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Decision Support System for Spatial Analysis of Private Schools in Tobruk, Libya Based on GIS

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نظام دعم القرار للتحليل المكاني للمدارس الخاصة في طبرق، ليبيا، باستخدام نظم المعلومات الجغرافية

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Abstract:
Effective metropolitan planning for educational services requires precise spatial analysis of both service locations and consumers. This paper presents an integrated Decision Support System based on Geographic Information Systems (DSGIS) to evaluate the distribution efficiency of private schools in Tobruk, Libya. The proposed model uses web-based geolocation acquisition and IP-to-coordinate conversion to map the spatial density of students and schools across various metropolitan polygons. Methodologically, the system organizes spatial data into distinct GIS layers (Base Map, Customer Layer, and Private Schools Layer) to facilitate geostatistical comparison. The results reveal a significant spatial misalignment, indicated by a weak correlation coefficient of - 0.318 between school locations and student concentrations. These findings suggest that the current distribution of private schools is largely spontaneous rather than planned. The study concludes that the DSGIS model provides a robust digital foundation for municipal decision-makers to optimize resource allocation, ensure equitable access to education, and support future metropolitan expansion based on empirical spatial data.

Keywords: Decision Support Systems (DSS), spatial decisions, Spatial Decision Support Systems (SDSS), Geographic Information Systems (GIS).

الملخص
يتطلب التخطيط الحضري الفعال للخدمات التعليمية تحليلًا مكانيًا دقيقًا لمواقع الخدمات والمستفيدين منها. تقدم هذه الورقة البحثية نظام دعم قرار متكاملًا قائمًا على نظم المعلومات الجغرافية (DSGIS) لتقييم كفاءة توزيع المدارس الخاصة في طبرق، ليبيا. يستخدم النموذج المقترح تقنية تحديد الموقع الجغرافي عبر الإنترنت وتحويل عناوين IP إلى إحداثيات لرسم خريطة الكثافة المكانية للطلاب والمدارس عبر مختلف المناطق الحضرية. منهجياً، يُنظّم النظام البيانات المكانية في طبقات نظم المعلومات الجغرافية المتميزة (الخريطة الأساسية، طبقة العملاء، وطبقة المدارس الخاصة) لتسهيل المقارنة الإحصائية الجغرافية. تكشف النتائج عن تباين مكاني كبير، يُشير إليه معامل ارتباط ضعيف (-0.318) بين مواقع المدارس وتجمعات الطلاب. تُشير هذه النتائج إلى أن التوزيع الحالي للمدارس الخاصة عشوائي إلى حد كبير وليس مُخططاً له. وتخلص الدراسة إلى أن نموذج نظم المعلومات الجغرافية المكانية (DSGIS) يُوفر أساساً رقمياً متيناً لصناع القرار في البلديات لتحسين تخصيص الموارد، وضمان تكافؤ فرص الحصول على التعليم، ودعم التوسع الحضري المستقبلي استناداً إلى بيانات مكانية تجريبية.

الكلمات المفتاحية: نظم دعم القرار (DSS)، القرارات المكانية، نظم دعم القرار المكاني (SDSS)، نظم المعلومات الجغرافية (GIS).

1. Introduction

Geographic Information Systems (GIS) are highly effective in contemporary life, and the internet and networks are extensively utilized today. Most real-world complex problems can be regarded as spatial decision problems, as they are typically situated in a specific location and possess a spatial component. [1]. in these circumstances, the decision-making process is typically influenced by both the data site and spatial relationships. Decisions about urban renovation, environmental risk assessment, or politics, for instance, have a significant spatial component that should be scanned and incorporated as a new dimension into the decision-making process. As a result, spatial decision problems should be geographically linked and computer-represented using GIS. In certain situations, decision-makers rely solely on GIS's strong data storage and visualization capabilities to support their preferences, leaving the analysis and interpretation tasks to the decision-maker. However, in a dynamic setting, these intricate spatial decision problems require consideration of a wide range of characteristics, policies, expert and stakeholder perspectives, and alternatives. Plotting all the digital data to be examined in a GIS environment becomes challenging or perhaps impossible as the problem's complexity rises [2, 3].

1.1. Internet Protocol (IP) addresses.

IP geolocation [4] is a popular technique for determining the geographic location of Internet users or web servers. Researchers can convert IP locations into real-world coordinates (latitudes and longitudes) or geographic areas by using IP geolocation methods. The site analysis of website visitors has become an important ingredient in Web log analysis research. There are two types of IP geolocation techniques: strong IP geolocation and negative IP geolocation. Strong IP geolocation techniques depend on one IP address to another. However, the strong method requires complex calculations and cannot handle a very large volume of IP geolocation. Passive IP site is a database-driven procedure that relies on relational databases (such as MS SQL or MySQL databases). The IP geolocation databases include the index for mapping various levels of IP addresses.

1.2. Geographic Information Systems (GIS)

GIS is a computer system designed for the detection, storage, manipulation, presentation, and analysis of geographic data. The geographic location is the component that distinguishes geographic information from other types of information. Without a location, data are described as non-spatial and would have little value in a GIS. Location is, thus, the basis for much benefit of GIS: the ability to map, the ability to measure distances, and the ability to splice different types of information together because they indicate the same site [5].

Figure 1.GIS components [5]

1.3 Decision support system

A Decision Support System (DSS) is a specific group of information systems that supports business and organizational decision-making activities. A properly designed DSS helps decision makers to collect helpful information from raw data, documents, personal knowledge, and/or business models to identify and address problems to make decisions [6]. According to the components of a decision support system (Figure 2): A Database Management System, a Model Management System, and a User Interface [7].

1. A Database Management System that includes tools to support 14 data collection and storage, the management of data for models, and the capability to restore data from storage.
2. A Model Management System that provides a set of tools and models that is supported by items and produces new information (description, explanation), relevant for the decision-making process. This new information is aligned/designed to management objectives and policy goals.
3. A User Interface supporting the visualization of the data Collections and output from models (current and alternate scenarios) in a form that makes it clear whether administration objectives and policy goals are being or are likely to be achieved.

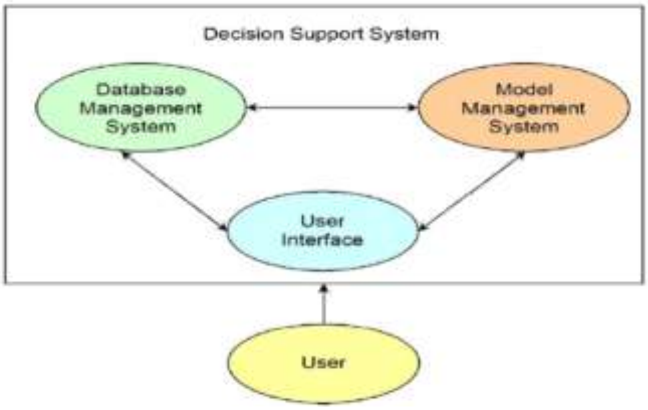

Figure 2. Components of decision supports system

SDSS is an important subset of DSS whose fast growth has been facilitated by technical developments and the economize of appropriately inexpensive technologies for manipulating spatial data. Spatial technologies, of which GIS are central, involve data paid software with explicit spatial or geographical dimensions. Data is geo-referenced for storage, manipulated, retrieved and spatially displayed (Batty and Densham, 1996) describes a typical SDSS as having four components [8]:

1. Analytical tools: enabling data investigation.
2. Decision models: enabling scenario based investigations.
3. Geographic: Spatial database: enabling storage and analysis of geographic information.
4. User interface: providing easy access to components 1, 2, and 3, as well as an attractive and comprehensive display of the output.

2. Literature review

Nyoman presented the SDSS concept to the Web-based GIS, especially for searching business or commercial marketplace. By combining the spatial data, such as latitude, longitude, region, and general data such as category, address, comment, and company name. It has a variety of benefits such as: increasing the popularity of a business helps visitors determine the business or the marketplace that they like [9]. However, users occasionally find difficulty in finding the site of a storage or business place they want because there is little information to be found, and the information is usually subjective.

F. B. Abdullah focused on the development of a web-based GIS for the public healthcare system. The development of this system is motivated by providing opportunities for the healthcare workers to gain access to vital information that can aid him/her in the selection of viable hospitals [10]. It economizes opportunities for the healthcare practitioners to obtain access to information that can aid in the diagnosis of patients' health conditions or the development of suitable treatment plans, and for the patients to enjoy an enhanced level of healthcare services. The problem in the study is that the insulation of existing standalone sicknesses management systems leads to data participation. The study identified a significant limitation that is most of the health information systems have a closed structure, and even the ones that use web-based technology are difficult to integrate. This study focused on the development of a web-based GIS for the public healthcare system. However, he ignored other services such as governmental, educational, or financial … etc.

(Waleed Lagrab, Noura AKNIN) They analyzed the spatial distribution of kindergarten facilities in the study area using Geographic Information Systems (GIS), testing the effectiveness of the technology to redistribute the current kindergarten and pick the best location going forward, while using the established criteria for choosing suitable locations for kindergarten. In order to do this, they gathered data and information through interviews and detailed statistics on the educational resources in the Mukalla districts of Yemen, which helped create a geographic database for the research region. The kindergarten spatial patterns are then being examined in terms of their relationship to one another and how other nearby pieces of land—such as roadways, roads, factories, etc. [11]. Abulibdeh et al. (2024) investigated the distribution and accessibility of both public and private schools in Qatar utilizing Geographic Information Systems (GIS) techniques. The research applied various spatial analysis approaches, including Kernel Density Analysis, Nearest Neighbor Analysis, and Network Analysis, to evaluate the fairness and accessibility of educational resources. The results indicated a notable concentration of schools in urban locations, especially in Doha, whereas rural and outlying areas showed decreased accessibility. The authors suggested that strategic planning be implemented for the development of new schools in areas lacking services to improve spatial equity and guarantee equal access to educational resources [12].

Despite the extensive research on Spatial Decision Support Systems (SDSS) and GIS applications in urban planning, there remains a critical gap in integrating real-time web-based geolocation to address the spatial mismatch between private educational services and actual consumer demand in developing urban contexts. Most existing studies focus on static data or public sector infrastructure. This research bridges this gap by proposing a dynamic framework that utilizes internet-based geolocation to identify the precise locations of both customers and private school centers. By employing geo-statistical analysis, this study aims to evaluate the efficiency of service distribution, providing a data-driven approach to mitigate the imbalance where schools exist without clients, and high-demand areas remain underserved.

The Proposed model

The proposed model (DSGIS) involves the integration of DSS, private school, and GIS (DSGIS). It shows the contents of the procedural sequence of "DSGIS" which is made up of five major components. As Table 1. To ensure the empirical validity of the spatial analysis, data were systematically collected from a representative sample within Tobruk city. The study involved 100 participants (comprising students and parents) whose precise geolocations were obtained through the proposed web-based interface. In parallel, 59 private schools were identified and georeferenced as primary service points across the metropolitan area. The data collection phase was conducted over a period of [2 months]. A purposive sampling method was employed to select 20 distinct metropolitan polygons (neighborhoods), ensuring a comprehensive representation of various urban densities, residential clusters, and existing educational infrastructure to accurately evaluate the spatial misalignment.

Table 1. DSGIS components

	COMPONENT	ROLE
1	Geolocation Acquisition (GA)	Tool mainly websites login, web register that utilize any browser for accepting users IP. Which used as Geolocation acquisition through internet.
2	Geolocation Determination (GD)	GD used to determine both latitude and longitude (Geolocation).
3	Spatial GIS Data (SGD)	The Geolocation saved permanently in Excel Sheet this Sheet is imported to spatial Database through QGIS.
4	GIS layers (GISL)	a data layer composed of a group of logically attached geographic Advantages and their features. These study create a three layers Represented (Geolocation). Layer Base Map, Layer customer and private schools layer
5	Spatial Decision Support System (SDSS)	This component is analyzed and the process of location of the number of customers for each polygon are get on the graph, as well as the number of private school for each polygon are get on the graph and the comparison is between them and obtain the appropriate decision.

Figure 3. The Proposed System "DEGIS"

3.1 Geolocation Acquisition

Geolocation Acquisition (GA) consists of two pages: the login page and registration page, which are websites that were designed and implemented using HTML5 and JavaScript. Fig 4 describes the operations of the login site. It is designed to determine the geographic location, which allows the user to use the system to enter a username and password and download the home page.

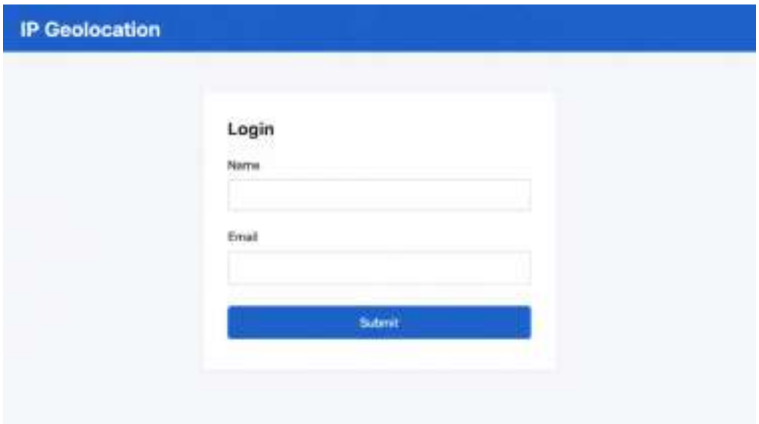

Figure 4. Shows login

3.2 Geolocation Determination

The main operation of the system is to determine both latitude & longitude (Geolocation) for users. Geolocation data Determination requires visiting the service's Internet site (private schools) through the login page. The login page contains Geolocation Acquisition; it is responsible for the processing between the server and the service. This operation accepts the user's IP and converts it to the corresponding Geolocation. The (IP) transferred to Geolocation latitude and longitude Geolocation latitude and longitude login user data in the database as shown in the following figure (5).

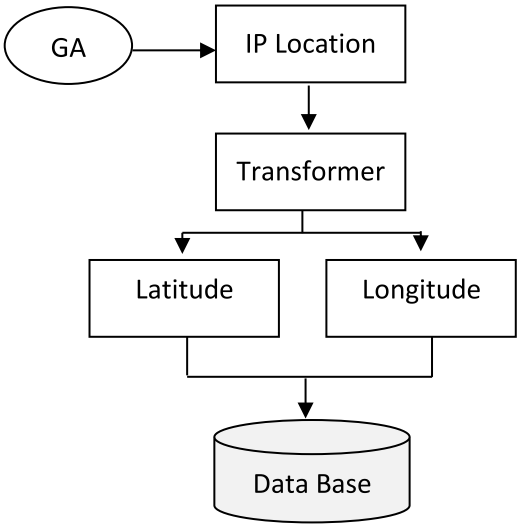

Figure 5. Show Geolocation Determination

3.3 SPATIL GIS DATA (SGD)

While spatial data are received as a result of user log-in, and private schools' geolocation for both customers and private schools are saved as Excel data tables, Figure (6-a) and Figure (6-b) spatial data can be dealt with in geographic information systems.

C	B	A
Latitude	Longitude	school_name
32.06853	23.92338	ABC
32.07025	23.94522	AHBAB ELRAHMAN
32.0685	23.96388	STARS OF KHALEEG
32.08604	23.96111	ALMUSTASHAR
32.07971	24.00197	MANARA TOBRUK
32.05293	23.95929	JAWAHER TOBRUK
32.07924	23.99125	REWAQ ALALM
32.10482	23.95963	ALTAWFEEQ
32.09029	23.95295	EMAN
32.06924	23.94188	TAWHEED
32.05122	23.9628	ALGALAM ALARABE
32.08463	23.94138	ALTAMEEZ ALDAEEM
32.07523	23.93719	ROEEA ALMASTAQBAAL
32.07806	23.88416	ALAWAEEL
32.04603	23.95462	ALBURHAN
32.09576	23.94694	ALAMTEAZ
32.05575	23.91344	ALRAAEED ALARABE
32.08942	23.93964	AL AFAQ ALJADEED
32.08371	23.96203	SALAM ALNAJAH
32.08619	23.97814	ALBUTNAN ALHADEETHA
32.08605	23.97511	ALBEDAI
32.07825	23.92893	ALNEBRAS
32.0815	23.9482	ALKETAAB ALARABE
32.09716	23.95846	ALGEEL ALSAAD
32.09094	23.96922	GEEL ALKARAMA
32.0768	23.9495	ALMUTAHEDA
32.07702	23.96121	ALMOADA
32.0783	23.94291	ALMOADA2
32.07909	23.98526	ALSAFAA
32.07824	23.90797	BASAMAT ALALM
32.09161	23.8857	ZEDNEE ALMAN
32.08281	23.99142	TAREEQ ALAZDEHAR

E	D	C	B	A	
			legth	lug	1
			32.07846	23.91011	2
			32.07873	23.90939	3
			32.07884	23.90817	4
			32.07926	23.90842	5
			32.07791	23.90955	6
			32.07786	23.91104	7
			32.07873	23.91094	8
			32.07791	23.90979	9
			32.07786	23.91034	10
			32.03457	23.96298	11
			32.03454	23.96358	12
			32.03458	23.9647	13
			32.03405	23.96296	14
			32.03377	23.96483	15
			32.03404	23.9657	16
			32.03533	23.96469	17
			32.03336	23.96309	18
			32.06431	23.97736	19
			32.06403	23.97667	20
			32.06333	23.97616	21
			32.06336	23.97533	22
			32.06306	23.97477	23
			32.06276	23.97435	24
			32.06344	23.9773	25
			32.06283	23.97341	26
			32.06241	23.9729	27
			32.08117	23.96044	28
			32.08102	23.95987	29
			32.0806	23.96025	30
			32.07031	23.93899	31
			32.06866	23.93838	32

Figure 6.a,b: Excel Sheet

Figure 7 illustrate this process

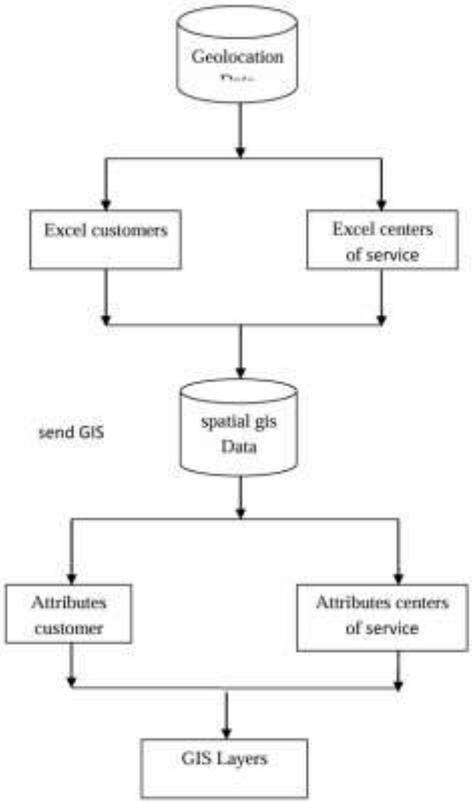

Figure 7. SPATIL GIS DATA (SGD).

3.4 GIS layers

A data layer composed of a group of logically attached geographic advantages and their features. This study creates a three-layer representation (Geolocation). Layer Base Map, Layer customer, and centers of service layer [12].

3.4.1 Layer Base Map

In this study, we used a map of the OpenStreetMap, and we have identified the geographical site of both customers and private schools that use the Base map to store data in a spatial database, as shown in the following figure8.

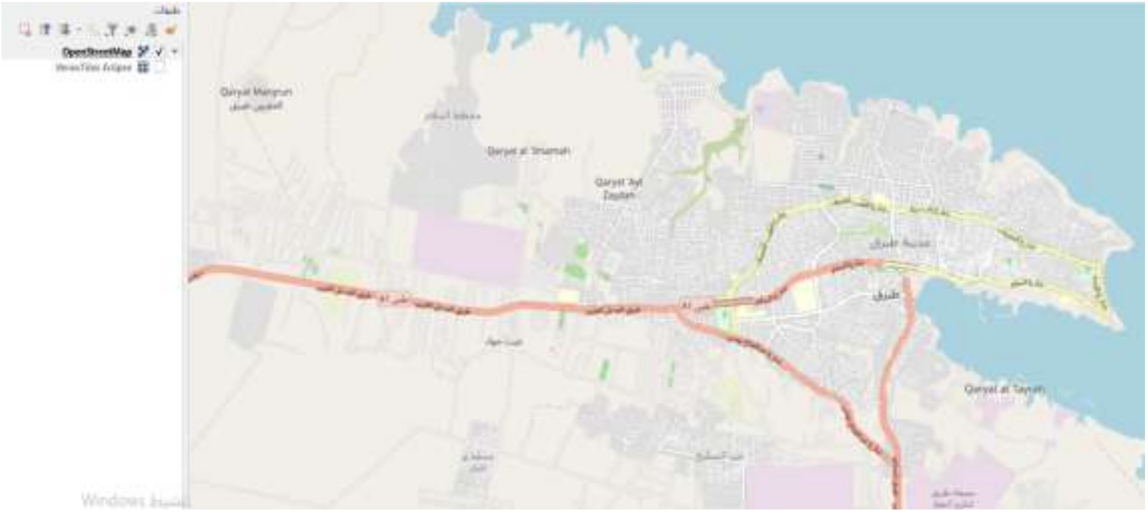

Figure 8. Base Map.

3.4.2 Layer customer

This layer uses geographical locations stored for customers and calculates the number of customers for each polygon as shown in the following figure.

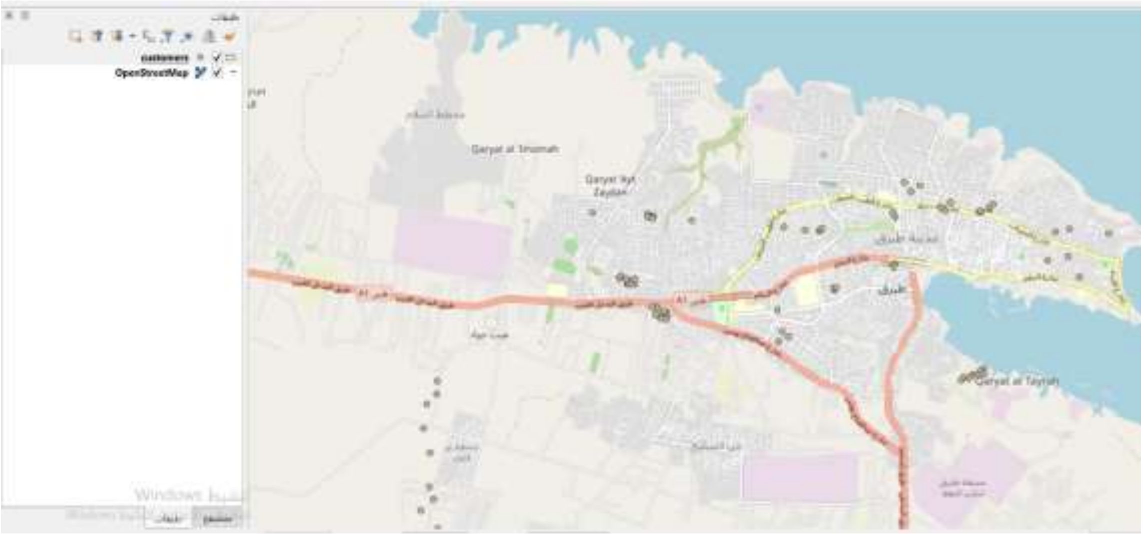

Figure 9. Spatial Distribution Map of customers in Tobruk City.

3.4.3 Layer private schools

This layer uses geographical locations stored for private schools and calculates the number of schools for each polygon, as shown in the following figure

Figure 10. Spatial Distribution Map of Private Schools in Tobruk City.

3.5 SDSS

The final phase of the system involves data analysis, wherein the customer count for each polygon is represented on the graph, alongside the number of private schools for each polygon. A comparative analysis is conducted between these metrics to derive an appropriate decision, as illustrated in Fig 11.

Figure 11. Spatial Distribution Map of Private Schools and customers in Tobruk City.

3. Result

A private school's website was designed and implemented to check the system and the relationship between customers and private schools based on the location. Figure 12 shows the number of customers and points of service charts are based on the neighborhoods (Geolocation).

Table 2: Value customers and private schools.

	Street	Customer	Point of private school
1	Al-Mukhtar	3	5
2	ALKHLEEG	9	1
3	ALHADAEEQ	6	4
4	ALNASR	3	8
5	ASHBILIA	9	1
6	ALQADS	9	3
7	SOOQ ALAGAG	3	3
8	AMRERA	3	0
9	JABELLA SHARQEA	3	2
10	ALHATTEA	3	1
11	ALZOHOOR	3	0
12	ALMATAR ALQADEEM	3	2
13	ALMANARA	3	7
14	ALSNENAT	3	7
15	BAB DERNA	3	2
16	ALANDALAS	3	7
17	ALZAGAM	3	1
18	NAJMA ALKHALEEJ	9	2
19	ALTASLLEH	9	1
20	KROOM ALKHEEL	10	2

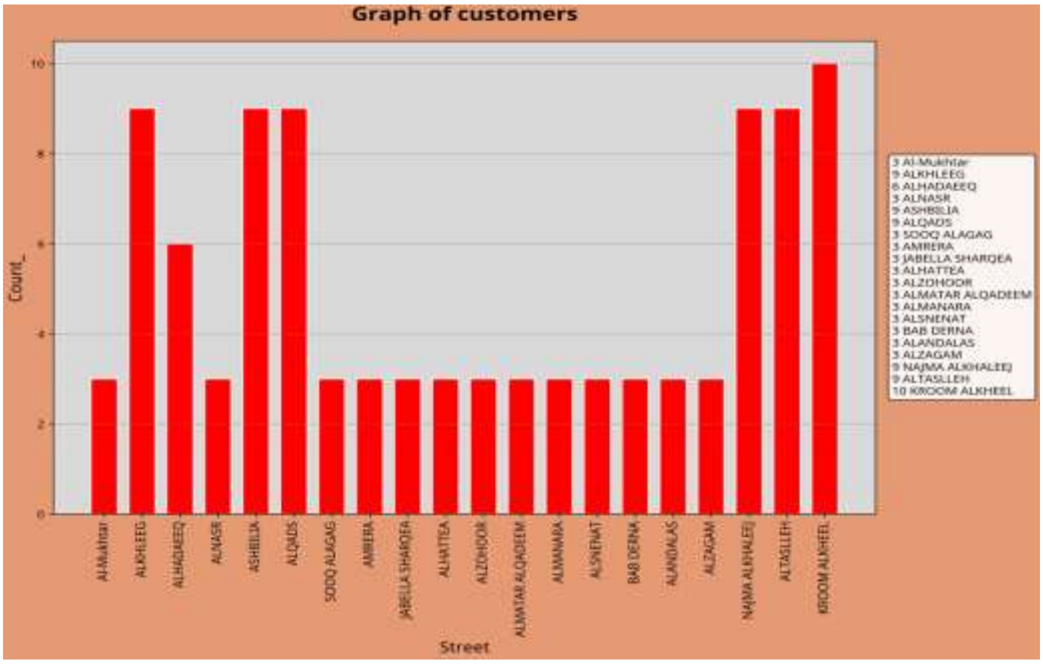

Figure 12.a. customer graph.

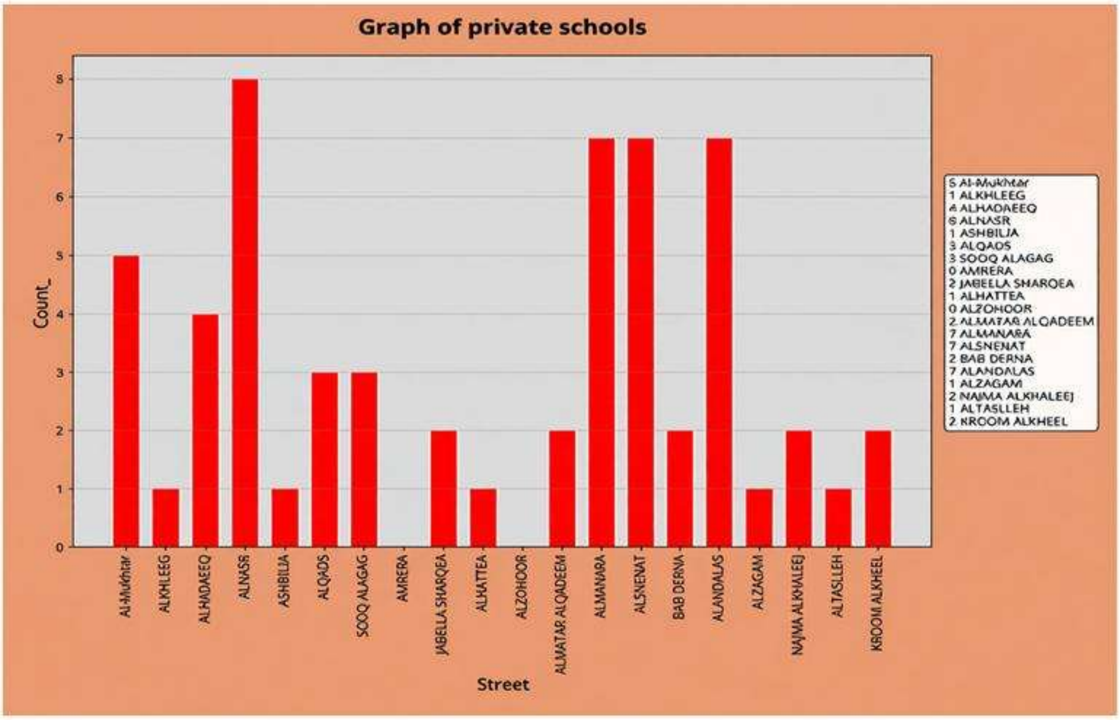

Figure 12.b. point of private school's graph.

4. Conclusion and Recommendations

This study demonstrates the utilisation of geographical information systems (GIS) on the Internet, to enable private schools to leverage location services for enhanced decision-making. We illustrated the application of our system and provided validation and preliminary results regarding the use of GIS for private schools.

The user's geolocation (latitude and longitude) is determined through their IP address. Geolocation serves as a spatial data layer in GIS, which includes layers such as base map, customers, and private schools, to calculate the number of customers and schools within each polygon using spatial statistics (geostatistics). Analysis of test data produced a correlation coefficient of - 0.318, indicating a weak relationship between the distribution of private schools across polygons (geographical zones) and the number of customers in each zone. This indicator guides decision-makers in redistributing private schools among building areas based on customer intensity, as determined by geographical zone.

Causes of Spatial Misalignment

The following factors contribute to this weak correlation:

- Private schools are often created based on commercial opportunities or accessibility to key roadways, rather than considering residential density.
- Decision-makers typically lack access to real-time student distribution maps, resulting in "blind" licensing for new schools.
- Tobruk's increasing urbanisation has outpaced the construction of educational infrastructure, resulting in underserved regions.

The persistence of this spatial gap has several negative consequences:

- Increased Traffic and Logistics: Students residing in underserved zones are compelled to commute long distances to reach schools in congested areas, thereby increasing traffic pressure and transportation costs for families.

• Inequity in Educational Access: The concentration of schools in certain "clusters" (such as the city center) causes a gap where pupils in remote locations have fewer options and limited access to private education.

• Financial Inefficiency: Private school investors may experience lower enrolment rates if they choose to locate in overcrowded areas or distant from their intended population.

The suggested DSGIS (Decision Support Geographic Information System) is more than just a visualization tool; it is a strategic intervention designed to address these spatial disparities through the following mechanisms:

1. The DSGIS uses IP-based geolocation to capture a "live" snapshot of prospective student access points, unlike static maps. This enables a dynamic heat map of demand that changes with urban trends, guaranteeing that planning is based on up-to-date information.
2. 2. Municipal sources can use the SDSS (Spatial Decision Support System) component to simulate "what-if" scenarios. For example, before awarding a license to a new private school in a given polygon, the system can compute the influence on the correlation coefficient. If the new school would overcrowd an existing congested area, the algorithm would suggest alternate places in high-demand/low-supply zones.
3. The system's polygon-based charts give clear visual proof to help investors and governments solve educational gaps. This results in a more balanced urban environment in which educational services are dispersed appropriately to population density, lowering the pressure on city infrastructure and increasing inhabitants' quality of life.

The study made several suggestions, including the following:

- The city experiences a significant deficit of private schools, particularly in neighborhoods distant from the city center, which possess a limited number of such institutions and fail to adhere to planning rules.
- To mitigate educational service issues and enhance their efficiency, the Tobruk municipality must take the lead in utilizing geographic information systems to establish a database of educational services, serve as a reference for planning and decision-making in the implementation of educational projects, and prevent the occurrence of spontaneity and randomness in the distribution of private schools.
- In addition, work to build additional educational service sites to address the study area's shortage, taking into account urban expansion and anticipated population growth rates.

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