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Reformulation: the Impact of the Sun's Spatial Size and Orbital Path on the Calculation of Zuhr Prayer Start Time

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Abstract

The determination of the start time for Zuhr prayer in its calculation does not refer to the actual natural phenomena but is based on the Sun's transit at the meridian, plus a specific margin of safety (ihtiyath) that differs from the ihtiyath values used for other prayer times. This study demonstrates the duration of the Sun's decline throughout the year to validate the use of this specific ihtiyath for Zuhr. The calculation of the Sun's decline duration uses data on solar declination and semi-diameter, which are then simulated for the entire year of 2025. The simulation results show that the duration of the Sun's decline ranges from 63.64 to 70.85 seconds. When rounding up the duration of the decline and adding an ihtiyath value of 2 minutes (similar to the ihtiyath for other prayer times), the conclusion from this study suggests that the ihtiyath for Zuhr should be 4 minutes. However, it would be better if the calculation of the start time for Zuhr prayer used corrections based on solar declination and semi-diameter data to indicate the actual phenomenon of the start time for Zuhr prayer and to avoid misconceptions by using a uniform ihtiyath for all prayer times.

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A. Introduction

The times for the five obligatory prayers have been established based on a sahih (authentic) hadith found in the book of Sunan an-Nasa'i: "Yusuf bin Wadlih reported to us, he said; Qudamah, who is Ibn Shihab, narrated to us from Burad, from Ata bin Abu Rabah, from Jabir bin Abdullah. Jabir bin Abdullah (may Allah be pleased with him) said that 'Jibril came to the Prophet (peace be upon him) to teach him the times of prayer. Jibril moved forward, and the Messenger of Allah (peace be upon him) stood behind him, while the people stood behind the Messenger of Allah (peace be upon him). Then, Jibril prayed Zuhr when the sun had declined, and he came back when the shadow was the same as its object and did as he did the first time. Jibril moved forward, and the Messenger of Allah (peace be upon him) stood behind him, while the people stood behind the Messenger of Allah (peace be upon him). Then, Jibril prayed Maghrib when the red twilight had disappeared. Jibril came again, and Jibril moved

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forward, and the Messenger of Allah (peace be upon him) stood behind him, while the people stood behind the Messenger of Allah (peace be upon him), and then Jibril immediately prayed Isha. When dawn began to break, Jibril came again, then Jibril moved forward, and the Messenger of Allah (peace be upon him) stood behind him, while the people stood behind the Messenger of Allah (peace be upon him), then Jibril prayed Fajr.

On the second day, Jibril came when a person's shadow was equal to his height and did as he did the day before, praying Zuhr. He then came again when a person's shadow was twice his height, did as he did the day before, and immediately prayed Asr. Then, he came again when the sun set, and did as he did the day before, and prayed Maghrib. We then slept, woke up, slept again, woke up again, and Jibril came and did as he did the day before, then prayed Isha. The next day, when dawn was well spread, and it was already morning, Jibril came while the stars were still bright. He immediately did as he did the day before, then he prayed Fajr. Then he said, 'The time of prayer is between the two prayers of the day before.'". In its wording, the condition of the sky at that time served as a reference to mark the specific prayer times.

Zuhr time begins when the Sun starts to decline (Zawal as-Shams), which occurs just after the Sun transits the meridian and moves westward by the distance of its own spatial size. This is based on a hadith from Jabir bin Samurah, who said: "The Prophet (peace be upon him) used to perform the Zuhr prayer when the sun had started to decline (tilted to the west)".

Ihtiyath is a precautionary measure in determining prayer times by adding or subtracting time to ensure that one does not start the prayer before its designated time or exceed the end of the prayer time. The various types of ihtiyath used by experts in Islamic astronomy (falak) include:

- Kemenag Ephemeris: All prayer times have a 2-minutes, except for Zuhr, which has a 3-minutes.
- Noor Ahmad SS: Uses a 3-minutes for every prayer time calculation, except for Zuhr, which has a 4-minutes. .
- Ibn Zahid ‘Abd al-Mu‘îd in the Ramadan 1430 H Imsakiah uses a 2-minutes for every prayer time calculation, except for the start time of Zuhr, which has a 4-minutes.
- Muhammadiyah uses a 1-2 minute buffer in the calculation of prayer start times.
- Almanak Menara Kudus establishes a 4-minutes for the calculation of prayer times.

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The difference in ihtiyath values for Zuhr prayer is based on the concept of the Sun's decline. Decline refers to the appearance of a shadow extending westward or increasing in length after the shortest shadow of the day. A longer buffer time is used compared to other prayers because the start time for Zuhr is not based directly on the phenomenon of the Sun's decline (i.e., when the Sun has actually declined) but rather on the Sun's transit at the meridian.

The approach to calculating prayer times differs significantly between Zuhr and Maghrib prayers. For Maghrib, corrections are made for the Sun's diameter, horizon parallax, atmospheric refraction (dip), and altitude above sea level to closely match the timing phenomenon. In contrast, for Zuhr, the calculation does not directly use the phenomenon of the Sun's decline (Zawal) but rather applies a fixed ihtiyath of 3 minutes after the Sun's transit at the meridian. The use of dip in Maghrib time calculations is due to the Sun not always aligning with the celestial equator, whereas similar corrections are not applied to Zuhr, despite both considering the Sun's spatial size and movement across the sky.

This study will examine the differences in the calculation of the Zuhr prayer start time between the ephemeris provided by the Indonesian Ministry of Religious Affairs and calculations using corrections for the Sun’s position when it is not at the celestial equator, with the meridian distance from the Sun equal to half the Sun’s diameter. The diameter of the Sun will be adjusted to account for its elliptical orbit around the Earth.

The study will analyze the discrepancy between these calculations to determine if the difference is significant enough to warrant a change from the 3-minute ihtiyath used in the Ministry's ephemeris or if it should remain unchanged.

B. Method

Meridian Transit Sun Times

The time when the Sun crosses the celestial meridian is also known as Local Apparent Noon (LAN) or Local Apparent Time (LAT), which occurs at 12:00 AM or, alternatively, Absolute Solar Time (AST) or True Solar Time at 12 hours. The local time when the Sun transits the upper meridian at a specific location is referred to as Local Meridian Noon (LMN)

LMN = LAN – EoT

EoT = Equaion of Time

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With LAN, a correction is applied for the local longitude (λ) divided by 15º/hour, minus the time zone (TZ) used for that region. This is often referred to as the Local Time Correction (Koreksi Waktu Daerah, KWD).

$$LMN = 12:00 - EoT - TZ - \lambda/15$$

In the Ministry of Religious (Kemenag) ephemeris, the calculation of Zuhr time involves adding the Local Meridian Noon (LMN) to the ihtiyath buffer.

t_{zuhur} = LMN + *ihtiyath*

Correction of the Initial Calculation of Zuhur Time

The Sun does not always move precisely along the celestial equator; it can be inclined northward (from March 22 to September 22) or southward (from September 24 to March 21). As shown in Figure 1, the Sun has a distance from the celestial equator known as declination. The greater the declination, the longer the Sun takes to move from its meridian position to the Zawal (decline) position.

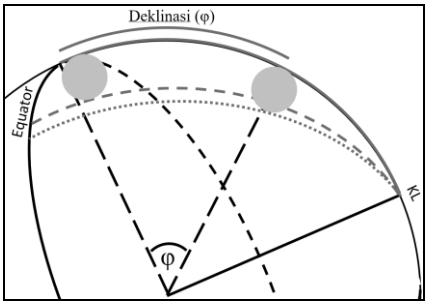

Figure 1. Comparison of the position of the Sun with different declinations

The correction due to declination is based on when the Sun is in the celestial meridian until the Sun completely slips. This small orbit makes the Sun appear to be moving more slowly and it takes longer to complete its path to the zawal position on the orbit. The equation used to calculate the travel time for the sun to slip is:

$$dt = \frac{d\theta}{\omega}$$

With a distance dθ equal to half the spatial size of the Sun and ω as the Sun's orbital speed given by 2π/T, and accounting for the correction due to declination (ϕ), resulting in a change in spatial movement by cos (ϕ), then:

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$$dt = \frac{d\theta}{\omega} = \frac{\frac{1}{2} r_{\odot}}{\frac{2\pi \cos(\varphi)}{T}}$$

With 2π/T representing the celestial object's orbital period of 15" per second, the time interval for the Sun to move from the meridian position to the Zawal position is:

$$t_T = \frac{r_{\odot}}{7{,}5 \cos(\varphi)}$$

t_T = decline time (menit)

r_Θ = Sun Semi-diamater (‘)

φ = Sun declination(º)

If we only consider the declination, the minimum value occurs when the Sun is at the equinoxes, on March 21 and September 23, while the maximum value occurs at the solstices, on June 22 and December 22.

The spatial semi-diameter of the Sun is calculated by considering the distance from the Earth due to Earth's elliptical orbit, thus:

$$r_{\odot} = \frac{1}{2} \tan^{-1}\left(\frac{2\ x\ 695700}{d_{\odot}\ x\ 149597870{,}7}\right)$$

d_Θ = Sun-Earth distance (au)

r_Θ = Sun semi diameter (’)

C. Results and Discussion

Research Results

The simulation run for one year in 2025, as shown in Figure 2, it is observed that the Sun travels a varying or non-constant arc distance. The Sun does not always travel an angular distance of 360º or along a great circle on the sphere's surface, but on average, it covers a distance of 345.28º, with the minimum distance at the solstices being around 330.30º.

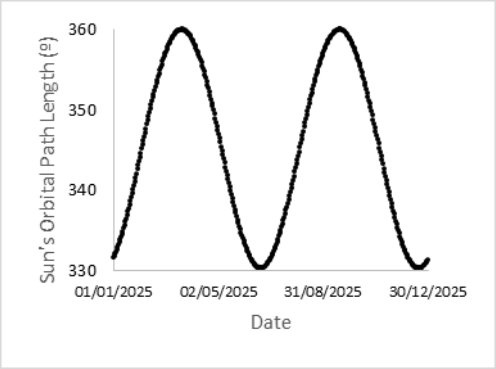

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Figure 2. Graph of the Sun's Orbital Path Length on the Celestial Sphere at 2025

The length of a day is not always exactly 24 hours; it can vary, sometimes being slightly more or less. The maximum deviation is only +0.00014 seconds above 24 hours, and the minimum deviation is -0.00099 seconds below 24 hours. Therefore, it can be approximated that the Sun's motion across the celestial sphere is constant at 24 hours or 86,400 seconds.

With this assumption, the Sun's speed on the celestial sphere (degrees per hour) is not a constant 15º per hour. As shown in Figure 3, which represents the calculation of the Sun's movement on the celestial sphere, the Sun's speed ranges from a minimum of 13.76º per hour to a maximum of 15º per hour.

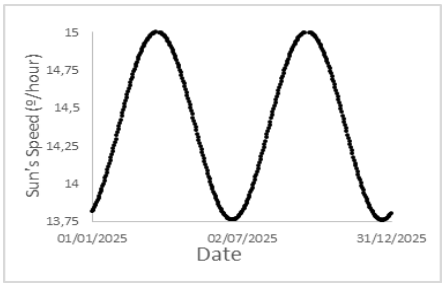

Figure 3. Graph of the Sun's Speed on the Celestial Sphere at 2025

The variation in the Sun's speed affects the duration it takes to travel an arc length of 32" (the average spatial size of the Sun). Therefore, both declination and semi-diameter influence the duration from the Sun's meridian transit to its decline. If this correction is included in the calculation for the Zuhr prayer time, the equation becomes:

$t_{zuhur} = LMN + t_T + ihtyat$

t_{zuhur} = Zuhr prayer time

The simulation of the Zuhr prayer start time calculation was run for one year in 2025 without any *ihtiyath*. The results were observed after the meridian transit. The calculation results are displayed in Figure 4.

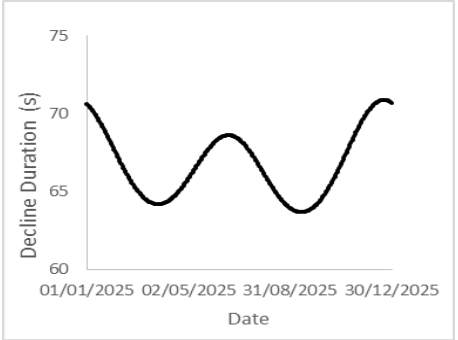

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Figure 4. Graph of the Duration from Meridian Transit to Zawal Position of the Sun at 2025

From the simulation, the average duration for the Sun's decline was found to be 66.75 seconds, with a maximum of 70.85 seconds and a minimum of 63.64 seconds. When this value is added to a 2-minute *ihtiyath* (used for other prayer times) and a 3-minute *ihtiyath* for Zuhr (calculated from the meridian transit), the difference from the prayer schedule is only about 6.75 to 10.85 seconds.

Discussions

The difference of 6.75 to 10.85 seconds from the prayer schedule is not significant, as it is less than 30 seconds. The 30-second threshold is used as a reference because the smallest unit for displaying prayer times in tables is 1 minute.

Even though the simulation results show that adding a correction for declination is not significant, using a 3-minute *ihtiyath* to accommodate the 6.75-10.85 seconds discrepancy can lead to misconceptions about *ihtiyath*. According to the definition, *ihtiyath* is a safety margin added to prayer time calculations to ensure that all residents, whether in the eastern or western parts of a city, can perform their prayers within the correct time. *Ihtiyath* is used to account for regional time variations since the calculation is based on the city or district center. Some functions of *ihtiyath* include:

[1] Rounding in Data Collection: Rounding can occur in data sources or during calculations. Although the rounding might be small, it can result in differences in the final outcome.

[2] Consistency in Prayer Schedules: A prayer schedule is often used for many years or even indefinitely. Even though changes in prayer times from year to year are minimal, accuracy corrections are needed. Annual publication of prayer schedules by each district or city is an effort by the Ministry of Religious Affairs to improve the accuracy of prayer times used by the community.

[3] Geographical Coordinates: Latitude and longitude of a city are typically measured at a central point in the city (at that time). This central point is determined by local scholars, whether in the capital, at zero point, or at the geographical center of the region. Ihtiyath time is required to account for areas to the west of the central point. This is one reason why some regional offices of the Ministry of Religious Affairs implement different ihtiyath policies for each area. The safety margin time is based on Earth's equatorial

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circumference of 40,000 km, which the Sun traverses in 360º in 24 hours. The Sun travels 27.77 km per minute on Earth's surface. Therefore, a 1-minute ihtiyath can accommodate a distance of 27.77 km from the reference geographical coordinates (central point) to the western edge of the city. Thus, the 2-minute ihtiyath policy in the Ministry of Religious Affairs' ephemeris can accommodate a city area of up to 55.54 km westward.

[4] Elevation Differences: Ihtiyath time is used to account for variations in elevation within a city, where some parts may be highlands and others lowlands. The height correction formula is:

$$t_h = 7{,}6\sqrt{\Delta h}$$

th = Elevation Corection (s)

Δh = positiom deference level with markaz (m)

This correction is used to determine the start of the Maghrib prayer time.

From the explanation of the functions of *ihtiyath*, its use is intended to accommodate regional variations and correct calculation errors, even when prayer times are calculated based on the Sun's position. The value of ihtiyath will vary depending on the area's size and topographical features. Therefore, the 2-minute *ihtiyath* value used as a standard in the Ministry of Religious ephemeris can be adjusted based on regional needs.

For example, in Tanjung Jabung Barat Regency in Jambi Province, a 4-minute ihtiyath can effectively accommodate the entire region.

According to Slamet Hambali, the method for using ihtiyath in prayer time calculations is as follows:

[5] Any number of seconds should be rounded to the nearest minute, except for sunrise times, where any additional seconds should be discarded.

[6] Add an additional 2 minutes to the calculated time, except for sunrise, where 2 minutes should be subtracted.[1].

The simulation results show that the duration the Sun takes to move from the meridian to the position of zawal ranges from 63.64 to 70.85 seconds. The *ihtiyath* value is set to 4 minutes due to rounding this duration (63.64 to 70.85 seconds) to 2 minutes.

The ephemeris book of the Ministry of Religious Affairs contains data on the Sun's and Moon's positions from various variables. The necessary data, such as the semi-diameter of the Sun and the Sun's declination, is available hourly in the ephemeris book.

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For the Western Indonesian Time (WIB+7), the data for the column “UTC” at “5 AM” can be used, as the Absolute Solar Time (AST) is 12 hours when the Sun is on the meridian. Subtract 7 hours for the WIB time zone. For Central Indonesian Time (WITA+8), use the data for UTC “4 AM” (AST 12 hours - 8 hours), and for Eastern Indonesian Time (WIT+9), use UTC “3 AM.”

Implementing the corrections for declination and the semi-diameter of the Sun in the calculation of Zuhr prayer times leads to a uniform and consistent use of *ihtiyath* (except for Maghrib due to topographical corrections). Consequently, a standardized *ihtiyath* value can be established for each region. For example, the Tanjung Jabung Barat Regency office of the Ministry of Religious Affairs sets the *ihtiyath* value at 4 minutes. This consistent value not only standardizes the *ihtiyath* but also helps avoid misconceptions about its definition and function.

D. Conclusion

From the simulation of the initial Zuhr prayer time calculation using the Sun's declination correction throughout the year 2025, it was found that the time required for the Sun to move from the meridian position to the *zawal* position ranges from 63.64 to 70.85 seconds. With the rounding concept always up, this duration is rounded to 2 minutes. Adding this to the 2-minute *ihtiyath* as per the Ministry of Religious Affairs' ephemeris, the appropriate *ihtiyath* for the initial Zuhr prayer time is 4 minutes. If a uniform *ihtiyath* is applied to all prayer times, then this declination and semi-diameter correction should be used to enhance the accuracy of the Zuhr prayer time calculation based on the phenomenon, while also avoiding misconceptions about the function of *ihtiyath* itself.

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