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THE URGENCY OF MAGNETIC DECLINATION IN QIBLA DIRECTION MEASUREMENT USING A COMPASS IN THE IBU KOTA NUSANTARA (IKN) AREA

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Abstract: This study analyzes the urgency of correcting magnetic declination in determining the accurate direction of the Qibla, particularly for mosque construction in the area of Ibu Kota Nusantara (IKN), Indonesia. Using a literature review and quantitative approach, magnetic declination data from 1590 to 2024 was collected using the NOAA magnetic declination calculator with the IGRF-13 model at the IKN coordinates. The data was analyzed to identify temporal and spatial variations and then visualized using LabPlot software. The results show significant changes in magnetic declination that affect the accuracy of the Qibla direction if not corrected. The total percentage of magnetic declination values beyond the tolerance limit or *iḥtiyāṭ al-qiblah* (0.4º) is 77.18%. This study emphasizes the importance of using reliable declination calculators from credible institutions such as NOAA and visualization tools to ensure that the Qibla direction aligns with technical and Sharia standards, making it a guide for urban planning in IKN, especially in determining the direction of public buildings such as mosques, schools, and government offices.
Keywords: *Magnetic declination; Iḥtiyāṭ al-qiblah; IKN; Urgency.*

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Introduction

Determining the direction of the Qibla is an essential element in mosque construction, as it is a prerequisite for the validity of the prayer for Muslims. The accuracy of the Qibla direction has both a spiritual and technical dimension, especially when the direction is determined using tools like a compass. A compass, with its magnetic needle, consistently points to the north and south. However, the direction indicated by the compass needle is not true north, which refers to the geographical North Pole, but magnetic north, which is influenced by the Earth's magnetic field. To obtain true north, magnetic declination correction is required, which is the angular difference between magnetic north and true north (NCEI, 2024).

Magnetic declination is not constant; it varies depending on geographic location and time. This variation poses a challenge in using a compass, especially in determining the Qibla direction, which requires a high level of accuracy. The sensitivity of the compass needle to the surrounding magnetic field and environmental influences also requires caution. Therefore, measuring the Qibla direction using a compass must be done carefully, including considering an accurate magnetic declination correction based on up-to-date data (Fadhel, 2022).

In addition to magnetic declination, the influence of the Earth's magnetic field must also be accounted for through geomagnetic correction. Geomagnetic correction is a step to eliminate the effects of the Earth's main magnetic field on the measured data, using a theoretical magnetic field reference known as the International Geomagnetic Reference Field (IGRF). The IGRF defines the theoretical, undisturbed magnetic field at every point on the Earth's surface. With this correction, the measured magnetic field value is adjusted by subtracting the IGRF value for that region, resulting in more accurate data free from the influence of the Earth's main magnetic field. This is important considering that the Earth's magnetic field moves from the poles to the equator, and its influence can vary regionally (HT, 2011).

Ibu Kota Nusantara (IKN), as the new center of government in Indonesia, presents both opportunities and challenges in the construction of mosques that adhere to both technical and Sharia standards. In this context, the influence of the geomagnetic conditions of the IKN region becomes a crucial factor to consider. Errors in accounting for magnetic declination and the Earth's magnetic field can lead to deviations in the Qibla direction, potentially affecting the validity of the prayers performed in the mosque.

As a solution, the *National Oceanic and Atmospheric Administration* (NOAA) provides a web-based magnetic declination calculator that allows for accurate calculation of declination based on specific geographic coordinates and time (NOAA, 2022). This study uses this tool to identify the level of magnetic declination and geomagnetic correction based on the IGRF in the IKN region, assess its impact on the accuracy of Qibla direction determination, and provide practical technical guidance.

Through an approach that integrates the science of astronomy and geophysics, particularly in determining the Qibla direction using a compass, this study aims to ensure that the Qibla direction in mosques in IKN meets both technical accuracy standards and Sharia requirements. The findings of this study are expected to not only serve as a reference for mosque construction in IKN but also become a guideline for various stakeholders, including architects, engineers, and religious institutions, in ensuring the quality of worship for Muslims in the future.

Method

This study employs a combined approach of document analysis and quantitative methods to examine the urgency of magnetic declination in determining the Qibla direction using a compass. A literature review was conducted to explore the fundamental theory of magnetic declination, its impact on the accuracy of the Qibla direction, and the use of modern technology in its measurement. Scientific journals, technical guidelines, and official documents from the *National Oceanic and Atmospheric Administration* (NOAA) serve as primary sources. This research emphasizes the importance of NOAA's web-based magnetic declination calculator as a key tool for accurately calculating declination values based on specific geographic locations and timeframes. It also discusses declination variations from 1590 to 2024 to provide a comprehensive overview of changes in the Earth's magnetic field.

The quantitative approach involved collecting magnetic declination data from the NOAA calculator for points within the Ibu Kota Nusantara (IKN) area, selected based on potential mosque construction sites. Data were calculated for various years from 1590 to 2024 to evaluate temporal variations in magnetic declination. These data were then visualized using LabPlot software to generate graphs and charts showing the fluctuations in declination values over an extended period.

As for the tolerance parameter in analyzing Qibla direction deviation, the study incorporates a concept proposed by Ma'rufin Sudibyo, known as *iḥ tiyāṭ al-qiblah*. This concept emphasizes precision in accuracy and observation of Qibla direction deviations, as demonstrated by the alignment of Masjid Quba'. The tolerance value in this concept is equivalent to a radial deviation of 45 km from the Kaaba, based on the deviation of the Qibla direction at Masjid Quba'. Ma'rufin Sudibyo concluded that the permissible deviation for Indonesia, or the *iḥ tiyāṭ al-qiblah* value, is 0^o

24′ or 0.4° in decimals (Sudibyo, 2011). Finally, the distribution of curves and data is analyzed to assess the percentage of magnetic declination correction urgency, measuring how significant the corrections are within the defined tolerance limit.

By integrating theoretical and quantitative approaches, this study aims to provide comprehensive data on magnetic declination variations in the IKN region from 1590 to 2024 and their implications for determining the Qibla direction. The results are expected to produce practical technical guidelines for stakeholders involved in mosque construction. Special emphasis is placed on utilizing NOAA's magnetic declination calculator and LabPlot software as innovative tools to ensure Qibla direction accuracy in accordance with Islamic Sharia standards.

Results and Discussion

Magnetic declination data collection was conducted using the IGRF-13 (International Geomagnetic Reference Field) mathematical model, utilized by NOAA on their magnetic calculator website. This mathematical model is the latest version used to describe the behavior of the Earth's main magnetic field mathematically. The IGRF is a geomagnetic modeling effort supported by institutions involved in the collection and dissemination of magnetic field data from satellites, observatories, and surveys worldwide. The coefficients of this mathematical model can describe the annual rate of change in the Earth's magnetic field. The current mathematical model is expressed in the following equation (Alken et al., 2021):

$$V(r,\theta,\phi,t) = a\sum_{n=1}^{N}\sum_{m=0}^{n}\left(\frac{a}{r}\right)^{n+1}\left[g_n^m(t)\cos(m\phi) + h_n^m(t)\sin(m\phi)\right]P_n^m(\cos\theta)$$

Based on the IGRF-13 model and the geographic coordinates of IKN (0.973028° S, 116.708833° E) within the time range of 1590 to 2024, researchers obtained magnetic declination data for 87 epochs (1 epoch = 5 years). The total data was then plotted using LabPlot software, resulting in the following graph.

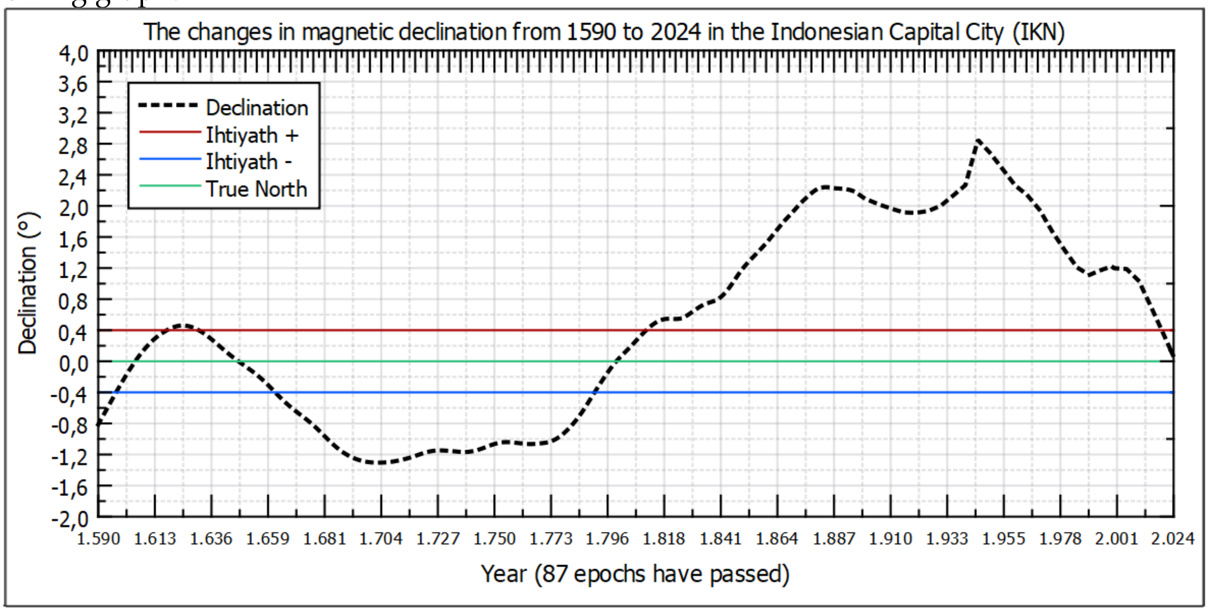

Figure 1. Curve of Magnetic Declination Changes in IKN from 1590 to 2024 (87 epochs).

Overall, the graph reveals significant fluctuations in magnetic declination in IKN over 87 epochs. Several key points can be analyzed. The general trend indicates that magnetic declination deviates from true north more frequently than aligning with it. This suggests that the compass needle in IKN rarely points directly toward the true north. During this period, the magnetic declination fluctuations are not constant but exhibit a complex pattern. There are periods where the declination changes rapidly and others where the changes are slower. Additionally, magnetic declination in some periods falls within the *iḥ tiyāṭ al-qiblah* range. The *iḥ tiyāṭ al-qiblah* lines (positive and negative) represent the tolerance limits that can be applied in Qibla direction measurements. The graph shows that magnetic declination often exceeds these tolerance limits, particularly during certain periods.

To explain the movement of the compass needle relative to true north between 1590 and 2024, the researchers illustrated this in Figure 2. The movement of the compass needle's north end is represented by the declination values. Two of *iḥ tiyāṭ al-qiblah* lines are included to identify the total number of years exceeding the tolerance limits for Qibla direction deviation.

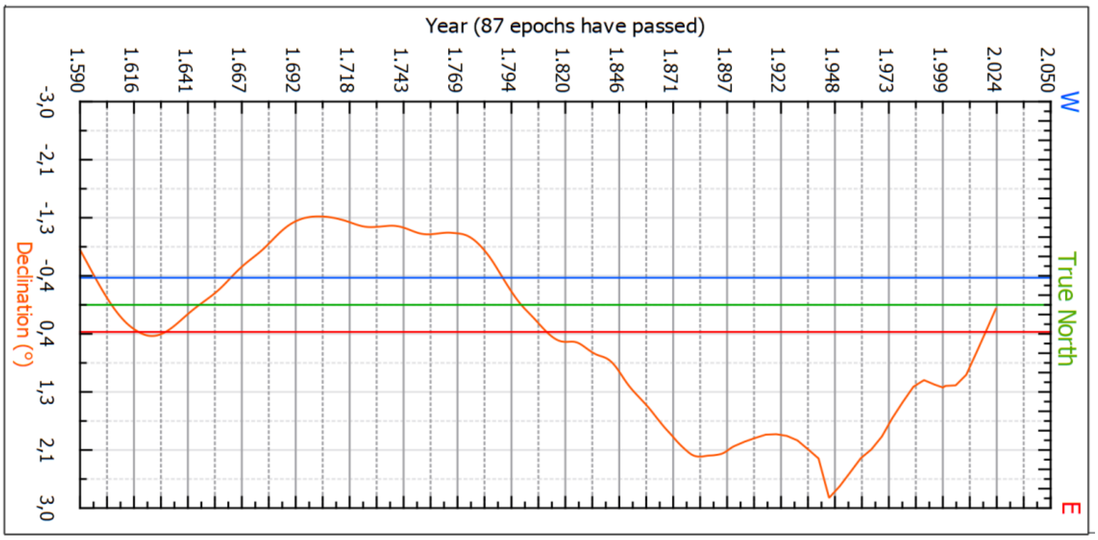

Figure 2. Compass Needle Movement Relative to True North.

Further analysis can be conducted by examining the data distribution based on the movement curve in Figure 1. The data distribution will reveal the tendencies of magnetic declination values in the IKN region.

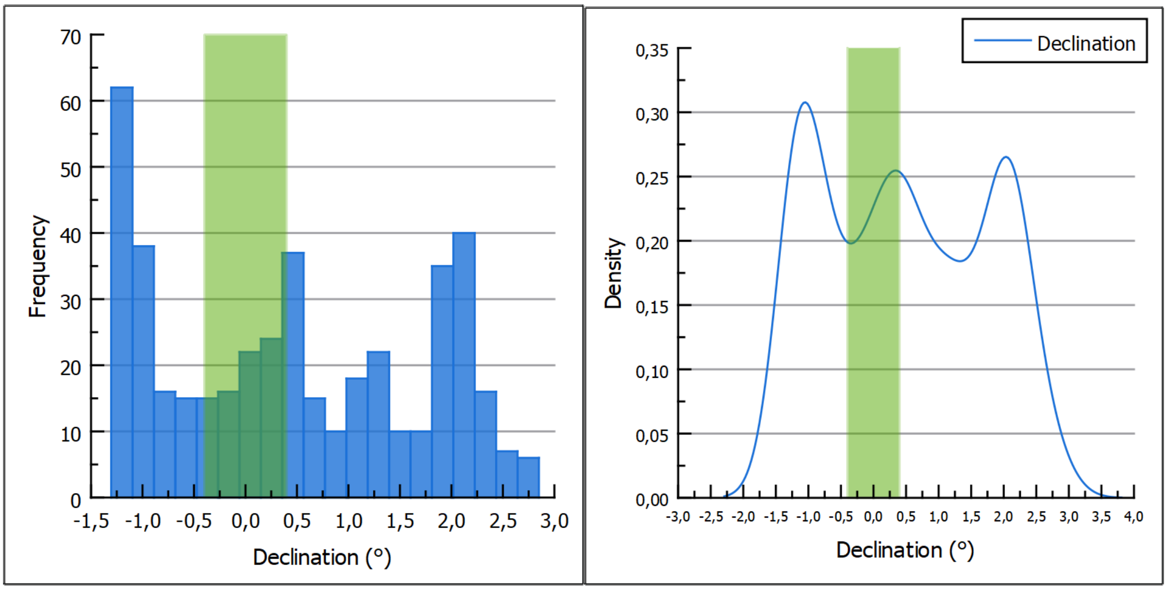

Figure 3. Distribution of Magnetic Declination Values in Terms of Frequency and Density.

The histogram graph displays the frequency distribution of magnetic declination values, ranging from -1.304810° to 2.849790°. Positive values indicate eastern declination, while negative values indicate western declination. This reflects a significant variation in the magnetic north direction relative to true north in the region. The distribution of magnetic declination values is uneven. Certain ranges have higher frequencies compared to others. The areas highlighted in green on the graph represent the frequency of magnetic declination values within the *iḥ tiyāṭ al-qiblah* range. Negative values show the highest frequency, indicating a tendency for consistent western declination within a certain range over long periods. Meanwhile, positive values reflect a tendency for eastern declination to fluctuate over extended periods as well.

The same explanation applies to the analysis of data density. The density graph in Figure 3 features a blue curve representing the continuous distribution of magnetic declination values, while the green-shaded area indicates the *iḥ tiyāṭ al-qiblah* limits. The distribution curve exhibits a multimodal shape, meaning there are several peaks or modes within the data distribution. This suggests the presence of multiple groups or subpopulations with distinct magnetic declination values, corresponding to the tendencies described earlier.

Based on the analysis of data distribution and tendencies, researchers can assess the extent of magnetic declination's urgency in using a compass for determining the Qibla direction in IKN. The urgency is measured against the threshold value of *iḥ tiyāṭ al-qiblah* (0.4°) and presented as a percentage of criticality.

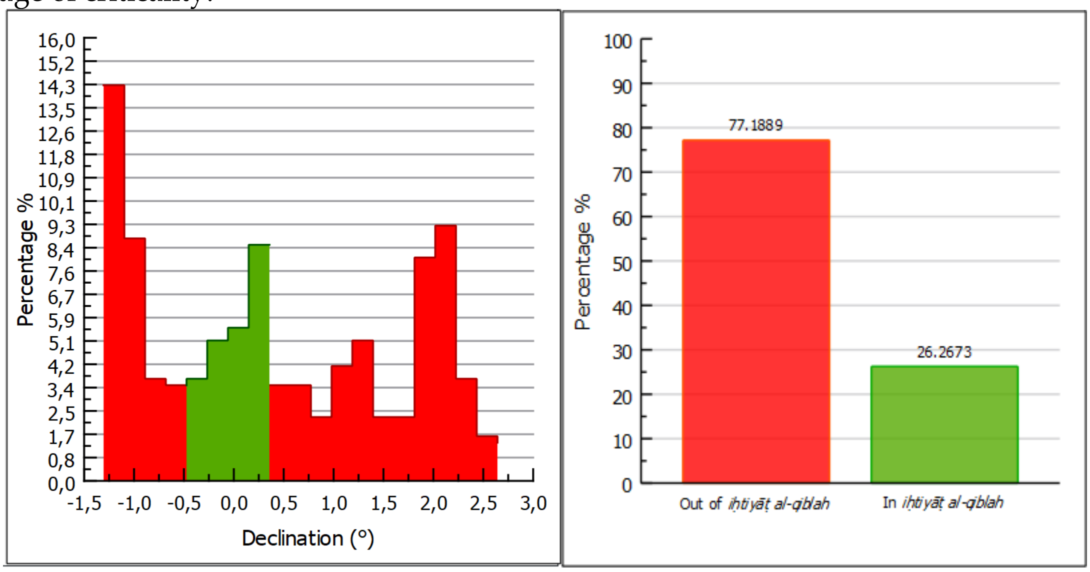

Figure 4. Percentage of Magnetic Declination Urgency in Compass-Based Qibla Direction Measurement in IKN.

The graph above illustrates the percentage distribution of the urgency of considering magnetic declination values when using a compass to determine the Qibla direction in IKN. The X-axis represents the magnetic declination values in degrees, while the Y-axis indicates the percentage of occurrences. The red bars represent data outside the tolerance limit for Qibla direction deviation (*iḥ tiyāṭ al-qiblah*), whereas the green bars indicate data within the tolerance limit. Most of the data (represented by the red bars) fall outside the *iḥ tiyāṭ al-qiblah* threshold, comprising 77.18% of the data. This indicates that using a compass without accounting for magnetic declination in IKN will significantly lead to errors in determining the Qibla direction. The highest percentage of errors occurs within certain ranges of magnetic declination, suggesting that errors are not uniformly distributed but are concentrated within specific values.

The analysis of the graphs presented above clearly explains the ongoing phenomenon of magnetic declination changes in IKN. Determining the Qibla direction using a compass will require careful consideration of magnetic correction, as deviations greater than 0.4° from true north will result in errors within the Ka'ba's equidistant circle, which is about 46 km (Sudibyo, 2011). The fact that 77.18% of the data lies outside the *iḥ tiyāṭ al-qiblah* tolerance limit is a significant figure, indicating a considerable potential for errors in determining the Qibla direction if magnetic declination is ignored. The geological conditions and dynamic infrastructure development in IKN could be factors influencing the variation in magnetic declination values in this region.

The implications for the development of IKN and spatial planning suggest that this data should be taken into serious consideration in the planning of IKN's urban layout, particularly in determining the orientation of public buildings facing the Qibla, such as mosques, schools, and government offices. Standardization of Qibla direction measurements is essential for both existing and future buildings in IKN. This standardization can include the use of well-calibrated measuring instruments and calculation methods that align with local conditions. The residents of IKN should be provided with intensive education on the importance of magnetic declination values and how to correct them when determining the Qibla direction using a compass. This can be achieved through various media such as socialization campaigns, workshops, and easily accessible information. Further research is also recommended to map in detail the variation in magnetic declination values throughout the IKN region. An accurate magnetic declination map will serve as an essential reference for both the public and experts in determining the Qibla direction. This analysis can be expanded by considering other factors, such as the influence of human-made magnetic fields on declination values, and the implications of Qibla direction errors on the social and cultural aspects of IKN's society.

The phenomenon of magnetic declination in the IKN region shows that using a compass without proper correction can lead to significant deviations in determining the Qibla direction. The data obtained highlights that the majority of magnetic declination values fall outside the *iḥ tiyāṭ al-qiblah* tolerance limit, with a percentage of 77.18%. This indicates that neglecting the magnetic declination factor will directly impact the accuracy of the Qibla direction, which ultimately affects the validity of prayers for Muslims in the region.

This urgency becomes even more relevant considering the dynamic geomagnetic conditions in the IKN region, influenced by ongoing geological factors and infrastructure changes. Local magnetic field variations, including the influence of human-made magnetic fields, can amplify the level of error if magnetic declination is not taken into account. Therefore, there is an urgent need to integrate scientific approaches in determining the Qibla direction, both through the use of modern measuring instruments and methods based on the latest data analysis.

As a follow-up, a comprehensive mapping of the magnetic declination variation across the entire IKN region should be conducted. A detailed and accurate magnetic declination map would not only be beneficial for the general public but also for professionals in architecture, civil engineering, and astronomy. This research can also be expanded by exploring the influence of other factors, such as human-made magnetic fields, satellite-based measurement technologies, and socio-cultural analyses related to the impact of Qibla direction deviation on the lives of the community.

By understanding this urgency, it is hoped that there will be synergy between researchers, government agencies, and the public to ensure that the qibla direction in the IKN (National Capital of Indonesia) not only meets technical standards but also adheres to religious guidelines. The Indonesian government institution responsible for geospatial matters, the Meteorology, Climatology, and Geophysics Agency (BMKG), has conducted research on the accuracy of the regional magnetic field data components across Indonesia. The regional geomagnetic model of Indonesia varies spatially in both latitude and longitude. Indonesia spans from -12° to 8° latitude and from 94° to 141° longitude, making it impossible to expect regular or linear variations due to dynamic structures beneath the vast regional area. The regional geomagnetic model produced for epoch 2020.0 contains more detailed information than the global model (IGRF). This is because global models are generally limited by accuracy and resolution constraints. Furthermore, the global model relies on a small number of observation stations in Indonesia, such as KPG, PLR, TND, and TUN. These efforts by the institution will contribute to creating a conducive environment for Muslim worship practices, while also supporting the development of integrated and sustainable spatial planning in the IKN region (Syirojudin et al., 2023).

In further studies, it was found that both magnetic declination values of less than one degree and those greater than one degree have a significant impact on the accuracy of the Qibla direction. Even the smallest deviation can affect the precision of the Qibla direction, especially if the magnetic declination is ignored during the determination process. The results of this analysis emphasize that inaccuracies in accounting for magnetic declination can lead to significant deviations from the correct direction (Sado, 2019).

This implication further strengthens the urgency of correcting magnetic declination in determining the Qibla direction, especially in regions like IKN, which experience dynamic geomagnetic conditions and intensive infrastructure changes. By taking this correction into account, the accuracy of the Qibla direction can be significantly improved, ensuring that the validity of prayers remains intact.

This effort is also relevant in the context of spatial planning and development in IKN, where standardization of the Qibla direction measurement methods needs to be carefully considered. Additionally, educating the public about how to account for magnetic declination, as well as providing accurate measuring instruments and standardized methods, becomes a strategic step to address this issue.

Through a comprehensive approach, including a more detailed mapping of the magnetic declination variations across the entire IKN area, as well as further research on the influence of artificial magnetic fields and modern measurement technologies, the accuracy of qibla direction can be continually improved. This will not only support the religious practices of Muslims but also contribute to the development of infrastructure that meets both technical and religious standards in the IKN area.

Conclusion

This study emphasizes the importance of considering magnetic declination in determining the qibla direction in IKN, as 77.18% of the data indicates significant deviations from the tolerance threshold of *iḥ tiyāṭ al-qiblah* (0.4°). The dynamic fluctuations of magnetic declination over the period from 1590 to 2024 show that the magnetic north direction in this area does not always align with true north, which could result in errors in determining the qibla direction if this factor is ignored. Therefore, the use of a compass for determining the qibla direction in IKN must be corrected by accurately factoring in magnetic declination, which can be obtained through the IGRF-13 model and web-based magnetic calculators. Standardized measurements that integrate magnetic declination corrections should be implemented in the planning and construction of mosques and other public buildings in IKN to ensure the accuracy of qibla directions. Additionally, educating the public about the importance of understanding and correcting magnetic declination is a crucial step in raising awareness and knowledge in daily religious practices. A more detailed mapping of magnetic declination variations across the entire IKN area will be an invaluable reference to address this issue. This research also opens opportunities for further studies on the influence of artificial magnetic fields and the application of satellite-based measurement technologies to support the accuracy of qibla direction determination, ultimately improving the quality of worship and infrastructure development that meets both technical and religious standards in the IKN area.

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