A Proposed Framework for Increasing the Volume of Sales Using Geographic Information Systems

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Abstract

This paper utilizes Geographic Information Systems (GIS) to analyze market distribution in Cairo and identify optimal locations for new markets. By integrating geographic data (such as population density and infrastructure), demographic data, as well as data on existing market locations, the research employs advanced techniques like network and proximity analysis to determine spatial relationships and evaluate the efficiency of the current market network. Findings reveal gaps in market distribution, highlighting underserved areas and proposing ideal locations for new markets. The study provides a framework to address these gaps and improve market accessibility.

The paper proposes several key recommendations: First, developing comprehensive market distribution plans considering population growth, transportation networks, and market saturation. Second, prioritizing infrastructure investments in underserved areas; Third, implementing targeted marketing campaigns to promote new markets and support local businesses. Finally, conducting further research on climate change impacts on market distribution and integrating findings into long-term planning.

Keywords: Market Site Selection, Geographic Information Systems (GIS), Proximity Analysis, Spatial Analysis, Network Analysis.

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إطار عمل مقترح لزيادة حجم المبيعات باستخدام نظم المعلومات الجغرافية

الملخص

تستخدم هذه الورقة البحثية نظم المعلومات الجغرافية (GIS) لتحليل توزيع الأسواق في القاهرة وتحديد المواقع المثالية لإنشاء أسواق جديدة. من خلال جمع وتحليل البيانات الجغرافية (مثل كثافة السكان والبنية التحتية)، والبيانات الديموغرافية، بالإضافة إلى بيانات مواقع الأسواق الحالية، تعتمد الدراسة على تقنيات متقدمة مثل تحليل الشبكات وتحليل القرب لتحديد العلاقات المكانية وتقييم كفاءة شبكة الأسواق الحالية. تكشف النتائج عن وجود فجوات في توزيع الأسواق، مع تسليط الضوء على المناطق التي تفتقر إلى الخدمات واقتراح مواقع مثالية لإنشاء أسواق جديدة. تقدم الدراسة إطارًا عمل لمعالجة هذه الفجوات وتحسين إمكانية الوصول إلى الأسواق.

تقدم الورقة عدة توصيات رئيسية: أولاً، وضع خطط شاملة لتوزيع الأسواق تأخذ في الاعتبار النمو السكاني، وشبكات النقل، ودرجة تشبع الأسواق لضمان وصول عادل إلى الخدمات التجارية؛ ثانيًا، إعطاء الأولوية للاستثمارات في البنية التحتية الخاصة بالنقل والمرافق ومرافق الأسواق في المناطق المحرومة لدعم إنشاء أسواق جديدة؛ ثالثًا، تنفيذ حملات تسويقية مستهدفة لزيادة الوعي بمواقع الأسواق الجديدة ودعم الأعمال المحلية؛ وأخيرًا، إجراء مزيد من الأبحاث لتقييم التأثيرات المحتملة لتغير المناخ على أنماط الاستهلاك وتوزيع الأسواق، مع دمج هذه النتائج في استراتيجيات التخطيط طويلة المدى.

الكلمات المفتاحية :اختيار مواقع الأسواق، نظم المعلومات الجغرافية (GIS)، تحليل القرب، التحليل المكاني، تحليل الشبكات.

1. INTRODUCTION

Geographic Information Systems (GIS) have become essential tools for spatial analysis, providing valuable insights for various sectors, including urban planning, housing, and importantly, market site selection. Integrating spatial data with non-spatial attributes, GIS allows stakeholders to effectively manage location-based activities. This study utilizes GIS to analyze market distribution in Cairo, Egypt, with the goals of optimizing market distribution by identifying ideal locations for new markets, improving retail service quality by addressing market distribution gaps, and developing a comprehensive framework for market distribution that considers various factors. Through the analysis of urban growth, land use changes, competitor locations, and consumer behavior, this study aims to demonstrate the critical role of GIS in informing market site selection decisions, ultimately contributing to sustainable urban development and enhancing citizens' quality of life [1] and [2].

Geographic Information Systems (GIS), by integrating spatial and non-spatial data, support decision-making across urban planning, housing, and marketing. GIS enables analysis of complex spatial relationships like land use, demographics, and environmental factors, crucial for sustainable urban development. It streamlines urban planning through real-time data analysis and scenario modeling, improving resource allocation and infrastructure planning. Integrated with remote sensing and address systems, GIS monitors urban growth and land use changes, informing policy. With increasing urban challenges like environmental adaptation and population growth, continuous GIS-based observation is essential. GIS, by integrating diverse data and visualizing complex urban phenomena spatially, is a key tool for better urban decision-making and strategic planning [3], [4], [5], [6] and [7].

A GIS system combines hardware, software, geographic data, and personnel to efficiently capture, store, update, manipulate, analyze, and display geographically referenced information. Its analytical and solution-driven nature benefits various business functions, from operational to strategic decision-making. In retail, GIS is particularly valuable for determining points of sale, retail site selection, and analyzing future and competitive developments , GIS helps businesses understand spatial customer distribution by analyzing geographic factors influencing market demand and supply, enabling them to identify underserved areas, optimize store locations, and improve distribution networks for enhanced market penetration and performance [8], [9] and [10].

Site selection is crucial for industry success, impacting operational efficiency, cost-effectiveness, resource access, and market proximity. Building on prior GIS-based location selection research, this study explores GIS application in Cairo's urban market analysis. While previous studies demonstrate GIS effectiveness in integrating spatial data with multi-criteria decision-making for diverse sectors, this research focuses specifically on Cairo's unique urban market context. It distinguishes itself by analyzing Cairo's complex networks, considering existing market locations, distribution, and high population density, identifying served and underserved areas for a more accurate market location model, contributing to improved urban planning and community service Additionally, it identifies served and underserved areas, allowing for the development of a more accurate model for determining optimal market locations, thereby contributing to improved urban planning and community service [11].

2. RELATED WORK

Location analysis is crucial for business success, requiring careful evaluation of potential sites [12]. Key factors include site economics, demographics, competition, and traffic patterns. [13], [14], [15] and [16].

This paper explores using the Factor Rating Method (FRM) for manufacturing site selection, validated by the Analytic Hierarchy Process (AHP). AHP allows for a more comprehensive evaluation by considering multiple criteria simultaneously and using pairwise comparisons to determine each criterion's relative importance, providing decision-makers with a clearer understanding of their impact. These studies demonstrate the application of advanced fuzzy logic approaches for warehouse and dam site selection [17] and [18].

In [19], Puviarasu, et al., presented a hybrid multi-criteria decision-making model based on STEEP factors (Social, Technological, Environmental, Economic, and Political) for evaluating the location of battery recycling plants, promoting sustainable decision-making in the recycling industry.

In [20], Li, et al., introduced an optimal site selection framework for near-zero carbon emission power plants, incorporating the perspectives of multiple stakeholders to ensure sustainable and inclusive decision-making in the energy sector.

In [21], Akdeniz, et al., assessed the suitability of shrimp farming sites in Turkey using GIS and AHP, providing valuable insights for informed decision-making within the shrimp farming industry. GIS has emerged as a powerful decision support tool, leveraging the spatial characteristics of data to inform decision-making across various sectors.

3. METHODOLOGY

This paper aims to select optimal sites for market centers in urban areas by utilizing GIS to develop a proposed framework for identifying the best locations. The research will focus on market center accessibility and analyze their geographical distribution as illustrated in Figure 1.

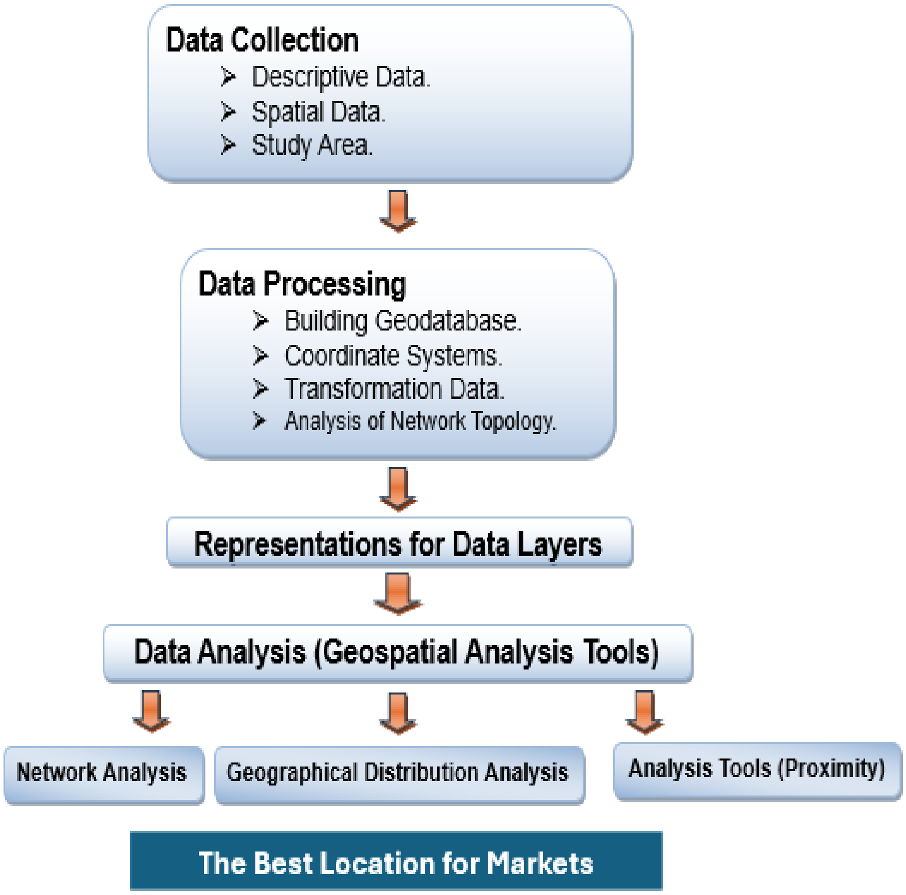

Figure 1. Proposed Framework for Increasing the Volume of Sales.

3.1 Data Collection

This paper relied on Spatial analysis tools by using program Arc GIS 10.8 to determine the geographical distribution, determine the nearest neighbor, the intermediate location, the standard distance and Inclination, the buffer zone, the intersection, and analyze the road map to discover the nearest market center.

3.1.1 Study Area

The study area includes (El-Sherouk City, New Cairo City, and Badr City). This study area is shown as in figure 2.

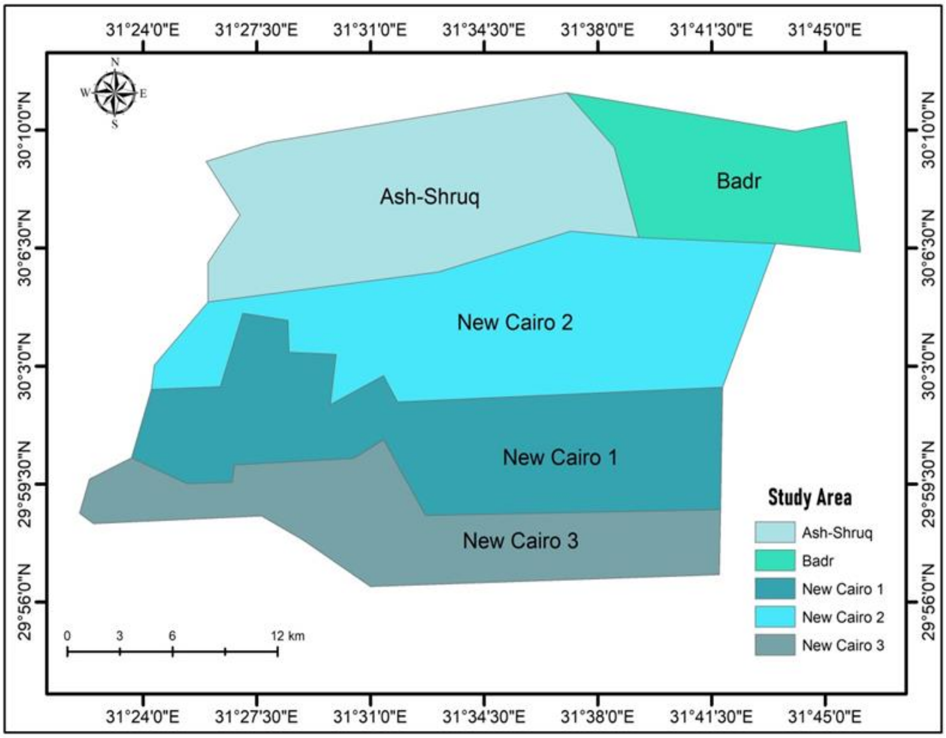

Figure 2. Study Area in ARC GIS 10.8 Programs.

- El-Shorouk City is a city located in the northeast of Cairo and in the north of New Cairo, in the province of Cairo, in Egypt, which is part of Greater Cairo.

- New Cairo City is a city covering an area of about 30,000 hectares (70,000 acres) on the southeastern edge of Cairo Governorate, 25 kilometers (15 mi) from Maadi.

- Badr City is a city located northeast in the Cairo Governorate, Egypt. Badr is planned as an industrial city and includes 129 factories. In addition to this, 350 factories are still under construction. The study area covers a total of 714,967,319.476299 square units.

3.1.2 Study Areas in Google Earth Program

The researcher presented the study areas on the Google Earth program in order to confirm the accuracy of this information shown in figure 3.

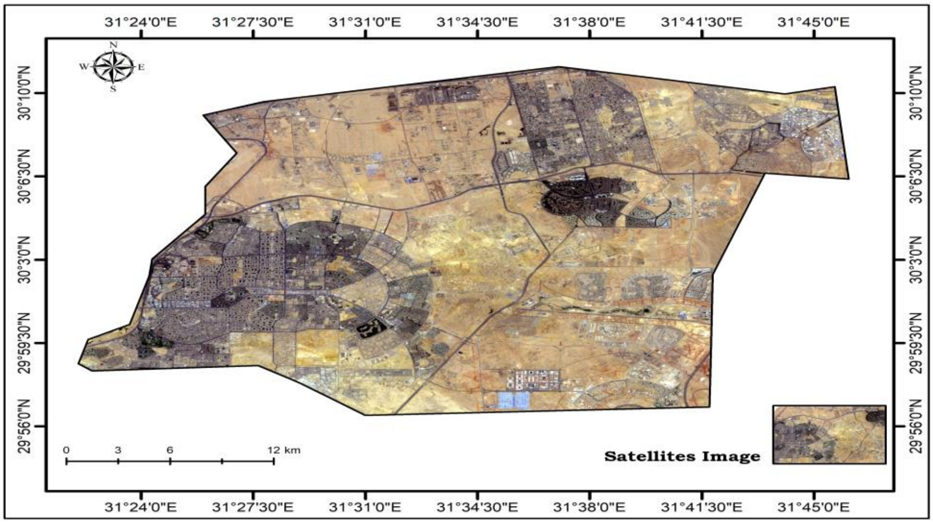

Figure 3. Study Areas in Google Earth Program.

3.2 Data Processing

This phase involved integrating Spatial Data and Descriptive Data, building a Geodatabase, establishing a consistent coordinate system, conducting data transformation and network topology analysis, and performing other essential operations to create a comprehensive database for the study area.

- Building Geodatabase: The geographic database is one of the most important results of this study. Databases that represent geographic characteristics and attributes, which are stored within the relational database management system (RDMS).
- A coordinate system is a reference system used to represent the locations of geographic features, imagery, and observations, in this study, coordinate systems using universal transverse Mercator (UTM) in shown coordinate for study area.
- Transformation Data: In this step, data is converted from KML to layer and converted from AutoCAD to Geodatabase
- Analysis Network Topology: Topology refers to the relationship between spatial features or objects. In this study, the researcher used Network Topology tools to correct the wrong data and ensure the accuracy of routes and data of the streets until we ascertain the road layer of the study areas.

This phase involved the creation of a comprehensive geodatabase by integrating spatial and descriptive data. Key steps included establishing a consistent UTM coordinate system, transforming data from various sources (KML, AutoCAD) into the geodatabase, and conducting network topology analysis to ensure the accuracy and consistency of road network data.

3.3 Data Layers

Layers are the mechanism used to display geographic datasets in Arc GIS software. Each layer references a dataset and specifies how that dataset is portrayed using symbols and text labels.

3.3.1 Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is a widely used index in remote sensing for assessing vegetation health and vigor.In Figure 4 presents an NDVI map illustrating vegetation health, with yellow indicating high vegetation cover and red indicating low vegetation cover. Spatial analysis reveals concentrated vegetation in the central and eastern portions, while sparse vegetation is observed in the western and southern parts.

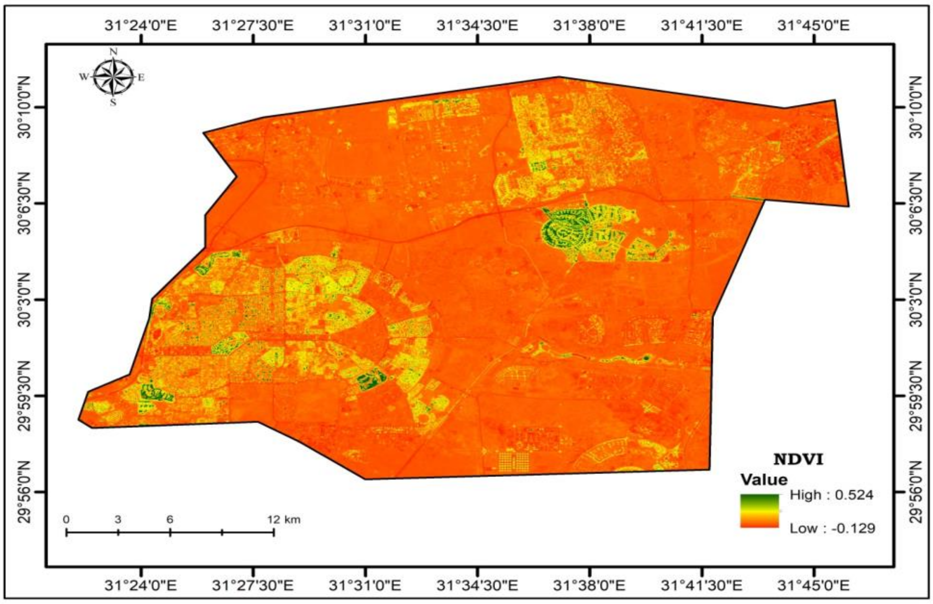

Figure 4. Normalized Difference Vegetation Index for Study Area.

3.3.2 Digital Elevation Model (DEM)

The DEM map effectively depicts the region's terrain, showcasing variations in elevation through a color scale where lighter colors represent lower elevations, and darker colors represent higher elevations. It reveals a variety of landforms, including mountains, hills, valleys, and possibly plateaus. The density of contour lines indicates the steepness of slopes, and their orientation suggests the general direction of slope shown that in figure 5.

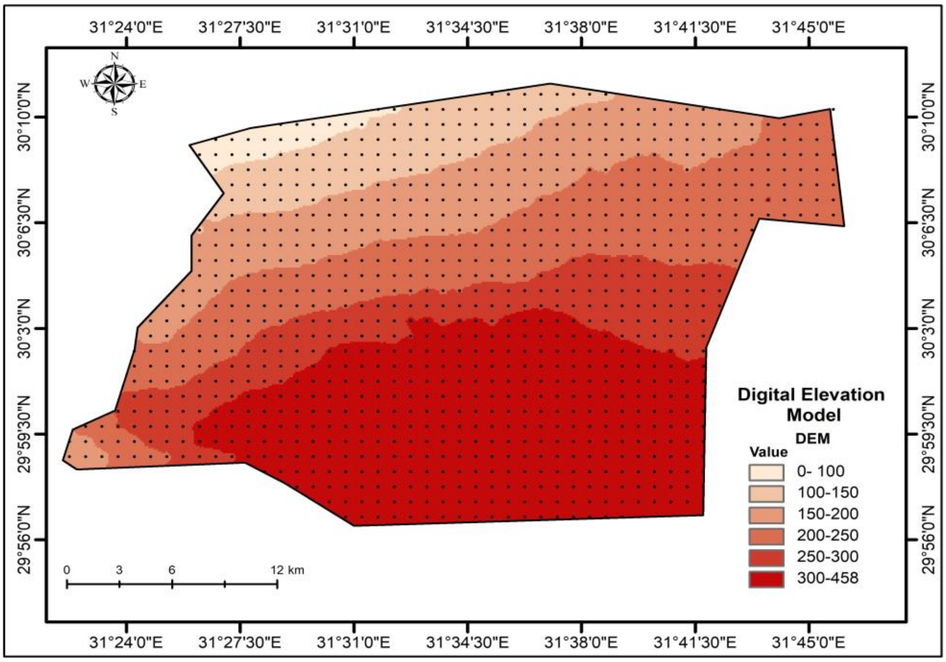

Figure 5. Digital Elevation Model (DEM).

This DEM is valuable for applications such as land use planning, hydrology, and hazard assessment. However, it's crucial to remember that the map provides a two-dimensional representation, and its accuracy depends on the resolution of the data used to create it.

Table 1. Presents a distribution of land area across six elevation categories. Each category represents a specific altitude range, with corresponding values for area in square kilometers and its percentage contribution to the total land area.

Table 1: Elevation Areas in KM in Study Areas

No	Elevation	Area km	Area per%
1		14.92	2.09
2	100-150	62.39	8.73
3	150-200	118.82	16.62
4	200-250	167.62	23.44
5	250-300	102.17	14.29
6	300-458	249.03	0-100
	Total Area	714.96	100

3.3.3 Rainfall and Temperature Maps

- The December rainfall map of Cairo exhibits significant spatial variability, with most areas receiving less than 3 millimeters. Higher rainfall rates are observed in the eastern and southeastern parts, while a gradual decrease in rainfall is evident from east to west across the city, as shown in figure 6.
- The August temperature map (Tempmax) reveals a concentration of high temperatures in the central and eastern parts of the study area, highlighting significant spatial variation. The urban heat island effect is evident, with urban areas experiencing higher temperatures than surrounding rural areas. In contrast, the December temperature map (Tempmin) shows significantly lower temperatures overall. However, spatial variation persists, with higher temperatures observed in urban areas shown that in figure 7.

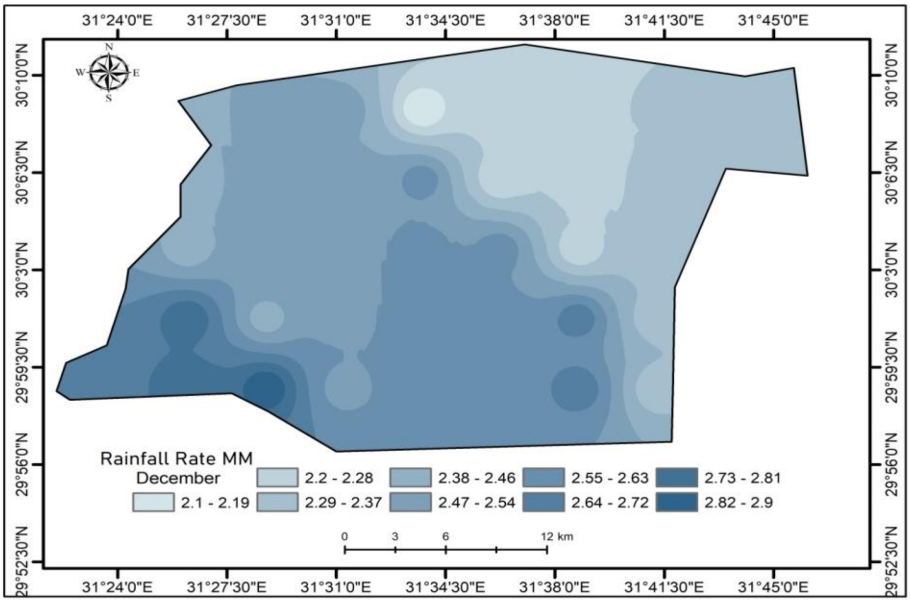

Figure 6. Summary for Rainfall

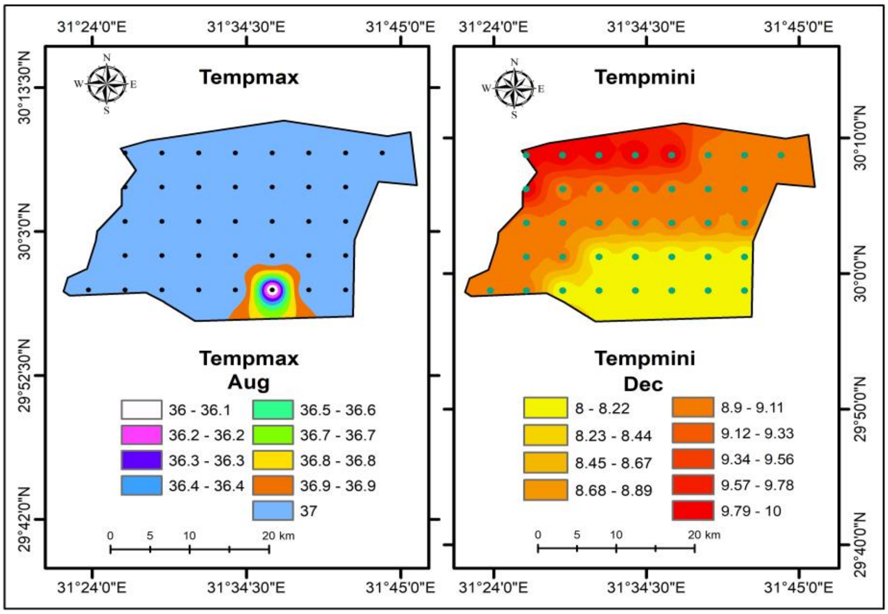

Figure 7. Summary for Temperature Maps

3.3.4 Markets

The map illustrates the concentration of health centers in certain areas, while markets are more dispersed. While the presence of both in some areas suggests a comprehensive approach to serving residents, disparities in distribution may impact accessibility for some.

Figure 8. Sample Markets in Study Area

The figure 8illustrates the distribution of healthcare services and markets in the study area.

Uneven Distribution: This Figure 8 reveals that the distribution of healthcare services and markets is not uniform throughout the area. Some areas have a high concentration of these services, while others have a low concentration.

- Service Clustering: Certain areas exhibit a clustering of healthcare services and markets, indicating the presence of urban centers or major commercial zones.

4. Discussion and Analysis

A. Population

The population distribution in New Cairo exhibits heterogeneity, with high density concentrated in specific areas like New Cairo 1 and 2. This disparity reflects variations in attractiveness, influenced by factors like service availability and infrastructure. The map also reveals a clear pattern of urban expansion, with densely populated areas showing significant growth. Shown that in figure 9.

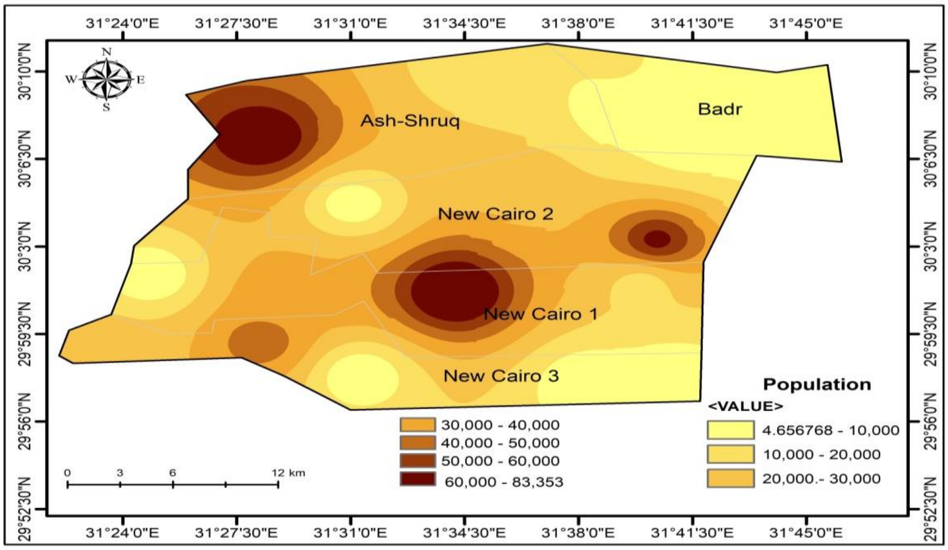

Figure 9. Populations in Study Area.

The population distribution in New Cairo is heterogeneous, with high densities in certain areas and low densities in others. This disparity reflects variations in attractiveness factors. The map reveals rapid urban expansion, indicating a need for infrastructure development and equitable distribution of services to ensure sustainable growth in New Cairo.

Population density, a crucial factor in urban planning, varies significantly across the study area. This spatial variation necessitates differentiated planning approaches. Identifying these disparities is crucial for allocating resources effectively, ensuring adequate service provision, and promoting sustainable development in all regions shown that in figure 10.

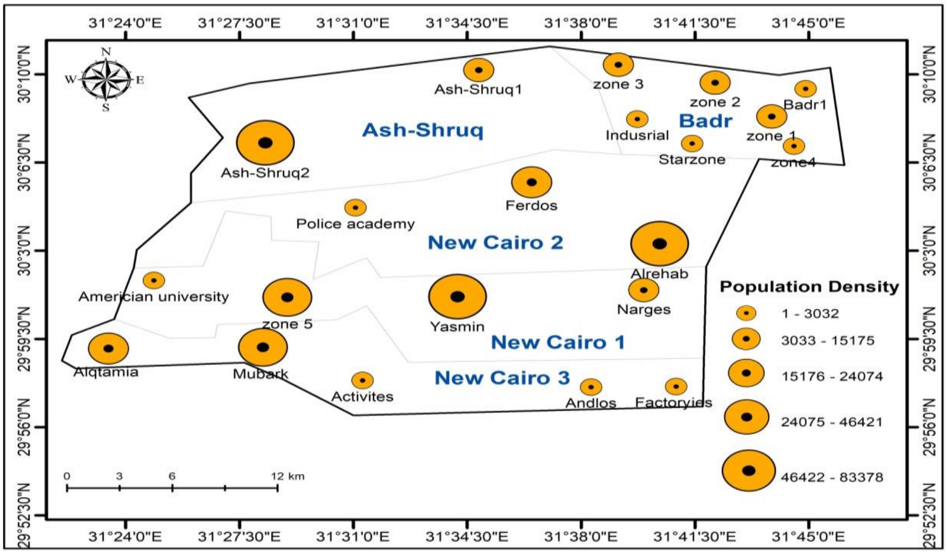

Figure 10 Population densities in study Area.

This figure illustrates several key population characteristics in New Cairo. A significant population disparity exists, with areas like "Yasmin" and "Ash-Shruq2" exhibiting high densities, while "Activities" and "Factories" show very low densities. "Yasmin" and "Ash-Shruq2" dominate the population, likely due to attractions like better services or infrastructure. A relatively balanced gender ratio is observed across most areas, suggesting a balanced population structure. Several areas, including "Activities" and "Factories," have extremely low densities, possibly due to their industrial or service-based nature or a lack of services and infrastructure.

B. Proximity Analysis

Proximity analysis is a powerful technique in Geographic Information Systems (GIS) that allows you to examine the spatial relationships between geographic features based on distance or proximity.

- **Buffer for Markets in Study Area**

In figure 11 reveals a concentrated distribution of markets in the central area, suggesting strong attractive factors such as high population density and infrastructure availability. This is accompanied by a circular distribution pattern, likely influenced by historical or geographical factors. A clear correlation exists between market density and population density, with increased market density observed towards the center.

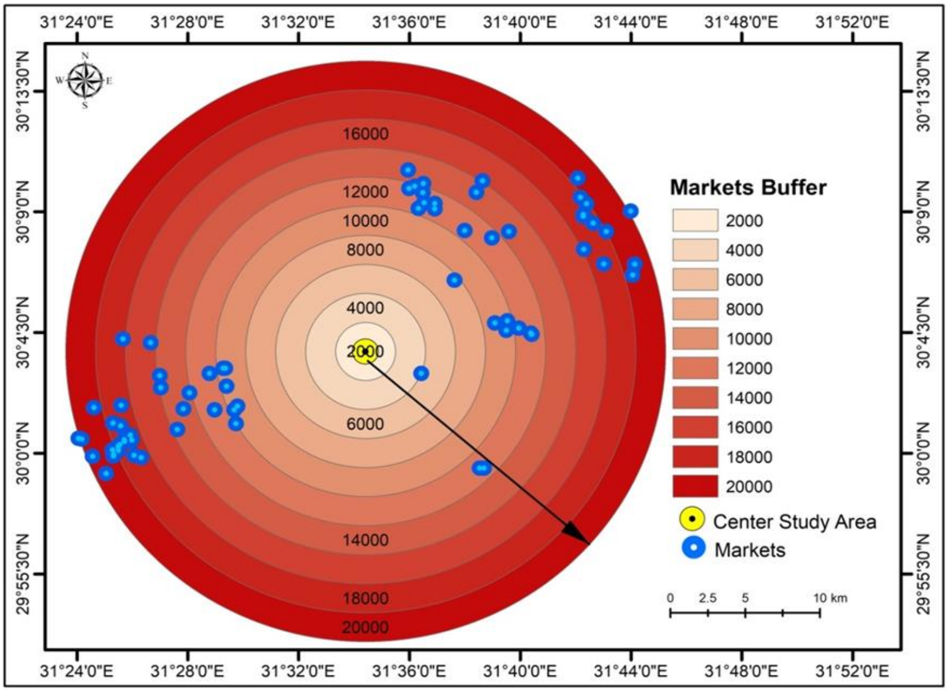

Figure 11. Buffers for Markets in Study Area.

• Buffer for Hospitals in Study Area

The map in figure 12 shows a circular distribution of hospitals around a central study area. The concentric circles with varying colors represent different coverage areas for these hospitals, indicating a relationship between the location of hospitals and the healthcare services provided to the area's population.

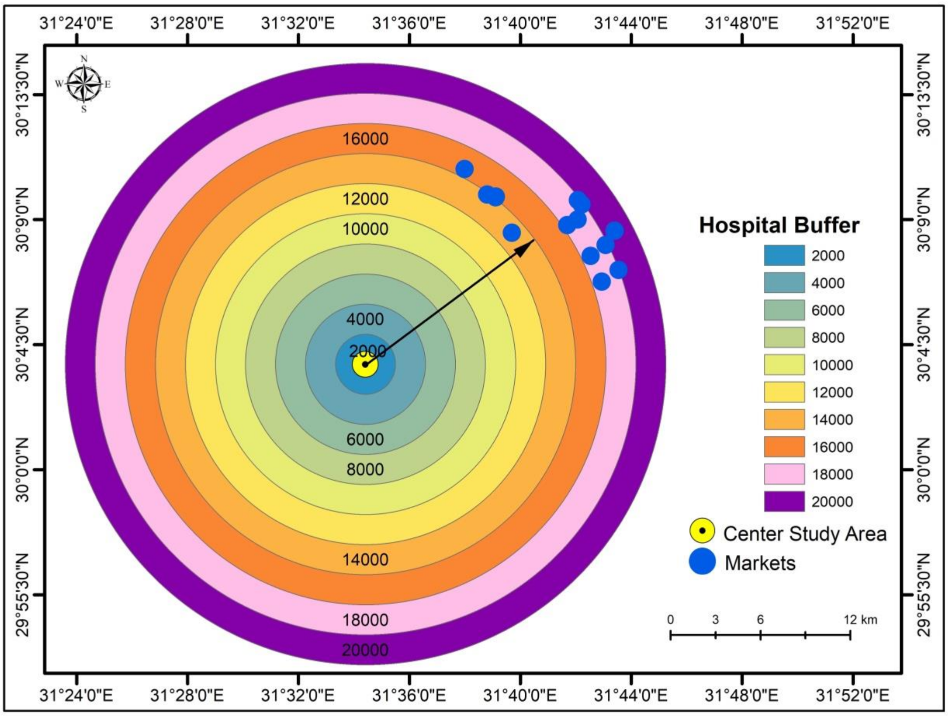

Figure 12. Buffers for Hospitals in Study Area.

In figure 13 shows a concentrated market distribution pattern with service areas radiating outwards. Finally, the analysis suggests potential disparities in market accessibility, with peripheral **areas** potentially facing greater challenges in accessing markets compared to the central area.

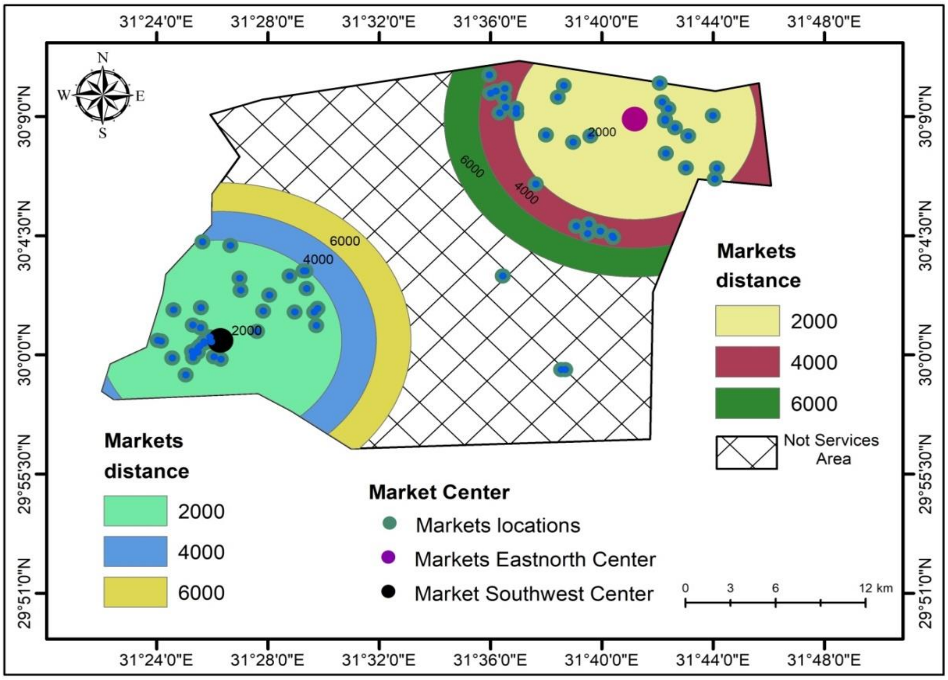

Figure 13. Distance for Markets In study Area.

In Table 2, the researcher presents a summary of the buffering analysis conducted in the study area.

Table 2 .Result for Buffering Analysis

Result for Buffering Analysis	
Buffer Radius Level	Buffer Distance
Markets	Buffer 2000km to 20000km in the Study Area
Hospitals	Buffer 2000km to 20000km in the Study Area
Result	• Study Area=714,967,319.476299km • Service Area =399,550,186.522989 km • No Service Area=315,417,132.95331km

C. Distribution for Study Area

The majority of markets are concentrated in a specific central area, with some dispersion towards the periphery.

- Central Feature "Central Feature" refers to the central element or focal point in a region. This could be an important location or a key point on the map shown that 15.
- Standard distance refers to the standard distance, a statistical concept used to measure the dispersion or spread of data around a central point.
- Directional Distribution The map in figure 14 reveals a non-random distribution of markets within the study area, with significant concentration in a specific region and following an elliptical pattern.

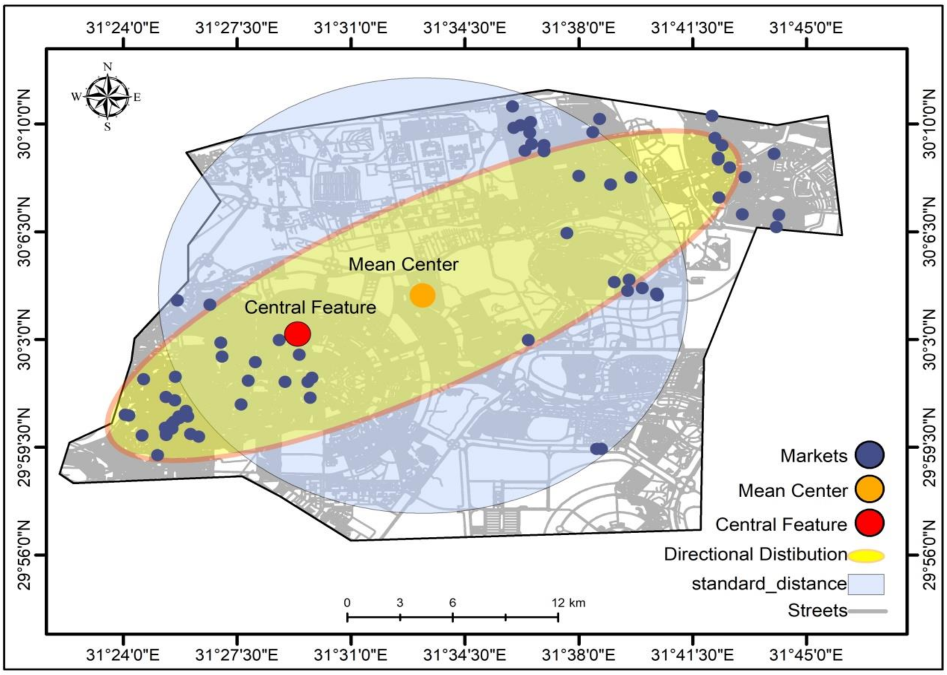

Figure 14. Directional distributions for Study Area

D. Network Analysis

The main objective of the network analysis is to know the reality of the roads in the study area as it will help us to choose sites for markets [22].

A service area is a geographical region encompassing all locations accessible within a specified time or distance from a central point. The analysis reveals that certain areas are not currently **served** and may require the establishment of new markets to improve accessibility shown in figure 15.

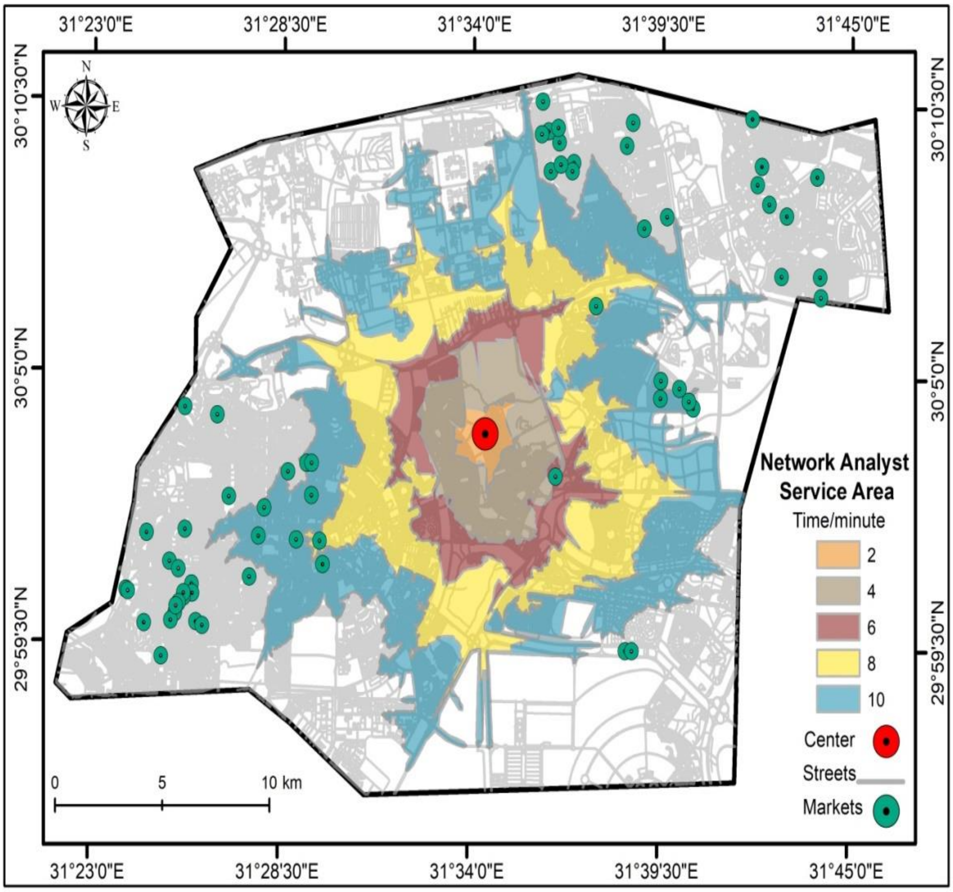

Figure 15. Service Area in study Area

5. RESULTS and Findings

- Total Study Area (714,967,319.476299 km): This represents the entire geographical area under consideration for market assessment and service distribution analysis. It provides the overall framework within which the distribution of services and markets is evaluated.

- Serviced Area (399,550,186.522989km) This area encompasses regions that are currently served by various services, ranging from essential utilities like water and electricity to commercial services such as stores and restaurants. This figure indicates the extent of service coverage within the study area.

- Unserviced Area (315,417,132.95331 km): This significantly large area corresponds to regions that lack access to essential and commercial services. These underserved areas present the most substantial opportunities for market expansion.

- This paper utilizes an enhanced GIS-based network analysis tailored to the Cairo Road network. The system focuses on optimizing route finding between locations, particularly for accessing markets from residential areas. Key features include:

- Optimal Route Determination: The system helps consumers identify the most efficient routes to their preferred markets, considering factors like traffic congestion and peak hours.

- Nearest Market Identification: The system pinpoints the closest markets to a given location, benefiting both consumers and market operators by improving market accessibility and aiding potential customer bases.

6. CONCLUSION

This paper utilized Geographic Information Systems (GIS) to analyze market distribution in Cairo, revealing significant gaps in market accessibility. Some areas suffer from a severe lack of retail services, while ideal locations for new markets were identified to serve underserved communities. The findings highlight the need for comprehensive market distribution plans that consider population growth, transportation networks, and market saturation. Key recommendations include prioritizing infrastructure investments in underserved areas, implementing targeted marketing strategies, and further research on the impacts of climate change on consumption patterns and market distribution.

The paper aimed to optimize Cairo's market distribution, enhance retail service quality, and develop a framework for improving decision-making in the retail sector. A GIS-based network analysis system was employed to optimize routes to markets, taking into account factors such as traffic congestion and road conditions. This approach provides valuable insights for both consumers and market operators. Finally, the study advocates for wider adoption of GIS in urban planning and service development to support data-driven decisions, improve consumer satisfaction, and enhance economic efficiency.

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