Indian Journal of Information Sources and Services
ISSN: 2231-6094 (P) Vol.16, No.2, 2026, pp.68-78

DOI: https://doi.org/10.51983/ijiss-2026.16.2.08

Visual Perception of Population Maps of Baghdad Governorate (Comparative Study Between Cartographic Representation Using Graphical Methods within the ARC & GIS)

Wissam Ahmed Rasheed[1*]

[1*]Assistant Professor, Department of Geography and Geographic Information Systems, College of Arts, University of Baghdad, Iraq
E-mail: [1]wesamahmed@coart.uobaghdad.edu.iq
ORCID: [1]https://orcid.org/0009-0002-7696-7026
(Received 20 February 2026; Revised 25 March 2026, Accepted 08 April 2026; Available online 05 June 2026)

Abstract **-This paper will juxtapose the effectiveness of conventional methods of graphical cartography and GIS-interpolation methods in presenting the population distribution of the Baghdad Governorate in 2023. The study touches upon the efficiency of two types of cartographic techniques to present demographic data and is concerned with the speed and clearness of the visual perception. The analysis involves the use of traditional techniques (square, triangle, column and divided circle) and the GIS techniques (Kernel Smoothing, Kriging and Inverse Distance weighting) to describe the male, female and aggregate population. Fifty respondents used their comprehension speed on the maps as the sample. The findings demonstrate that the traditional techniques, especially the square, triangle and the divided circle, gave faster understanding and they scored 9/10 within 2 seconds. Conversely, GIS-based techniques, including Kernel Smoothing, depicted a sharp underperformance in visual perception, with a score of 2/10 in 20 seconds only. These GIS techniques though accurate in spatial interpolation, were not very clear especially at the district level hence limiting their application in urban planning. The research also brings out the issue of the difficulty in representing both sexes in one map through the use of GIS. Based on the results, traditional techniques are more effective in visualizing demographics because they are clearer and faster, particularly in the setting of urban planning, where fast decision-making is paramount. There is need to conduct further research to refine GIS techniques so as to enhance visual perception and district-accurate which will be more beneficial to urban planners and resource managers.**

Keywords: **Cartography, Visual Perception, RIG GIS, Population Mapping, GIS Interpolation, ArcGIS, Demographic Data**

I. INTRODUCTION

Population mapping is fundamentally a spatial analysis that reveals patterns to support planning and decision-making. With the advance of GIS technologies, not all methods of analysis or visualization are equally effective in representing demographic data. The present study analyses the distribution of the population for Baghdad governorate in 2023 by two methods: one is through traditional graphical cartographic representation; the other method applies GIS-based interpolation techniques. It determines which approach gives clearer visual comprehension for quick recognition of demographic patterns and also tests participants' ability to correctly interpret maps produced by both techniques, so as to find out a better method based on visual perception (Belarem, 2025).

Research Problem

The research problem focuses on determining the most effective cartographic method for communicating demographic patterns in Baghdad Governorate, particularly when comparing traditional graphics with GIS-based interpolation techniques**.**

1. Can maps produced using graphical cartographic representation adequately convey population data?
2. Can maps generated through advanced ArcGIS programs effectively communicate population data to the reader?
3. Which method enables faster and clearer communication of information to the reader: traditional graphical representation or advanced ArcGIS programs, based on the principle of visual perception?

Research Hypotheses

A: Capability of Representation

- The good old traditional graphical cartographic methods can adequately show the spatial distribution of the population within Baghdad Governorate at any scale.
- Also, GIS interpolation methods inside ArcGIS can be used to display demographic data at the district scale.

B: Efficiency in Visual Perception

- There is a difference that can be measured and quantified between both forms concerning visual perception, i.e., how easily or with difficulty they are viewed graphically.

- Traditional graphical methods are visually perceived more quickly and clearly than GIS interpolation methods.

Research Objectives

The main goal of this study is to examine the population distribution of Baghdad in 2023 by the conventional graphical cartographic analysis, as well as the ArcGIS interpolation analysis. This paper seeks to find out which technique presents the most accurate reflection of demographic data, considering which approach is more effective at presenting trends in the population. The other important goal is to investigate the visual perception and comprehension of various cartographic practices by people, and how they perceive them, and whether they are clear and easy to understand. Furthermore, the study involves a statistical examination of other significant demographic parameters like population density, age composition, and dependency ratios, which gives further information about the population characteristics of Baghdad. Finally, the research is aimed at assessing the trends in population growth over the years, which can be useful to define a better understanding of how the population dynamics can change and how these trends can be used in determining the urban planning design.

Significance of the Study

This paper will compare the perceived efficacy of two radically different mapping techniques, the traditional graphical techniques and the GIS interpolation techniques, to identify which one can be more fitting when required to visualize population data (Fairbairn et al., 2025). The study incorporates some of the most important demographic variables (density, age structure, and growth trends), which makes it more useful in terms of spatial interpretation and enables getting a complete picture of the population dynamics of Baghdad. The study also establishes the constraints in the popular GIS interpolation methods, especially when applied to the categorical administrative data, and indicates the difficulties that such methods have in generating an accurate, district-level population description. Moreover, the paper reveals the practical importance of the visual perception test as an essential parameter of testing cartographic efficiency, where population data is dispatched in a form that is most easily understandable and readily available. Lastly, connecting demographic visualization to service distribution and infrastructural requirements, the research will be useful to city planners, and it will help them make better decisions concerning sustainable city planning (Lama, 2023).

Key Contribution

- Comparison between the old graphical cartographic analysis and GIS-based interpolation techniques of population mapping in Baghdad Governorate.
- Conventional graphical analyses were quicker and easier to understand population information than GIS-based ones.
- GIS interpolation techniques were also found to be unable to give accurate population data at the level of a district to be used in urban planning and the allocation of resources.
- Discuss the significance of the velocity of visual perception in cartography, which will make the accurate representation of the demographic and the making of decisions more efficient.

The structure of the paper will follow as: Section I provides the focus of the research, which is the comparison of conventional graphical cartographic techniques with the techniques of GIS interpolation as the method of population mapping. Section II is the literature survey on GIS-based methods. Section III describes the research methodology, limits of the study, and data sources of the study. Section IV presents the findings of the comparative analysis of the two mapping techniques. The last section V concludes with recommendations and future research directions.

II. Literature Survey

The efficiency of GIS-based approaches to population mapping has been the theme of many studies. The study compared spatial interpolation techniques, i.e., Kriging and Inverse Distance Weighting (IDW), to display the age distribution of the population in Thi Qar Governorate in Iraq (Kazem & Rasheed, 2024). Their research showed that GIS-based techniques are useful for developing effective visual representations of demographic data required for urban planning and resource allocation. It was, however, observed that the interpolation technique was constrained by the absence of the ground-truth data, which made the methods less accurate, and they pointed out that more accurate validation is one of the necessary requirements in such studies. Also, it did not investigate the speed of visual perception of the maps, which is also a significant factor when processing the population data (Rodríguez et al., 2025).

The recent research examined how geo-spatial data literacy can be applied when interpreting choropleth maps, which is the case of COVID-19 case distributions (Jürgens, 2020). This paper has highlighted the necessity of studying the way of reading and interpreting maps by the masses. Although it concentrated on health data, it also provided a useful idea on the cognitive component of reading maps, that the enhancement of the visual data literacy can yield a better understanding of the demographic maps (Juergens, 2020). But the study had a limitation that it only utilized choropleth maps and did not consider other forms of GIS-based interpolations and their capabilities to depict the patterns of demographics (Viau et al., 2025).

The previous study evaluated the application of GIS tools in the Iraqi population and housing census and compared the old technology with the new GIS technologies, such as IDW and Kriging (Laaribi, 2022). The paper has emphasized the benefits of GIS in mapping and data analysis in demographic and housing data, and specifically in urban planning. Nonetheless, it had not taken into consideration the real-time

data integration, which might have given a more dynamic insight. Similar to the earlier research, this research did not focus on the perceptual efficiency of GIS-based techniques, especially regarding the speed and clarity with which demographic data can be analyzed (Rasslan & Sameh, 2022).

These studies have all confirmed the importance of GIS in demographic mapping, but they also point out the gaps in the knowledge of the perceptual effectiveness of these techniques. Although GIS techniques offer precise forms of data depiction, their graphical understanding, particularly in speed, is an important area that requires more research. This research will fill this gap by comparing the conventional graphical cartographic techniques with GIS-based interpolation techniques, and determining which of the two techniques is better able to enable faster and more straightforward communication of the population data.

III. Research Methodology

The study employed a descriptive, inductive, and analytical approach to evaluate the maps produced through both traditional and modern cartographic methods.

Study Boundaries

The research design used was a descriptive, inductive, and analytical design in evaluating the maps created by the traditional and modern cartographic techniques. The physical limits of the study area include the Baghdad Governorate, in the middle of Iraq, which is the border with the province of Salah al-Din at the North, the Diyala at the East, Wasit and Babil at the South, and Anbar at the West, as shown in fig. 1. The governorate is situated between 320846N and 33046N and 435144E. It is conducted on the data of 2023, and the governorate occupies an area of 4378 km 2, which is 1.04-% of the total area of Iraq, which is 434128 km 2. Administratively, the governorate of Baghdad has ten districts, namely Al-Rusafa, Al-Adhamiya, Sadr 1, Sadr 2, Al-Karkh, Al-Kadhimiya, Al-Mahmudiya, Abu Ghraib, Al-Tarmiyah, and Al-Mada'in. Although it was subsequently proclaimed that two or three more districts existed, they were not actually decreed, and therefore the study is based on the previous official census and these new administrative corrections.

Fig. 1 Baghdad Governorate

Source: Researcher based on the Ministry of Water Resources, General Commission for Survey, *Map of Baghdad Governorate*, scale 1:150,000, 2010.

Cartographic Representation of Baghdad Governorate's Population for 2023 Using Graphic Representation Methods

Four graphical cartographic methods were applied to represent the population of Baghdad Governorate in 2023, namely: the square method, the triangle method, the column method, and the divided circle method. These are illustrated as follows:

Fig. (2): Distribution of males in Baghdad Governorate (Vargas Molina, 2025)

Source: *Prepared by the researcher based on table I.*

The square method was used to represent the male population in fig. 2. Results indicate that the highest concentration of males is in *Al-Rusafa District*, followed by *Al-Karkh* and *Al-Adhamiya*. The lowest concentrations appear in *Al-Tarmiyah* and *Abu Ghraib (Cybulski, 2025)*.

Fig. (3): Distribution of females in Baghdad Governorate

Source: *Prepared by the researcher based on table (I).*

The triangle method was used to represent the female population in fig. 3. Similar to the male distribution, the highest concentration of females is in *Al-Rusafa*, followed by *Al-Karkh* and *Al-Adhamiya*. The lowest concentrations are found in *Al-Tarmiyah* and *Abu Ghraib (Duncan & Gastner, 2024)*.

Overall, the spatial distribution of males across districts closely resembles that of females.

Fig. (4): Distribution of the total population in Baghdad Governorate (Zhang et al., 2024)

Source: *Prepared by the researcher based on table (I).*

The column method was used to represent the total population, as shown in fig. 4. The results show that *Al-Rusafa* has the highest population, followed by *Al-Karkh* and *Al-Adhamiya*, while *Al-Tarmiyah* and *Abu Ghraib* record the lowest populations. (Elias, 2023)

Fig. (5): Distribution of males and females in Baghdad Governorate

Source: *Prepared by the researcher based on table (I).*

The divided circle method was used to represent the distribution of males and females across the governorate's districts in fig. 5. The representation shows a relative balance between male and female populations across all districts; however, males consistently outnumber females slightly, although the difference is not visually pronounced. (Fairbairn, Gartner, & Peterson, 2025)

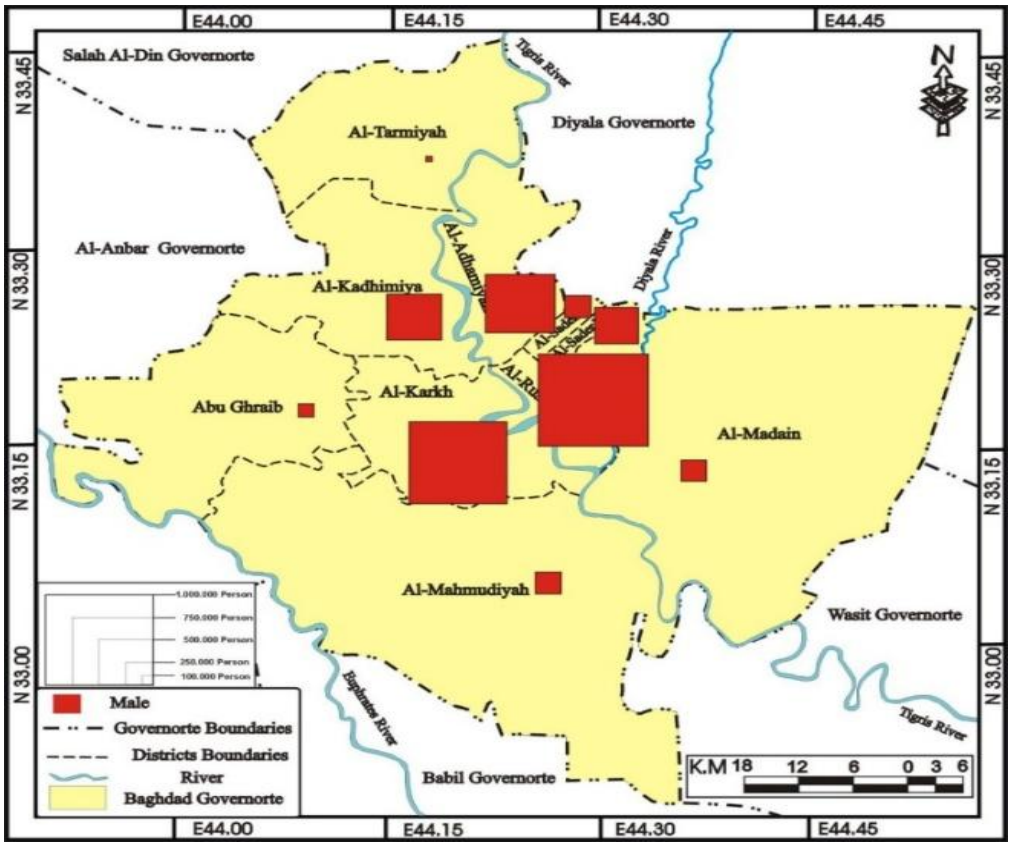

Fig. 2 Distribution of Males in Baghdad Governorate

Source: Researcher based on table I.

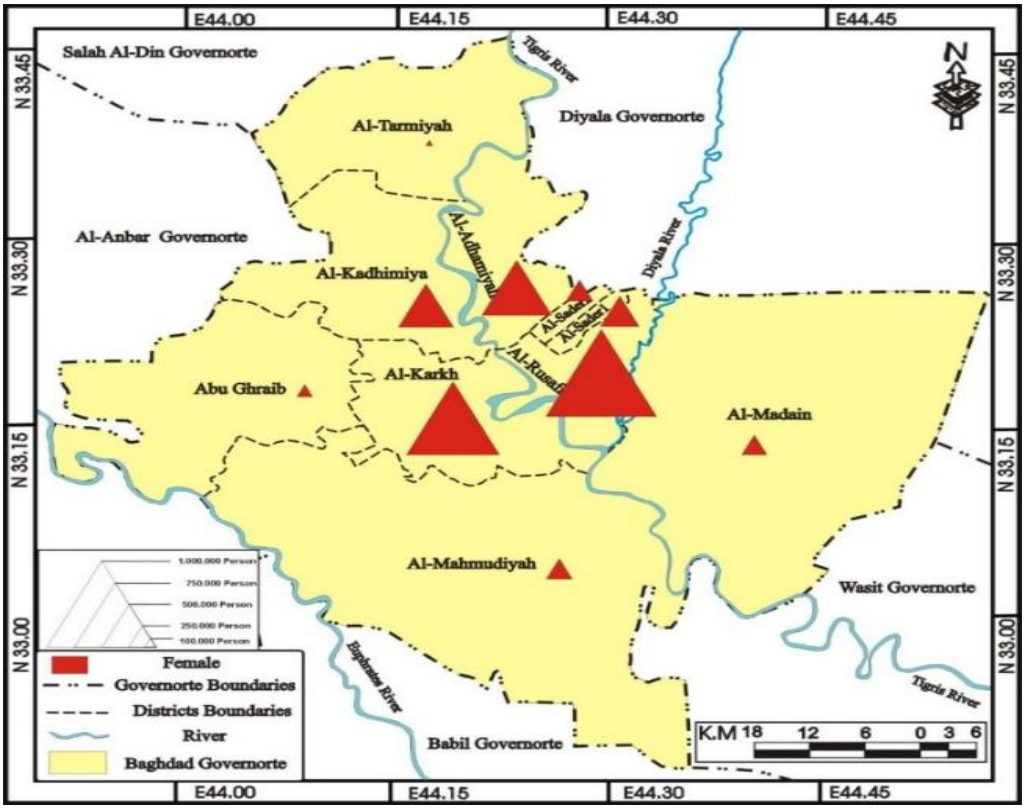

Fig. 3 Distribution of Furniture in Baghdad Governorate

Source: Researcher based on table I.

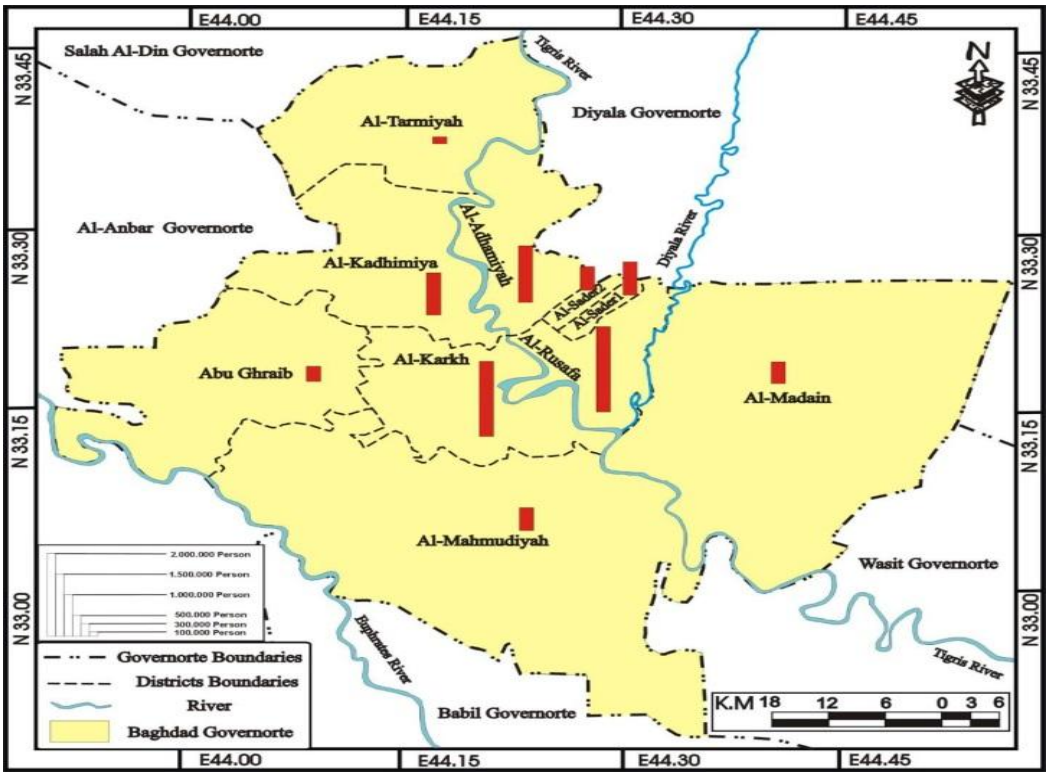

Fig. 4 Distribution of the population of Baghdad Governorate

Source: Researcher based on table I.

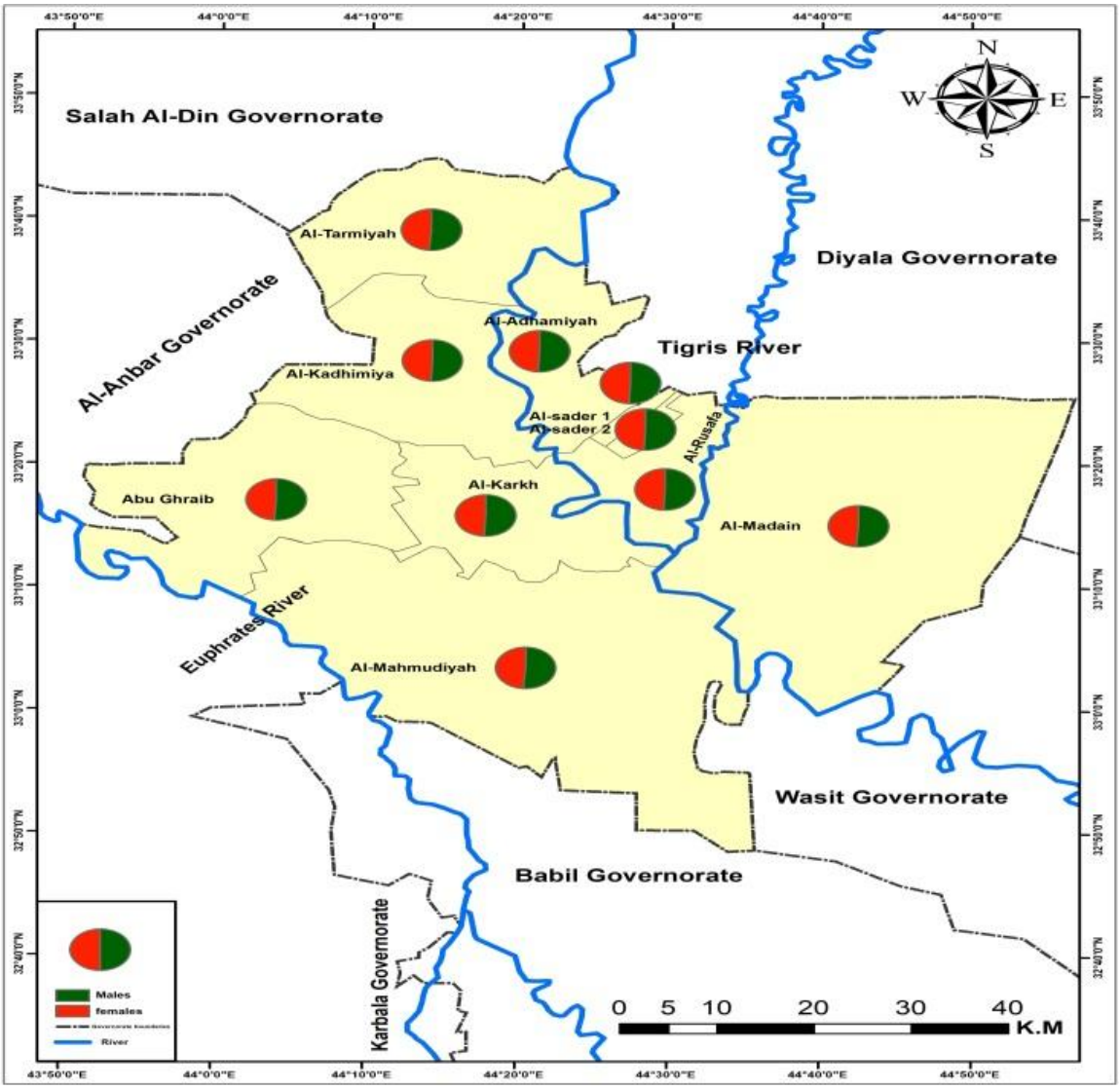

Fig. 5 Distribution of Males and Females in Baghdad Governorate

Source: Researcher based on table I.

TABLE I POPULATION OF BAGHDAD GOVERNORATE, 2023

District	Males	Females	Total
Al-Rusafa	1,041,138	1,015,127	2,056,265
Al-Adhamiya	692,271	674,231	1,366,502
Sadr 1	407,595	397,412	805,007
Sadr 2	289,684	282,446	572,130
Al-Karkh	916,975	894,067	1,811,042
Al-Kadhimiya	517,682	502,112	1,019,794
Al-Mahmudiya	281,770	268,251	550,021
Abu Ghraib	187,385	179,746	367,131
Al-Tarmiyah	84,590	80,335	164,925
Al-Mada'in	266,972	255,394	522,366

Source: Republic of Iraq, Ministry of Planning, Central Statistical Organisation, *Population Estimates of Baghdad Governorate for 2023*.

Table I presents the distribution of the population of Baghdad Governorate in the year 2023, including male and female populations and the total population in each district. The data point out that the population of Al-Rusafa is the highest, with 2,056,265 people, and the population of Al-Karkh is 1,811,042. Al-Tarmiyah also has the least population of 164,925. It is a table that has been sourced in the Republic of Iraq, in the Ministry of Planning, Central Statistical Organisation.

Cartographic Analysis of Maps Produced Using RIG GIS

The researcher represented the population of Baghdad Governorate for 2023 using the RIG GIS program, applying the same categories of data used in the graphical methods: total population, male population, and female population. Each dataset was processed using nine distinct methods available within RIG GIS (Goerlich, 2025):

1. Kernel Smoothing (KS) – Homogeneous Kernel
2. Kernel Smoothing (DK) – Diffused Kernel
3. Simple Kriging (SK)

4. Areal Interpolation (AL)
5. Empirical Bayesian Kriging (EBK)
6. Inverse Distance Weighting (IDW)
7. Radial Basis Functions (RBF)
8. Global Polynomial Interpolation (GPI)
9. Local Polynomial Interpolation (LPI)

Cartographic Representation of the Male Population

This method of presenting the male population in the Baghdad Governorate with the application of the RIG GIS was found to have serious limitations. Although approaches used (IDW, RBF, and AL) yielded a better approximation of high and low-density areas, the rest of the techniques (LPI, EBK, KS, GPI, and SK) were highly distorted (Jürgens, 2020). These methods had difficulties in defining the borders of districts, and they could not represent the distribution of the population with the required degree of accuracy. Also, the broad conclusions of these methods failed to provide the analysis of the male population on the fine scale to comprehend the trends of the male population at the district level. The results with the methods of LPI and GPI were highly blurred images, and EBK and KS represented incomplete data, which made the resulting maps inapplicable to urban planning purposes (Ju et al., 2025).

Cartographic Representation of Female Population

The same issues were witnessed in representing the female population. Methods such as GPI, EBK, KS, SK, and DK could not show clear distributions, with some categories of the population being left off, or the patterns were twisted. These methods could not give the required district-specific breakdown. They also could not tell the difference between urban and rural regions, which is needed in the allocation of resources and urban development. Other techniques, such as IDW, RBF, and AL, were somewhat more successful, offering a more realistic picture of the concentrations of the female population, but were still not accurate at the district level (Kazem & Rashid, 2024). These approaches had the problem of population differences in low-population districts, which resulted in missing major information and requiring sufficient data to develop policies (Keskin et al., 2023).

Cartographic Representation of Total Population

The use of GPI, EBK, KS, SK, and DK when depicting the entire population leveled the population distributions, therefore, it was hard to differentiate between heavily and underpopulated districts (Laaribi, 2022). Although other methods, like IDW, RBF and AL, were a little more successful, they also could not give the detailed view of information which is required to comprehend accurate population distribution. These techniques failed to demarcate the boundaries of districts clearly and some of these techniques blurred the distinction between districts with different population density. The GIS methodologies did not give a clear definition of the levels of populations across districts and so these were not suitable in the demographic analysis of districts (Liaskos & Krassanakis, 2024).

Cartographic Representation of Both Males and Females

The RIG GIS techniques were problematic in combining males and females in same map. The two categories of population could not be combined in any of the techniques with the clarity of the traditional divided circle method. GIS techniques did not synthesize the two sets of data into a single map. A combination of the techniques like AL, IDW, and RBF may offer useful information to each gender separately, but the combination resulted in confusing and unclear visualizations (Láng-Ritter et al., 2025). This weakness serves to emphasize the necessity of a better way of representing a number of demographic groups at the same time as in traditional cartographical approaches such as the divided circle.

The nine GIS interpolation techniques applied to the male, female, and total population distribution in Baghdad Governorate did not give correct district-level representations. Although the methods of IDW, RBF, and AL were found to be relatively better since they tend to bring into focus the population densities, they were not accurate in showing the top-most and lowest population districts. Such techniques as LPI, EBK, KS, GPI, SK, and DK had distorted maps. Also, all the methods were not able to represent both male and female groups effectively as compared to traditional methods. The results highlight the shortcomings of RIG GIS to offer credible demographic data on urban planning.

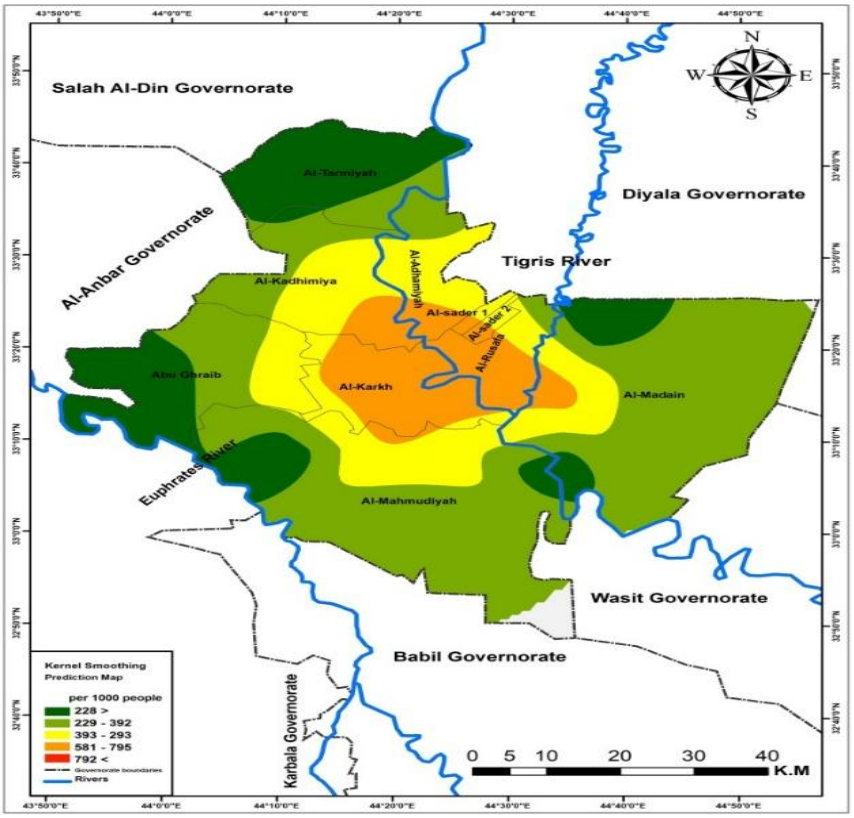

Fig. 6 Distribution of Males in Baghdad Governorate by the KS Method

Source: Researcher based on table I and the 10.6 ArcGIS program.

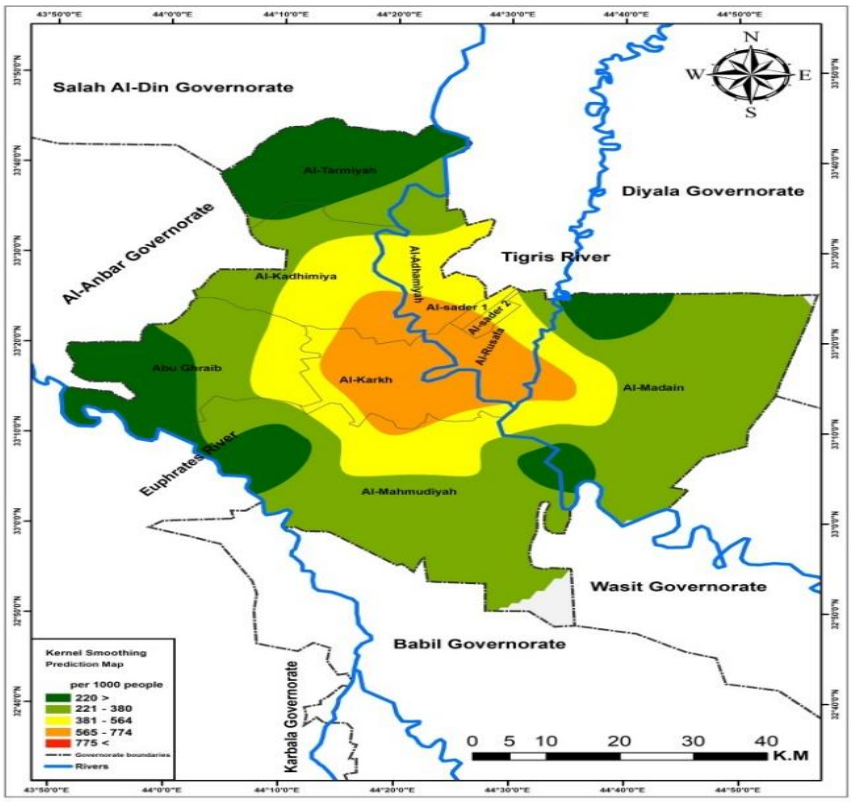

Fig. 7 Distribution of females in Baghdad Governorate (KS)

Source: Researcher based on table I and the 10.6 ArcGIS program.

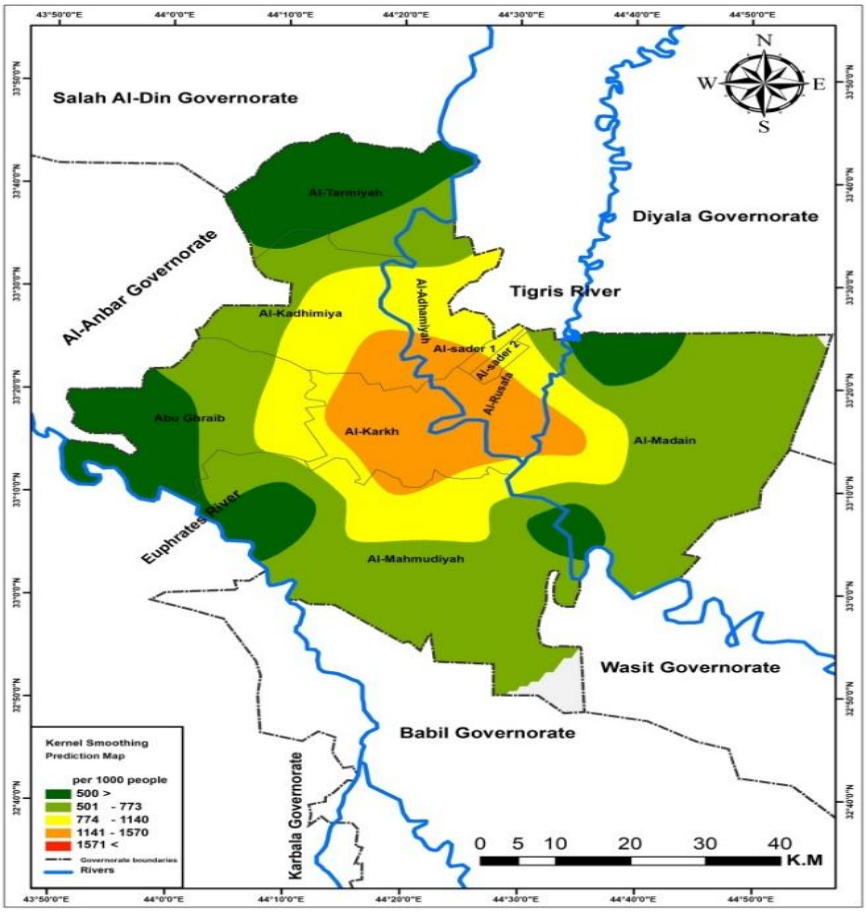

Fig. 8 Population Distribution in Baghdad Governorate by KS Method

Source: Researcher based on table I and the 10.6 ArcGIS

Fig. 6: Distribution of Males in Baghdad Governorate by the KS Method

Source: Researcher based on Table I and the 10.6 ArcGIS program

Fig. 6 shows the distribution of the male population in Baghdad by the Kernel Smoothing (KS) technique. It emphasizes the high-density spaces, particularly in Al-Rusafa and Al-Karkh; however, it is not very clear on the district boundaries and details, especially in Al-Tarmiyah and Abu Ghraib. Although KS is useful in demonstrating the general trends in the population, it lacks the ability to make accurate and district-specific comparisons because of its smoothing effect.

Fig. 7: Distribution of Females in Baghdad Governorate by KS Method

Source: Researcher based on table I and the 10.6 ArcGIS program.

The Kernel Smoothing of the female population distribution in Baghdad is provided in fig. 7. As in the case of the male community, it also accentuates densely populated cities such as Al-Rusafa and Al-Karkh. Although the map is able to show population trends, the smoothing process leaves out accurate delineations of a given boundary thus making it hard to analyse the population in detail.

Fig. 8: Distribution of the Total Population in Baghdad Governorate by KS Method

Source: Researcher based on table I and the 10.6 ArcGIS

Fig. 8 is the total population distribution in Baghdad Governorate that is Kernelled Smoothing (KS). It emphasizes regions of high population density, like Al-Rusafa and Al-Karkh, and the effect of smoothing makes it less useful in identifying boundaries that could be of interest to make specific population analysis on the districts.

Comparison Between Graphical Cartographic Representation and the Nine GIS Methods within ArcGIS

The researcher relied on a sample of 50 individuals (10 faculty members, 20 postgraduate students, and 20 undergraduate students) to conduct a comparative evaluation of the two approaches, with the objective of identifying which method more effectively represents population data

and, consequently, which method is perceived as more comprehensible (Metzger et al., 2024).

A set of questions was presented to the participants to assess whether each method could accurately and quickly convey population data to the reader: (Liu et al., 2024)

1. Which district has the largest population?
2. Which district has the smallest population?
3. Are there districts with similar population sizes?
4. Which method provides the highest level of visual comprehension compared to others?

In addition, the time factor was used as a criterion to measure perceptual speed. A period of 20 seconds was set as the benchmark for rapid comprehension, whereby increased time indicated weaker comprehension. For every two seconds, one point was assigned, so that a comprehension time of 20 seconds equalled 10 points. These points were then subtracted from the maximum of 10 points to determine the actual comprehension score of each map. Neal et al., (2022) accordingly, the shorter the time required for perception, the higher the true comprehension value of the map. The results are presented in table (II).

TABLE II TEST OF COMPREHENSION SPEED CRITERION FOR MAPS

Figure No.	Map Title	Comprehension Time (seconds)	Time Score (out of 10)	Visual Comprehension Score (10–Time Score)
2	Distribution of males in Baghdad Governorate	2	1	9
3	Distribution of females in Baghdad Governorate	2	1	9
4	Distribution of the total population in Baghdad Governorate	2	1	9
5	Distribution of males and females in Baghdad Governorate	4	2	8
6	Male distribution using KS method	20	10	0
7	Female distribution using KS method	20	10	0
8	Total population distribution using KS method	20	10	0

Source: *Prepared by the researcher based on test results using the comprehension speed criterion.*

IV. Findings and Discussion

The findings of this research have clearly shown that conventional graphical cartographic approaches are far much better in their visual perception and quickness of comprehension of population data portrayal in comparison to the RIG GIS interpolation tools. Table II reveals that the square, triangle, column and divided circle methods recorded a comprehension score of 9/10 in only 2 seconds and this shows that the methods are very effective in representing the data in population in a fast and accurate manner. Those approaches proved the best visual comprehension, and the special value of such approaches is in urban planning and decision-making where the quick and clear interpretation is essential.

The nine RIG GIS interpolation tools, of which Kernel smoothing (KS) Inverse Distance weighting (IDW) and radial basis functions (RBF) had a number of limitations in stark contrast with them. The best score in these techniques was only 2.5 /10 and it was only under the Areal Interpolation (AL) technique. Such poor perceptual recognition means that the RIG GIS techniques did not help to communicate the population information to the participants effectively. KS, IDW and RBF, although having some more precision than the rest, nevertheless did not reflect population distributions in the district level. Moreover, approaches such as GPI, EBK, KS, SK and DK resulted in skewed maps with undefined boundaries of the districts, which did not allow drawing any significant population patterns, particularly at a smaller scale.

Besides, the RIG GIS techniques could not represent male and female populations in a definite and effective manner as in the separated circle technique applied in the traditional cartography that could merge both genders into one understandable map.

In general, GIS tools can be a great way to understand the trends in population, but in terms of its visualization, perceptual and district level accuracy, they are not as ideal when it comes to real time urban planning and demographic analysis, which require understandable, easily interpretable maps.

Recommendations

Time in visual perception must be given much consideration in determining the effectiveness of cartography since it is important to have a quick understanding in most applications of cartography that require quick understanding. Also, data is to be thoroughly examined in order to identify the most suitable cartographic techniques that would allow drawing a clear and proper picture, so that the selected approach could be adequate in relation to the peculiarities of data. More work is required to form and perfect the methods of representation in ArcGIS to make them more appropriate in population research especially in spatial resolution and precision. Finally, modern GIS techniques should be instructed with consideration to which type of data they are most appropriate since each of the methods and programs possesses its advantages and particular areas of use that should be known to be used.

V. CONCLUSIONS

This paper has contrasted the usefulness of the conventional graphical cartographic representations and the GIS-based interpolation tools in visualizing the distribution of population in Baghdad Governorate in 2023 regarding the speed of visual perception as well as its clarity. The results indicated that the traditional graphical techniques such as square, triangle, column and divided circle techniques performed better than GIS techniques in the speed of understanding in which the comprehension score at 2 seconds of time was 9/10. On the contrary, GIS tools, especially Kernel Smoothing, were very slow, and the score is 2/10 in 20 seconds. These findings demonstrate the problems of real-time urban planning to be performed with the help of GIS techniques, where fast and clear visualization is very important. Although the GIS methods, including Kernel Smoothing, Kriging and Inverse Distance Weighting, give a good spatial interpolation, it failed to accurately delineate the population distributions by the district. These approaches were not clear enough to the urban planners particularly in determining particular population densities and patterns. Moreover, the challenge of having both the male and female population well represented in one GIS map illustrates the weakness of GIS techniques in integrated analysis of demographics. The statistical analysis proved that the traditional methods were always better than GIS techniques in visual perception. These results imply that better GIS techniques should be employed, specifically, the excellence of visuality and the precision of the districts. The next step in GIS research should be on improving the GIS techniques to make them more effective in communicating demographic information. Some of the potential areas of improvements are refining the methods of interpolation, incorporation of more precise real-time data, and experimenting with hybrid methods of combining classic and GIS techniques to visualize demographics in the urban planning process.

REFERENCES

[1] Belarem, M. (2025). The dots density method as a cartographic tool for population analysis: The case of the city of Jeddah (Saudi Arabia). *Open Access Library Journal, 12*(10), 1–31.

[2] Cybulski, P. (2025). Predicting Cartographic Symbol Location with Eye-Tracking Data and Machine Learning Approach. *Journal of Eye Movement Research*, *18*(4), 35. https://doi.org/10.3390/jemr18040035

[3] Duncan, I. K., & Gastner, M. T. (2024). Comparative evaluation of the web-based contiguous cartogram generation tool go-cart. io. *Plos one*, *19*(5), e0298192. https://doi.org/10.1371/journal.pone.0298192

[4] Fairbairn, D., Gartner, G., & Peterson, M. P. (2025). Experiencing mapping and maps: a human cognition perspective. *International Journal of Cartography*, 1-21. https://doi.org/10.1080/23729333.2025.2533814

[5] Goerlich, F. J. (2025). HIPGDAC-ES: historical population grid data compilation for Spain (1900–2021). *Scientific Data*, *12*(1), 280. https://doi.org/10.1038/s41597-025-04533-8

[6] Ju, Y., Liang, Y., Kong, J., Wang, X., Wen, S., Shang, H., & Wang, X. (2025). 100-m resolution Age-Stratified Population Estimation from the 2020 China Census by Township (ASPECT). *Scientific Data*, *12*(1), 1058. https://doi.org/10.1038/s41597-025-05401-1

[7] Juergens, C. (2020). Trustworthy COVID-19 mapping: Geo-spatial data literacy aspects of choropleth maps. *KN-journal of cartography and geographic information*, *70*(4), 155-161. https://doi.org/10.1007/s42489-020-00057-w

[8] Kazem, N. J., & Rashid, W. A. (2024). Evaluating spatial interpolation maps of the age structure of the population of Thi Qar Governorate using geographic information systems (GIS) technologies. *Evolutionary Studies in Imaginative Culture, 8*(2), 1379–1400. https://doi.org/10.70082/esiculture.vi.1510

[9] Keskin, M., Krassanakis, V., & Çöltekin, A. (2023). Visual attention and recognition differences based on expertise in a map reading and memorability study. *ISPRS International Journal of Geo-Information*, *12*(1), 21. https://doi.org/10.3390/ijgi12010021

[10] Laaribi, A. (2022). *Assessment of GIS for the population and housing census in Iraq*. United Nations ESCWA. https://www.unescwa.org/sites/default/files/pubs/pdf/assessment-gis-population-housing-census-iraq-english_0.pdf

[11] Lama, S. E. (2023). Analysis of the geographic distribution of the population of Baghdad. *Kurdish Studies, 11*(3), 16–26.

[12] Láng-Ritter, J., Keskinen, M., & Tenkanen, H. (2025). Global gridded population datasets systematically underrepresent rural population. *Nature Communications*, *16*(1), 2170. https://doi.org/10.1038/s41467-025-56906-7

[13] Liaskos, D., & Krassanakis, V. (2024). OnMapGaze and GraphGazeD: A Gaze Dataset and a Graph-Based Metric for Modeling Visual Perception Differences in Cartographic Backgrounds Used in Online Map Services. *Multimodal Technologies and Interaction*, *8*(6), 49. https://www.mdpi.com/2414-4088/8/6/49

[14] Liu, L., Cao, X., Li, S., & Jie, N. A. (2024). A 31-year (1990–2020) global gridded population dataset generated by cluster analysis and statistical learning. *Scientific Data*, *11*(1), 124. https://doi.org/10.1038/s41597-024-02913-0

[15] Metzger, N., Daudt, R. C., Tuia, D., & Schindler, K. (2024). High-resolution population maps derived from sentinel-1 and sentinel-2. *Remote Sensing of Environment*, *314*, 114383. https://arxiv.org/abs/2301.11275

[16] Neal, I., Seth, S., Watmough, G., & Diallo, M. S. (2022). Census-independent population estimation using representation learning. *Scientific Reports, 12*(1), 5185. https://doi.org/10.1038/s41598-022-08935-1

[17] Rasslan, A. H., & Sameh, A. E. (2022). The population density map of the greater Cairo Region Comparison of 2017 choropleth map and dasymetric map. *Asian Journal of Geographical Research*, *5*(1), 37-46. https://doi.org/10.9734/ajgr/2022/v5i1123

[18] Vargas Molina, S. A. (2025). Epidemiological cartography: Comparison of three spatial analysis methods with GIS and free software for COVID-19 in Malaga, Spain. *Revista Cartográfica*, (111), 31–54. https://doi.org/10.35424/rcarto.i111.5932

[19] Viau, L., Raveneau, V., Poncelet, P., Rodriguez, N., Sallaberry, A., & Trottier, C. (2025). A comparison of hybrid maps for the visualization of two geolocated quantitative variables. *Information Visualization*, *24*(3), 269-283. https://doi.org/10.1177/14738716251325133

[20] Zhang, R., Li, M., Zhang, X., Guo, Y., Li, Y., Gao, Q., & Liu, S. (2024). Identification of the spatial structure of urban polycentres based on the dual perspective of population distribution and population mobility. *Land*, *13*(8), 1159. https://doi.org/10.3390/land13081159