

## Qibla Direction Accuracy in Bangka Belitung Mosques: An Astronomical-Geospatial Study

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### Abstract

Accurate Qibla orientation is essential for the validity of Muslim prayer; inconsistencies in both traditional and modern determination methods continue to produce significant inaccuracies, particularly in archipelagic regions. This study assesses the accuracy of Qibla direction in mosques across the Bangka Belitung Islands, Indonesia, and evaluates the methods used to determine it. A mixed-methods approach was employed, combining field measurements of 70 mosques using the solar shadow (*istiwā'aini*) method and GPS-based applications with semi-structured interviews. Measured orientations were compared with geodetically calculated azimuths, and spatial distribution patterns were analyzed using Geographic Information Systems (GIS). The results show that only 30% of mosques are accurately aligned ( $\leq 2^\circ$  deviation), while 54% are less accurate and 16% are significantly misaligned ( $> 10^\circ$ ). GIS-based analysis reveals spatial variability in deviation patterns, indicating unequal access to technical knowledge and measurement tools. This study contributes to integrating astronomical, geodetic, and geospatial approaches for Qibla determination and highlights the need for standardized verification practices in geographically fragmented regions.

**Keywords:** qibla direction, *istiwā'aini*, geospatial, magnetic declination, archipelagic.

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Akurasi arah kiblat merupakan syarat esensial dalam keabsahan ibadah salat, namun inkonsistensi dalam metode penentuan, baik tradisional maupun modern, masih menghasilkan ketidaktepatan yang signifikan, terutama di wilayah kepulauan. Penelitian ini bertujuan untuk menilai akurasi arah kiblat pada masjid-masjid di Provinsi Kepulauan Bangka Belitung serta mengevaluasi metode yang digunakan dalam penentuannya. Pendekatan mixed methods digunakan melalui pengukuran lapangan terhadap 70 masjid menggunakan metode bayangan matahari (*istiwā'aini*) dan aplikasi berbasis GPS, serta wawancara semi-terstruktur. Arah hasil pengukuran dibandingkan dengan azimuth kiblat hasil perhitungan geodetik, dan pola distribusi spasial dianalisis menggunakan *Geographic Information Systems* (GIS). Hasil penelitian menunjukkan bahwa hanya 30% masjid yang tergolong akurat ( $\leq 2^\circ$ ), sementara 54% kurang akurat dan 16% tidak akurat ( $> 10^\circ$ ). Analisis berbasis GIS menunjukkan adanya variasi spasial tingkat deviasi antar wilayah yang mencerminkan ketimpangan akses terhadap pengetahuan teknis dan alat ukur. Penelitian ini berkontribusi pada integrasi pendekatan astronomi, geodetik, dan geospasial dalam penentuan arah kiblat serta menegaskan pentingnya standarisasi verifikasi di wilayah kepulauan.

**Kata Kunci:** arah kiblat, *istiwā'aini*, geospasial, deklinasi magnetik, wilayah kepulauan.

## A. Introduction

Accurate determination of the Qibla direction is a fundamental requirement in Islamic ritual practice, particularly for ensuring the validity of *ṣalāh*. Classical Islamic jurisprudence unanimously holds that facing the *Kaaba* is obligatory under normal circumstances, reflecting both the legal and spiritual dimensions of worship. As Muslim communities expanded geographically, various methods were developed to determine the Qibla, ranging from observational techniques such as solar shadow alignment to mathematical and astronomical calculations. The development of modern science has significantly transformed the determination of the Qibla. Contemporary studies demonstrate the increasing use of geodetic calculations, GPS-based systems, and digital applications to improve directional accuracy.<sup>1</sup> However, traditional methods such as compasses and sun-shadow techniques remain widely used due to their accessibility, despite their susceptibility to angular errors and environmental interference. For instance, even a one-degree deviation may result in significant displacement from the *Kaaba* over long distances.

Recent scholarship highlights several unresolved issues in both theoretical and practical aspects of Qibla determination. From a theoretical perspective, many Islamic astronomy references in Indonesia still rely on spherical trigonometry, which does not fully align with modern geoscience models that represent the Earth as an ellipsoid. In addition, inconsistencies in the application of magnetic declination continue to generate discrepancies in compass-based measurements.<sup>2</sup> These theoretical limitations suggest that existing calculation frameworks may not fully accommodate contemporary geodetic accuracy standards. From a practical perspective, the rapid adoption of smartphone-based Qibla applications introduces new challenges. While such applications are widely used for convenience, their reliance on magnetic sensors and GPS calibration often leads to inconsistent accuracy. Empirical studies indicate that deviations in mobile-based Qibla determination may range from minor angular differences to significant directional errors, depending on calibration and environmental conditions. Similar findings have been reported in studies comparing smartphone sensors with theodolite measurements, which reveal deviations exceeding acceptable tolerances.<sup>3</sup>

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<sup>1</sup> Roslan Umar, "Accuracy of Qibla Direction: Evaluating Smartphone Apps with the Istiwa' Adzam Method," *Islamiyyat* 47, no. 1 (June 3, 2025): 3–14, <https://doi.org/10.17576/islamiyyat-2025-4701-01>; Nurulhuda Ahmad Zaki and Damia Batrisya Hidayatullah, "Analisis Ketepatan Aplikasi Kiblat Dalam Play Store Dan Apple App Store," *Jurnal Fiqh* 22, no. 1 (June 30, 2025): 1–35, <https://doi.org/10.22452/fiqh.vol22no1.1>; Mursyid Fikri, "Digital Vs Traditional Qibla: Qibla Direction Accuracy Using Istiwa Sticks And Metaverse," *Indonesian Journal of Islamic Jurisprudence, Economic and Legal Theory* 3, no. 2 (May 29, 2025): 1473–95, <https://doi.org/10.62976/ijjel.v3i2.1133>.

<sup>2</sup> Muhammad Said Fadhel, "Urgensi Deklinasi Magnetik Berdasarkan Perubahan Waktu Dan Perbedaan Tempat Dalam Pengukuran Arah Kiblat" (Universitas Islam Negeri Walisongo Semarang, 2022), <https://eprints.walisongo.ac.id/id/eprint/25201/>; Agung Laksana and Muh Rasywan Syarif, "Telaah Matematis Variasi Lebar Arah Kiblat Di Wilayah Indonesia," *El-Falaky: Jurnal Ilmu Falak* 6, no. 1 (June 28, 2022): 18–37, <https://doi.org/10.24252/ifk.v6i1.29587>.

<sup>3</sup> Akhmad - Husein, Ahmad - Izzuddin, and Muhammad Said Fadhel, "The Effect Of Magnetic Declination Correction On Smartphones Compass Sensors In Determining Qibla Direction," *Al-Hilal: Journal of Islamic Astronomy* 3, no. 2 (October 31, 2021): 43–74, <https://doi.org/10.21580/al-hilal.2021.3.2.8309>; Yusuf Nurqolbi DY, Ulil Albab Al aulia Alpaten, and Kurniawan Kurniawan, "Kajian Penentuan Arah Kiblat Dengan Sensor Magnetik Kompas Android," *Astroislamica: Journal of Islamic Astronomy* 3, no. 2 (December 1, 2024): 193–210, <https://doi.org/10.47766/astroislamica.v3i2.3429>; Fajar Fathurahman, "Innovative Development of Mobile Application for Qibla Direction Guidance Services Training," *Ilomata International Journal of Social Science* 1, no. 3 (July 31, 2020): 88–102, <https://doi.org/10.52728/ijss.v1i3.122>.

These challenges are further exacerbated in archipelagic regions such as Indonesia, where geographical fragmentation, limited access to technical expertise, and infrastructural constraints hinder the standardization of Qibla determination. Studies in regions such as *Kendari* and the *Ibu Kota Nusantara* (IKN) demonstrate that a significant proportion of mosques exhibit directional deviations due to reliance on uncorrected compass readings and non-scientific orientation practices.<sup>4</sup> Despite the growing body of literature, previous studies have primarily focused on methodological comparisons, instrument accuracy, or theoretical debates, with limited attention to spatially grounded, field-based assessments of Qibla orientation in real mosque settings. In particular, the integration of astronomical measurement, geodetic calculation, and GIS-based spatial analysis in archipelagic contexts remains underexplored.

Therefore, this study aims to evaluate the accuracy of Qibla direction in mosques across the Bangka Belitung Islands by integrating astronomical observation, geodetic computation, and GIS-based spatial analysis. This research provides empirical evidence of spatial patterns of Qibla deviation and identifies key factors influencing directional accuracy in geographically complex environments. This study makes a novel contribution by integrating astronomical observations, geodetic calculations, and GIS-based spatial analysis to evaluate Qibla direction accuracy within an archipelagic context. Unlike previous studies that focus primarily on methodological comparison or instrument testing, this research provides a field-based, spatially explicit assessment of mosque orientation using empirical data from multiple locations. Furthermore, it bridges the gap between theoretical inconsistencies in Islamic astronomy and practical inaccuracies observed in real-world settings. The incorporation of GIS to analyze the spatial variability of Qibla deviation represents a significant advancement in the study of Islamic astronomical practices.

## B. Method

This study employed a descriptive, quantitative approach, complemented by qualitative insights, to evaluate the accuracy of Qibla direction in mosques across the Bangka Belitung Islands, Indonesia. A total of 70 mosques were selected purposively to ensure representation across the districts of Pangkalpinang, Bangka, Bangka Barat, Bangka Tengah, Bangka Selatan, and Belitung. Primary data were collected through field measurements using the solar shadow (*istiwā'aini*) method, supported by GPS-based applications, to determine the existing Qibla orientation of each mosque. In addition, semi-structured interviews were conducted with mosque administrators and local religious officials to understand the methods, instruments, and decision-making processes used to determine the Qibla direction.

The collected data were processed by converting observed orientations to azimuth degrees and comparing them with theoretically calculated Qibla azimuths derived from geodetic formulas. Angular deviation was calculated for each mosque and classified into three categories: accurate

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<sup>4</sup> R. Muhalling et al., "Controversy of the Qibla Direction Determination in Kendari City, Indonesia," *Utopía y Praxis Latinoamericana* 26, no. 2 (2021): 161–70, <https://doi.org/10.5281/zenodo.4678868>; Abdi Samra Caniago and Gadis Arniyati Athar, "Proof of the Accuracy of Calculation of Trigonometric Formulas for Spherical Triangles with Magnetic Declination Correction at Istiwa A'zamin Determining the Direction of the Qibla," *International Journal on Advanced Science, Education, and Religion (IJoASER)* 7, no. 4 (2024): 166–77; Muhamad Syazwan Faid et al., "Development of Qibla Direction Determinant Using Sun Shadow," *Online Journal of Research in Islamic Studies (RIS)* 9, no. 1 (2022): 89–102, <https://doi.org/10.22452/ris.vol9no1.7>.

( $\leq 2^\circ$ ), less accurate ( $2^\circ - 10^\circ$ ), and inaccurate ( $>10^\circ$ ). Descriptive statistical analysis was used to examine distribution patterns across regions. Spatial visualization was conducted using approximate geolocation derived from mosque addresses, given the limited availability of precise coordinate data. This approach enabled the identification of spatial variability in Qibla deviation while maintaining methodological transparency. Qualitative data were used to support the interpretation of quantitative findings, particularly in explaining technical and socio-institutional factors influencing measurement accuracy.

## C. Result and Discussion

### 1. Qibla Determination Practices in Archipelagic Contexts

The determination of Qibla direction in the Bangka Belitung Islands reflects a dual structure of practice, characterized by the coexistence of traditional (*taqrībī*) and precise (*tahqīqī*) methods.<sup>5</sup> Field observations indicate that the *taqrībī* approach, primarily relying on simple instruments such as magnetic compasses and solar shadow estimation, remains dominant among local communities. This preference is largely driven by accessibility, affordability, and ease of use, particularly in areas where technical expertise and advanced equipment are limited. However, these methods are inherently susceptible to measurement errors, especially when magnetic declination and environmental interference are not properly accounted for.<sup>6</sup>

In contrast, the *tahqīqī* method, which employs more precise instruments such as theodolites and geodetic calculations, is mainly practiced by institutional actors, particularly officials from the Ministry of Religious Affairs. The findings reveal that the adoption of these advanced techniques has increased in recent years, especially following the provision of equipment and technical training programs. Theodolites enable high-precision angular measurements using solar references, thereby reducing subjective error. Nevertheless, their use remains uneven across districts due to high costs, operational complexity, and the limited availability of trained personnel.

This uneven distribution of methodological capacity highlights a structural gap between community-based practices and institutional standards. While government agencies promote scientifically grounded approaches to Qibla determination, most mosques continue to rely on inherited or experience-based methods. In many cases, Qibla orientation is determined during the initial construction phase using approximate tools or communal agreement, without subsequent verification.<sup>7</sup> This indicates that methodological choices are shaped not only by technical considerations but also by socio-institutional factors such as access to knowledge, resource availability, and levels of scientific literacy.

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<sup>5</sup> Ahmad Izzuddin, *Ilmu Falak Praktis; Metode Hisab-Rukyat Praktis Dan Solusi Permasalahannya* (Semarang: Pustaka Rizki Putra, 2012), 49; Susiknan Azhari, *Ilmu Falak: Perjumpaan Khazanah Islam Dan Sains Modern* (Yogyakarta: Suara Muhammadiyah, 2007), 75; Muhyiddin Khazin, *Ilmu Falak Dalam Teori Dan Praktik; Perhitungan Arah Kiblat, Waktu Shalat, Awal Bulan Dan Gerhana* (Yogyakarta: Buana Pustaka, 2004), 33.

<sup>6</sup> Slamet Hambali, *Ilmu Falak 1; Penentuan Awal Waktu Shalat Dan Arah Kiblat Seluruh Dunia* (Semarang: Program Pascasarjan IAIN Walisongo Semarang, 2011), 30; Lutfi Adnan Muzamil, *Studi Falak Dan Trigonometri* (Yogyakarta: Pustaka Ilmu, 2015), 16; Muhamad Zainal Mawahib, "Metode Pengukuran Arah Kiblat Dengan Segitiga Siku-Siku Dari Bayangan Bulan" (UIN Walisongo Semarang, 2016).

<sup>7</sup> Novarianto Novarianto, "Interview" (Bangka Belitung, 2025), September 7, 2025.

A transitional pattern is also evident, where hybrid practices emerge in certain areas. In such cases, compass-based measurements are occasionally cross-checked using GPS-based applications or verified through institutional re-measurement with theodolites. While this hybridization reflects a growing awareness of the importance of accuracy, it also reveals inconsistencies in implementation. The reliability of these practices depends significantly on user competence, particularly in calibrating digital instruments and interpreting geospatial data.

Overall, the findings suggest that a complex interaction between technical capability, institutional support, and local knowledge systems shapes Qibla determination practices in archipelagic contexts. The persistence of lower-accuracy methods alongside the gradual adoption of high-precision techniques reflects not merely a technological transition, but a broader process of knowledge diffusion and adaptation.<sup>8</sup> This condition underscores the need for systematic integration of astronomical, geodetic, and geospatial approaches, supported by accessible training and standardized verification procedures to ensure consistent Qibla alignment across geographically fragmented regions.

## 2. Accuracy Patterns of Qibla Orientation: Empirical Findings

The empirical assessment of Qibla orientation across 70 mosques in the Bangka Belitung Islands reveals a consistent pattern of deviation, indicating that accurate alignment remains limited. Based on the established classification, only 30% of mosques fall within the accurate category ( $\leq 2^\circ$  deviation), while the majority (54%) are categorized as less accurate ( $2^\circ - 10^\circ$ ), and 16% exhibit significant misalignment ( $> 10^\circ$ ). This distribution demonstrates that while extreme inaccuracies are relatively limited, systematic minor deviations are widespread. Such findings are consistent with previous studies indicating that Qibla misalignment in Indonesia is often characterized by moderate angular deviations rather than extreme directional errors.<sup>9</sup>

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<sup>8</sup> Iskandar Iskandar, "Interview" (Bangka Belitung, 2025), May 5, 2025.

<sup>9</sup> Rahman Helmi and Badrian Badrian, "Akurasi Arah Kiblat Masjid-Masjid Di Kabupaten Banjar," *Indonesian Journal of Islamic Jurisprudence, Economic and Legal Theory* 2, no. 1 (February 10, 2024): 215–27, <https://doi.org/10.62976/ijjel.v2i1.439>; Misrahul Safitri, "Studi Komparasi Terhadap Akurasi Istiwaaini Dengan Kompas Kiblat Android 'Muslim Go' Dalam Pengukuran Arah Kiblat," *Al-Afaq: Jurnal Ilmu Falak Dan Astronomi* 4, no. 1 (June 30, 2022): 78–94, <https://doi.org/10.20414/afaq.v4i1.5070>.

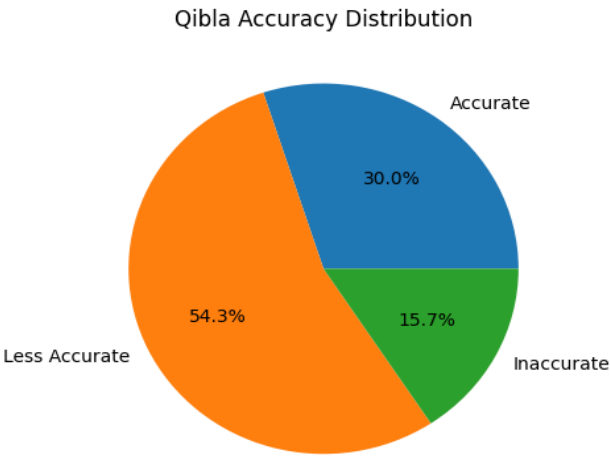


Figure 1. Distribution of Qibla Orientation Accuracy

The dominance of the "less accurate" category provides an important analytical insight. Rather than indicating random error, this pattern reflects a structural tendency toward approximate orientation practices. In many cases, mosque alignment appears to be based on initial estimations using compasses or architectural adjustments, without subsequent verification using more precise methods. This tendency aligns with earlier findings that reliance on uncorrected compass readings and non-astronomical approaches significantly contribute to Qibla deviation.<sup>10</sup> As a result, small angular deviations accumulate and persist across different locations.

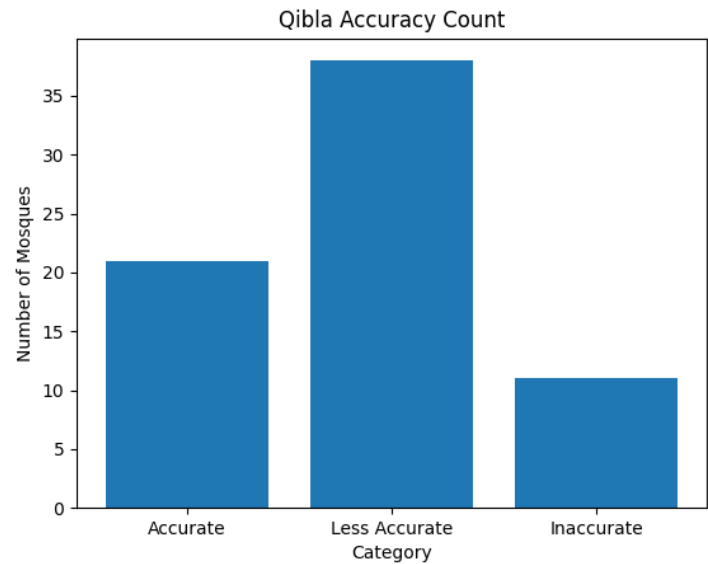


Figure 2. Number of mosques by Qibla accuracy category, by district.

<sup>10</sup> Caniago and Athar, "Proof of the Accuracy of Calculation of Trigonometric Formulas for Spherical Triangles with Magnetic Declination Correction at Istiwa A'zamin Determining the Direction of the Qibla"; Agung Laksana and Syarif, "Telaah Matematis Variasi Lebar Arah Kiblat Di Wilayah Indonesia."

A closer examination of district-level data reveals notable variability in accuracy across regions. Certain areas, such as West Bangka, demonstrate higher alignment accuracy, while others, particularly urban centers like Pangkalpinang, show lower precision. This variation suggests that Qibla accuracy is closely associated with institutional engagement and access to technical expertise, rather than purely geographic factors. Similar patterns have been observed in other Indonesian contexts, where the availability of trained personnel and measurement tools significantly influences alignment outcomes.<sup>11</sup>

In contrast, cases of significant misalignment ( $>10^\circ$ ) reflect more fundamental methodological issues. Field observations indicate that such deviations often originate in non-technical decision-making processes, such as alignment based on building orientation or community consensus. This phenomenon has also been reported in previous studies, in which mosque orientation was determined based on social consensus rather than precise geospatial calculations. In addition, the misuse or miscalibration of digital tools may further contribute to large deviations, as demonstrated in studies showing significant discrepancies between smartphone-based measurements and theodolite references.<sup>12</sup>

Overall, the empirical findings indicate that Qibla orientation in the Bangka Belitung Islands is characterized by widespread moderate deviation rather than isolated extreme errors. This pattern reflects the interaction between methodological limitations, technological constraints, and socio-institutional factors. From a broader perspective, these findings reinforce the argument that achieving high accuracy in Qibla determination requires not only improved measurement tools but also systematic validation practices and the integration of astronomical and geodetic standards, as emphasized in classical and modern studies of Qibla calculation.<sup>13</sup>

### 3. Integrative Evaluation and System Implementation in High-Latitude Prayer Time Determination

To further examine the spatial characteristics of Qibla orientation accuracy, a geospatial visualization was conducted using approximate geolocation derived from mosque distribution across districts in the Bangka Belitung Islands. Due to the limited availability of precise geographic coordinates, spatial representation was based on regional centroids while maintaining the proportional distribution of sampled mosques. This approach provides a general spatial framework for understanding the distribution of Qibla measurement outcomes without compromising methodological transparency.

The spatial mapping shows that the distribution of Qibla observation sites is not uniformly dispersed but rather reflects regional clustering, with the number of sampled mosques. As shown in Figure 3, districts such as Bangka and Belitung exhibit a relatively higher concentration of observation points. In contrast, other regions, such as Pangkalpinang and Bangka Tengah, show a

<sup>11</sup> Muhalling et al., "Controversy of the Qibla Direction Determination in Kendari City, Indonesia."

<sup>12</sup> Husein, Izzuddin, and Fadhel, "The Effect Of Magnetic Declination Correction On Smartphones Compass Sensors In Determining Qibla Direction"; Nurqolbi DY, Alpaten, and Kurniawan, "Kajian Penentuan Arah Kiblat Dengan Sensor Magnetik Kompas Android."

<sup>13</sup> J. L. Berggren and David A. King, "World-Maps for Finding the Direction and Distance to Mecca: Innovation and Tradition in Islamic Science," *Journal of the American Oriental Society* 121, no. 3 (July 2001): 512, <https://doi.org/10.2307/606696>.

more limited distribution. This variation corresponds to differences in sampling coverage and regional representation within the study.

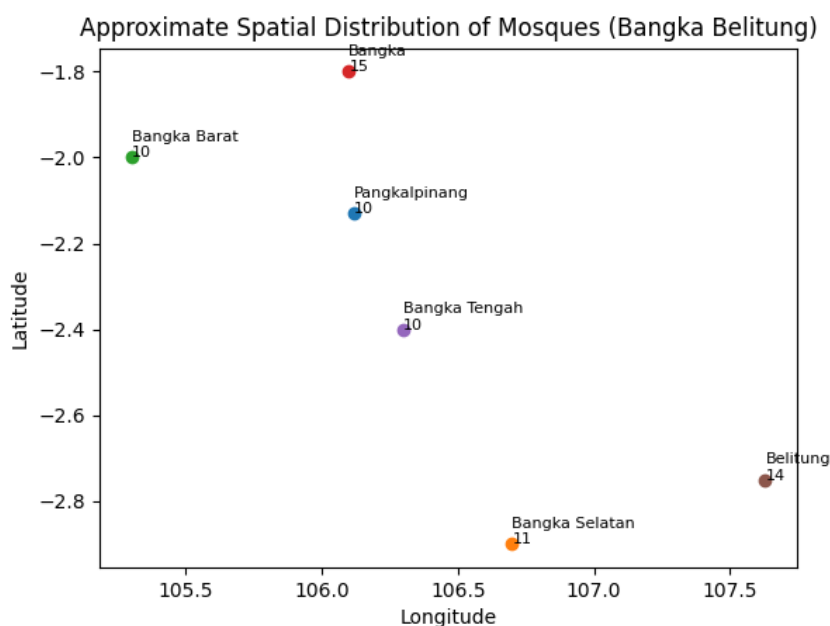


Figure 3. Spatial distribution of Qibla observation sites across the Bangka Belitung Islands.

The map illustrates the approximate spatial distribution of mosques included in the study, based on regional centroids. The numbers indicate the total sample of mosques in each district, providing a spatial overview of data coverage.

Although this visualization does not capture point-level precision, it allows identification of broad spatial tendencies in Qibla orientation practices. When interpreted alongside the statistical findings, the spatial distribution suggests that regions with higher institutional engagement and access to measurement tools tend to demonstrate better alignment accuracy. Conversely, areas with limited technical support exhibit greater variability in Qibla orientation, reinforcing the role of socio-institutional factors in shaping measurement outcomes.

Furthermore, the spatial perspective highlights that Qibla deviation in the Bangka Belitung Islands exhibits a non-random pattern: moderate inaccuracies predominate across regions, while extreme deviations occur as isolated cases. This pattern supports the argument that inaccuracies in Qibla determination are largely systematic, arising from consistent methodological practices rather than isolated errors. Therefore, GIS-based visualization, even at an approximate level, provides valuable insight into the spatial dimension of Qibla alignment and supports the need for region-specific strategies in improving measurement accuracy.

#### 4. Sources of Qibla Misalignment: Technical and Socio-Institutional Factors

The observed patterns of Qibla deviation in the Bangka Belitung Islands are not merely the result of random measurement error, but reflect a combination of technical limitations and socio-

institutional factors. One of the primary technical contributors is the widespread reliance on magnetic compasses without proper correction for magnetic declination. As compasses indicate magnetic north rather than true north, failure to apply declination adjustments introduces systematic angular deviations. Previous studies have emphasized that ignoring magnetic declination can lead to significant Qibla misalignment, often exceeding acceptable tolerance thresholds.<sup>14</sup> The findings of this study reinforce this argument, as the dominance of moderate deviation ( $2^{\circ}$ – $10^{\circ}$ ) closely corresponds to the typical error range of compass-based measurements.

In addition to traditional tools, the increasing use of smartphone-based Qibla applications introduces further technical challenges. Although these applications are widely adopted due to their convenience, their accuracy depends heavily on sensor calibration, magnetic stability, and GPS precision. Empirical studies demonstrate that smartphone-based measurements may differ by several degrees from theodolite-based observations, particularly in environments with magnetic interference.<sup>15</sup> Similar patterns are also reported in application-based studies, where a substantial proportion of Qibla apps show measurable deviations despite widespread public reliance. The present study confirms these findings, as interview data reveal that many users rely on digital tools without proper calibration or awareness of their limitations.

However, technical factors alone do not fully explain the observed misalignment patterns. Socio-institutional dynamics play a crucial role in shaping Qibla determination practices. In many cases, mosque orientation is influenced by non-technical considerations such as land constraints, building orientation, and community consensus. This tendency has been documented in previous studies, in which the Qibla direction was often determined through communal agreement rather than precise geospatial measurement.<sup>16</sup> The present findings align with this pattern, particularly in cases where significant deviations ( $>10^{\circ}$ ) were linked to architectural or practical considerations rather than measurement errors.

Another key factor is the uneven distribution of technical knowledge and measurement capacity across regions. Access to accurate instruments, such as theodolites, and to trained personnel capable of conducting precise measurements remains limited in many areas. This condition reflects a broader gap between advances in scientific methods and their implementation at the community level. Previous research has highlighted that inconsistencies in theoretical understanding, such as the continued use of spherical models and conflicting interpretations of magnetic declination, also contribute to inaccuracies in Qibla determination. This study extends these findings by demonstrating how such theoretical and technical gaps translate into observable inaccuracies in real-world mosque orientations.

Overall, Qibla misalignment in the study area can be understood as the result of an interaction between technical constraints and socio-institutional factors. While previous studies have often examined these factors separately, focusing either on instrument accuracy or on methodological frameworks, this study integrates both dimensions within a field-based empirical

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<sup>14</sup> Husein, Izzuddin, and Fadhel, "The Effect Of Magnetic Declination Correction On Smartphones Compass Sensors In Determining Qibla Direction"; Agung Laksana and Syarif, "Telaah Matematis Variasi Lebar Arah Kiblat Di Wilayah Indonesia."

<sup>15</sup> Husein, Izzuddin, and Fadhel, "The Effect Of Magnetic Declination Correction On Smartphones Compass Sensors In Determining Qibla Direction"; Nurqolbi DY, Alpaten, and Kurniawan, "Kajian Penentuan Arah Kiblat Dengan Sensor Magnetik Kompas Android."

<sup>16</sup> Muhalling et al., "Controversy of the Qibla Direction Determination in Kendari City, Indonesia."

context. The findings, therefore, contribute to a more comprehensive understanding of Qibla determination, emphasizing that improving accuracy requires not only better tools but also enhanced knowledge dissemination, institutional support, and standardized verification practices, particularly in geographically complex and resource-limited environments.

#### **D. Conclusion**

This study demonstrates that Qibla orientation in the Bangka Belitung Islands is predominantly characterized by moderate deviation rather than extreme misalignment, indicating that inaccuracies are systematic rather than incidental. With only 30% of mosques meeting the criteria for accurate alignment, the findings reveal a structural gap between scientifically grounded methods and their implementation at the community level. The persistence of deviation is closely associated with the widespread use of uncorrected magnetic compasses, limitations of smartphone-based applications, and non-technical factors such as architectural constraints and communal decision-making. By integrating field measurements with geodetic calculations and geospatial interpretation, this study highlights the interaction between technical limitations and socio-institutional dynamics as a key explanatory framework in understanding Qibla misalignment in archipelagic contexts.

Despite these contributions, this study has several limitations. The sample, although geographically distributed, does not fully represent all mosques in the region, particularly in more remote areas. In addition, the spatial analysis is constrained by limited geospatial data, which restricts deeper GIS-based modeling. Measurement results may also be affected by environmental conditions and instrument variability during field observations. These limitations suggest that the findings should be interpreted within the study area.

Future research should incorporate a larger, more representative dataset with precise geographic coordinates to enable more robust spatial analysis. Longitudinal studies are also needed to assess the impact of training and institutional interventions on improving Qibla accuracy. Furthermore, the development of standardized, accessible measurement protocols that integrate astronomical, geodetic, and digital approaches remains essential. Strengthening collaboration between religious authorities, academic institutions, and local communities will be crucial to ensuring consistent and reliable Qibla determination, particularly in geographically fragmented regions.

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