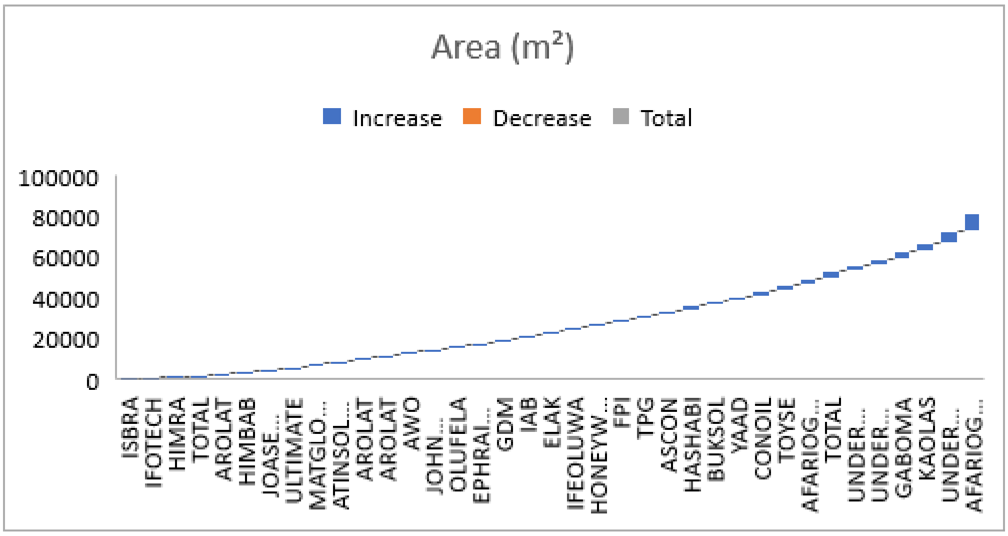

Figure 12: Graph showing the area of each filling station

Discussion

The results of the investigation are discussed in the series of figures, which also provide a detailed analysis of how closely filling stations in Ilaro adhere to approved planning criteria. Geospatial tools were meticulously used to conduct this assessment, underscoring the critical role that these tools serve in assessing conformity to legal requirements in urban planning and land use management.

The findings in Figure 6 and 12 showed a case where 30 out of 37 (81%) filling stations meet planning guidelines with regard to their dimensions of least area 1089m^2. This showed a high level of compliance, showing that the majority of these establishments followed the established land area requirements. Accurate size assessments were made possible by geospatial analysis and measuring techniques, which improved understanding of spatial relationships.

Figure 7 reveals the setbacks of filling stations from places of worship and showed that a sizeable fraction of the 30 filling stations do not comply with the required 100-meter distance. During widespread epidemics, this circumstance has the potential to present significant hazards. The geospatial evaluation stresses how important it is to follow safety regulations when near sensitive areas.

It is clear from Figure 8 that 24 filling stations complied with the requisite 400-meter distance from neighboring stations, whereas 13 filling stations do not. The geospatial analysis used here identifies spatial patterns and clustering tendencies that are essential for comprehending distribution dynamics and their possible effects on operational safety and competition.

The findings in Figure 9 highlighted a serious situation where 14 filling stations failed to maintain the required 100-meter distance from restaurants. This discrepancy prompts worries about potential risks these stations may have to the security of surrounding eating places. The used geospatial tools provide insightful information about potential land use conflicts and the need for updated zoning laws.

Figure 10 showed a single filling station that is closer to a hospital than the authorized 100 meters, emphasizing the necessity for rigorous adherence to safety regulations around healthcare institutions. These crucial safety factors are taken into account in urban planning, appreciations to geospatial analysis.

Figure 11 showed that 13 filling stations do not adhere to the required 9-meter buffer from highways, potentially posing safety risks and causing accidents. The importance of taking into account traffic and road safety when siting these facilities is highlighted by the use of geospatial techniques in compliance assessment.

These findings highlighted the importance of precise spatial analysis for ensuring that urban planning and land use comply with established regulations, which is consistent with earlier discussions on the use of geospatial tools in evaluating the conformity of filling stations to approved planning standards. The results highlighted the crucial role geospatial technologies play in encouraging safer, more environmentally friendly urban environments through in-depth adherence assessments.

Conclusion

The detailed analysis discussed in this study, highlights the crucial role that geospatial technologies play in determining compliance with urban planning and land use legislation. When these tools were used carefully, they provided insightful information about how closely Ilaro's filling stations adhered to established planning standards. The results in this study highlight areas of compliance and non-compliance while highlighting critical operational and safety factors with 81% do not comply with the required 100-meter distance from worship center and same 81% of filling stations meet planning guidelines with regard to their dimensions of least area $1089m^2$, 65% of filling stations complied with the requisite 400-meter distance from neighboring stations and 35% filling stations do not adhere to the required 9-meter buffer from highways, potentially posing safety risks and causing accidents. This geospatial research showed the crucial importance of sticking to safety requirements in urban design, from keeping correct distances from sensitive locations like places of worship and healthcare facilities to adhering to buffer zones from motorways. This study's overall conclusion highlights how geospatial technologies help to create safer and more aesthetically pleasing urban environments by offering subtle insights for better compliance evaluations.

Recommendations

Several suggestions that can successfully resolve the observed non-compliance concerns and improve the general urban planning and land use management process emerge in light of the findings provided in the discussion and the significant insights gained from the geospatial analysis therefore, the following recommendation are made:

- Enhance Adherence Awareness and Training: Organizations in charge of land use control and urban planning should launch awareness-raising efforts and training initiatives for owners and operators of gas stations. This could be used to highlight the importance of following established planning guidelines, particularly with regard to setbacks from sensitive locations like churches, hospitals, and highways. A culture of responsible land use can be promoted by informing stakeholders of the advantages of following safety laws and the potential risks of breaking them.

- Enhance Regulatory Oversight: In a bid to make sure that filling stations abide by predetermined planning criteria, regulatory organizations should enhance their monitoring and enforcement procedures. Geospatial tools can be used to conduct routine inspections and assessments that can offer accurate and current information on compliance. To discourage infractions, strict consequences for non-compliance should be put in place. Effective enforcement can be facilitated by cooperation between regulatory agencies, GIS specialists, and urban planners.

- Revision of Zoning and Planning Laws: In light of the study's conclusions, local governments should think about amending their zoning and planning regulations. This includes revising the laws governing filling station dimensions, buffer zones, and setbacks from sensitive regions. Zoning regulations must take into account how the urban environment is changing as well as new safety issues. By providing insights into spatial relationships and distribution dynamics that inform more useful and pertinent zoning laws, geospatial analysis helps direct the revision process.

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