Potential Combination of Theodolite and Sky Quality Meter in Determining Fajr

Fazili Anuar Md Yusuf*, Norziana Yusuf dan Othman Zainon

*Bahagian Ukur dan Pemetaan,
Institut Tanah dan Ukur Negara (INSTUN), Kementerian Tenaga dan Sumber Asli,
Behrang, Tanjung Malim, Perak, Malaysia. 35950

Universiti Teknologi Malaysia,
Faculty of Built Environment and Surveying, Department of Geoinformation,
Johor Bahru, Johor, Malaysia 81300

e-mail: fazili@instun.gov.my

Abstract

It is important for Muslims to determine the time of fajr prayer since it is one of the pillars. However, it is still challenging to start the fajr prayer due to the position of the sun that is below the horizon. To determine the time of Dhuhr, Asr, and Maghrib prayer is easy since the object and shadow of the sun can be seen clearly. The position of the sun is determined by the solar angle. The value is positive (+) when the sun is positioned at the north of the celestial equator and negative (-) when it is at the south of the celestial equator. Fajr time is determined by the brightness level of the sky at the eastern horizon. Thus, this research is conducted to ensure that the time to start and end the astronomical twilight is the same theoretically. Astronomical twilight determines the start and the end of Fajr and Isha prayers time. The combination of theodolite and Sky Quality Meter (SQM) has been used to determine the sky's brightness during dawn. The theodolite is used to establish the vertical angle of the instrument while the SQM is used to record the sky brightness data at the time of observation. Early research has been conducted at Balai Cerapan, Universiti Teknologi Malaysia. Finding has shown that the combination of theodolite and SQM has the potential and can be used to observe the brightness level of the sky. The SQM readings were taken at 2 minutes intervals. The finding has shown that the darkest site reading can be detected at a value of less than 20 magnitud second in the morning. The SQM reading values are compared with the sun elevation value which is the condition to determine the start of the Fajr prayer.

Keywords: Time, Theodolite, Sky Quality Meter, Determining, Fajr

Abstrak

Adalah penting bagi umat Islam menentukan waktu solat subuh kerana ia merupakan salah satu daripada rukun Islam. Namun begitu, bagi menentukan waktu solat subuh ianya masih sukar kerana kedudukan matahari yang berada di bawah garis ufuk. Untuk menentukan waktu solat Zuhur, Asar, dan Maghrib ianya lebih mudah kerana objek dan bayangan matahari dapat dilihat dengan jelas. Kedudukan sudut Sin ditentukan oleh sudut suria. Nilainya adalah positif (+) apabila matahari berada di cakerawala utara khatulistiwa dan nilai negatif (-) apabila ianya berada di cakerawala selatan khatulistiwa. Waktu Subuh ditentukan melalui beberapa tahap kecerahan langit di ufuk timur. Justeru, kajian ini dijalankan untuk memastikan masa bermula dan tamatnya senja astronomi adalah sama secara teori. Senja astronomi digunakan untuk menentukan permulaan dan akhir waktu solat Subuh dan Isyak. Gabungan theodolite dan Sky Quality Meter (SQM) digunakan untuk menentukan tahap kecerahan langit pada waktu subuh. Theodolite digunakan untuk menetapkan sudut vertikel cerapan manakala SQM digunakan untuk merekod data kecerahan langit pada masa cerapan. Kajian awal telah dijalankan di Balai Cerapan, Universiti Teknologi Malaysia. Penemuan telah menunjukkan bahawa gabungan theodolite dan SQM mempunyai potensi dan boleh digunakan untuk mencerap tahap kecerahan langit. Bacaan SQM diambil pada selang 2 minit. Penemuan telah menunjukkan bahawa bacaan cerapan paling gelap boleh dikesan pada nilai kurang daripada 20 mag/sec2 pada waktu pagi. Nilai bacaan SQM dibandingkan dengan nilai ketinggian matahari yang merupakan syarat untuk menentukan permulaan waktu solat Subuh.

Kata Kunci: Masa,Theodolite, Sky Quality Meter, Subuh

INTRODUCTION

The early morning dawn is very sensible in the determination of the prayer time for Muslims to fulfill their obligations. Many studies have been done to look at and measure this sadiq dawn phenomenon. Various studies have been conducted to obtain a value that can measure the light of sadiq dawn. Dawn looks very delicate and is like a white thread that appears before the sun rises on the horizon. Islamic and Western scholars have conducted studies to examine the movements of the sun and then present the early morning dawn theory with the support of scientific data. Therefore, 12 angles of the sun height have been identified around the world. According to King (2004), around the 10th century, Ibnū Yunus used altitude 19o as early morning dawn. Then, around the middle of the 11th century, Ibn Mu'ādh suggested that the beginning of the early morning dawn was at the parameters of the sun 18o.

Setting early morning dawn is said to be difficult compared to the time of Zuhr, Asar, and Maghrib. This is due to the factor that when the sun has set, the shadows are no longer visible. For example, according to King (2004), in Morocco, the dawn call is called before the dawn of ādiq. While in Turkey, Muslims began fasting 40 minutes earlier than they should have. Abdulkader (2015) subsequently carried out 12 early morning dawn observations throughout 2009/2010. The results suggest using the parameters of the sun 18o on the Eastern horizon. Semeida and Hasaan (2018) conducted a total of 38 observations of dawn time in Wadi Al Natron, Egypt (30 ° 30 U, 30 ° 09 T) from 2014 to 2015. The results show that the sun's altitude for dawn time is on position 14.57°. This shows the value that the altitude obtained differs from the current altitude used in Egypt, which is 19.5°. Tono (2019) has polled 220 data to determine early morning dawn throughout Indonesia. He concluded that the early morning dawn occurring at the depression angle of the sun on average was at -13.2o. The results clearly show that the early morning dawn in Southeast Asian countries is around 54 minutes.

In Malaysia, several studies on early morning dawn determination were carried out. The results showed that the parameters of the 20o sun positions used now are not in line with the study results. Next, comparison between sky brightening data in various parts of Malaysia with data obtained by the Department of Islamic Development Malaysia (JAKIM) were done. The results showed no significant difference between the data collected and the JAKIM prayer time data. Next, identification of the height of the sun below the horizon at the beginning of early morning dawn through changes in the value of sky brightness were conducted to distinguish the dawn of kazib and the dawn of sadiq.

The results of the study conducted by Shariff et.al (2011), Shariff et. al (2012), Nor and Zainuddin, (2012) and Raihana et al. (2016) found that early morning dawn began when the average sun height was at -18o 38' 20.3" ± 0.1 for the direction of SQM-LU 10, -18o 29' 18.6" ± 0.1 for the direction of SQM-LU 30o and -18o 06' 47" ± 0.1 for SQM-LU 50o. This value is different from the parameter value used in Malaysia i.e., 20o. The value of the brightness of the sky at the time of the loss of syafaq light is when the continuous level of brightness of the sky is 20.79 ± 0.36 mag/arc2. The value is derived by measuring using SQM-LE in Tanjung Aru, Sabah, East Malaysia (Niri et al., 2012).

Another recent issue related to practice during the early morning dawn in which the 116th National Council for Islamic Religious Affairs of Malaysia meeting received an average value of eight minutes for Fajr prayers (JAKIM, 2019). Seven research papers were presented at dawn prayer times, such as Kassim et al. (2019), which presented a paper on the re-evaluation of dawn prayer time in Nusantara. On 29 November 2019, the Mufti Department of Selangor made an initial announcement regarding the addition of eight minutes to the Fajr prayer in front of other states and it is effective in the state from the date of the announcement. (Aminnuraliff, 2019; Bernama, 2019; Noh, 2019; Sadali, 2019). According to Al-Bakri, (2019), ihtiyati is one of the reasons the average value of eight minutes is suggested in the determination of early morning dawn for dawn prayer. The reason the concept of ihtiyati is applied is to ensure that the prayer time is announced at the appropriate time and within the stipulated time. In addition, the basis for the proposed average value is based on the findings of recent research conducted by Kassim et al. (2019). The findings suggest that the average sun depression angle at dawn is 17.15o below the horizon. Thus, 18o has been proposed for a new average sun depression angle.

Studies on the issue of sun parameters to determine the early morning dawn are not only focused on the height of the sun. However, it is necessary to look at variations in the use of equipment in obtaining sun parameters. Therefore, the analysis of research from several studies still shows that the early morning dawn range for Malaysia is among the altitudes 13o to 18o. Thus, the study of early dawn determination should be continued to obtain a more accurate altitude by emphasizing several other aspects such as light factors, weather factors around the location of observations, techniques and equipment used in observation. This is to ensure that the data collected is accurate and free from pollution. Time adjustments should also be adjusted according to Malaysian Standard Times. In addition, the selection of the use of techniques and equipment is sensitive to the patterns of light changes. This light detection must also be in a position that corresponds to the direction of the sun's rise.

The study will detect and measure the early morning dawn using a combination of the Sky Quality Meter (SQM) and theodolite techniques. Theodolite is a tool that can give the value of the vertical angle more specifically and precisely to detect the sadiq dawn rays.

Morning Twilight

The author such as Nur Nafhatun et. al, (2013) and Tono (2019) reiterates that Isha' occurs when the sun has a certain angle of depression below the horizon that is in the twilight domain which falls easily. Twilight is defined as a period of semi-darkness after sunset or before sunrise during which the sun's zenith distance is more the 90 but less than some agreed number. Another term is dusk which is the time when the light has almost gone, but it is not yet dark. This evening twilight relates to Isha'. Ibn Muadh clarifies, "Twilight is due to the reflection of sunlight falling on vapors that rise from the Earth; the air does not reflect sunlight because of its rarity" (Nur Nafhatun et. al, 2013).

Ibn al-Shatir in King (2004) has described that twilight as a horizon phenomenon which is considered the night time is started by the disappearance of the light of the sun and the disappearance of the star from the night sky. In principle, the twilight phenomenon occurs once the sun sets or rises behind the horizon, there must be some sunlight visible as its' ray propagate in a long distance through the atmosphere. Therefore, twilight occurs due to sunlight hitting the earth's atmosphere and being scattered or its' path is bent as shown in Figure 1. The geometry of twilight allows light to reach us after the sun has dropped below the horizon. After sunset, as the depression of the sun increases, the sky gets darker gradually until no scattered light reaches the observer. The earth's atmosphere reflects and refracts sunlight causing the sun to appear dimmer and become reddened. Whilst the molecules of air scatter the violet, blue and green rays. The number of colourations depends on the air itself or instead on the aerosols or particulate matter suspended in the air.

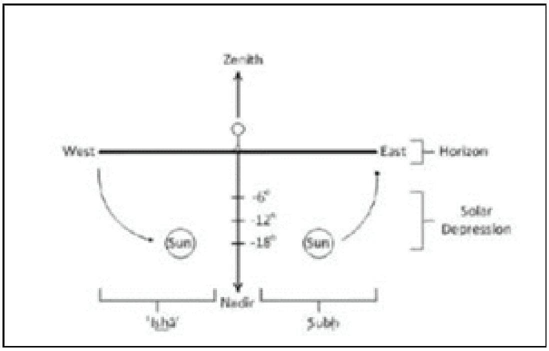


Figure 1: Geometrical of Twilights. Source: King (2004)

The absorption and reddening are caused by the combined effects of true absorption by water vapour, the ozone layer, scattering by atmospheric gases, aerosols, and dust. Reddening is the red light from the sun which penetrates to the eyes; its blue light is lost in producing the blue-sky colouration as shown in Figure 2.

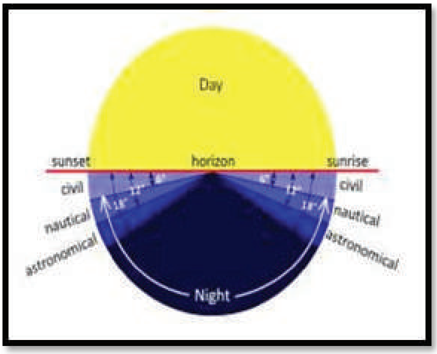


Figure 2: Different Types of Twilight. Source: https://w1.weather.gov/glossary/

Civil Twilight

It happens when centre of the sun is 6 below the horizon. The brightest stars are visible, and the horizon is clearly visible at sea. The purple light begins to fade away. The intensity of the purple light varies very much from one day to another. Apparently mingling with the horizontal stripes, for these are getting brighter and orange-coloured.

Nautical Twilight

This type of twilight occurs whilst the centre of the Sun is more than 6° but less than 12° below the horizon. The horizontal stripes are considerably weakened and are now a faded green.

Astronomical Twilight

It appears while centre of the Sun is more than 12° but less than 18° below horizon and the twilight glow has disappeared. Stars of fifth magnitude are now becoming visible. As explained by Shariff et al., (2013), a serious study of the colours of twilight will provide information concerning the condition of the layers of the atmosphere where cloud was formed and light was scattered. The length of time after sunset can be easily converted into altitude of atmosphere stratum. In the case of Fajr, the moment of sunset can generally be ascertained from the vantage of a minaret and the twilight phenomena are likewise readily observable (King,2004). As for the limitation, Ibn Yūnus limits twilight as the first appearance of the true morning twilight glow and the disappearance of the red twilight glow (Goldstein, 1985).

Modern Practices in Determining Fajrs Prayer Time

There are several early scholars like Ibn Shatir (704-777M), al-Khawārizmī (790-863M), Ibn Yunus (950-1009M) and al-Marrakusi (1256-132M) that contribute plenty within the analysis on sun's apparent motion based on the Qur'an and hadith in determining prayer time and record the prayer time in the form of table (King, 2004). As claimed by Sadali (2011), the timetable format continues to be getting used in the astronomical calculation until now. Fajr prayer time commences at the true morning twilight when the sky begins to lighten up at dawn time and the light scattering spreads laterally on the horizon. Fajr prayer time ends at sunrise.

Equation of Fajr Prayer Time

The prayer times for each location are different and the knowledge of the geographical coordinates of locations is the prerequisite for finding the actual prayer's time. The values of Sun declination as well as the correction factor resulting from the "Equation of Time" owing to the time discrepancy between the apparent solar time and mean solar times are universal and depend on the Julian day number. The declination of the sun (δ) is the angle between the sun's rays and the plane of the equation of the Earth's equator. The angle varies with in the seasons since the angle between the earth's axis and the plane of the Earth's orbit is nearly constant. The period is one year for the Earth to complete its revolution around the sun (Ismaail et al., 2009).

A fajr prayer time prayer starts with the dawn or morning twilight. It will end just before the sunrise. At normal locations, the solah altitude is equal to -18° as used in Malaysia which is also known as morning astronomical twilight. Below are the equations for the calculation of Fajr prayer times.

$$\text{Fajr} = \text{Transit} - ts \qquad (1)$$

From the trigonometry,

$$ts = \cos\text{-}1\ [(\cos Zs - \sin \delta s - \sin \theta) / \cos \delta s \cos \theta)] \qquad (2)$$

where ts represents the angle of the sun at the Fajr, Zs represents the position of zenith at Fajr, ⊠s represents the sun declination at Fajr, Φ represents the latitude at location studies.

It's best to be able to identify the position roughly, then place a window corresponding to the polynomial function that will produce the standard difference (root mean square error - RMSE). The general form of calling a 4-degree polynomial is given in equation (3) below:

$$yi = p1\ ti4 + p2\ ti3 + p3\ ti2 + p4\ ti + p5 \qquad (3)$$

$$yi = p1\ ti4 + p2\ ti3 + p3\ ti2 + p4\ ti + p5$$

Where yi represents observed sky brightness data (physical data) at ti p1, p2, p3, p4, p5 represents a polynomial 4th degree parameter to be estimated, ti represents Time at which SQM data is recorded.

Substituting all the data in the selected window into equation (3) will produce a series of linear functions. Equation (4) shows them in matrix format.

$$\begin{bmatrix} e1 \\ e2 \\ \vdots \\ en \end{bmatrix} + \begin{bmatrix} y1 \\ y2 \\ \vdots \\ yn \end{bmatrix} = \begin{bmatrix} t1^4 & t1^3 & t1^2 & t1^1 & 1 \\ t2^4 & t2^3 & t2^2 & t2^1 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ tn^4 & tn^3 & tn^2 & tn^1 & 1 \end{bmatrix} \begin{bmatrix} p1 \\ p2 \\ \vdots \\ p5 \end{bmatrix} \qquad (4)$$

Where, e represents vector difference, y represents vectors of polynomial parameters are estimated, A represents design matrix and y represents observational value vectors. The squared approach requires that $\sum_{i=1}^{n} e_i^2$ must be minimal. The relatively long derivation will end and in that we will be able to compute the 4th-degree parameter it calls from equation (5).

$$p = (At\ A)\ {-1} - At\ y \qquad (5)$$

The standard difference can be calculated from equation (6).

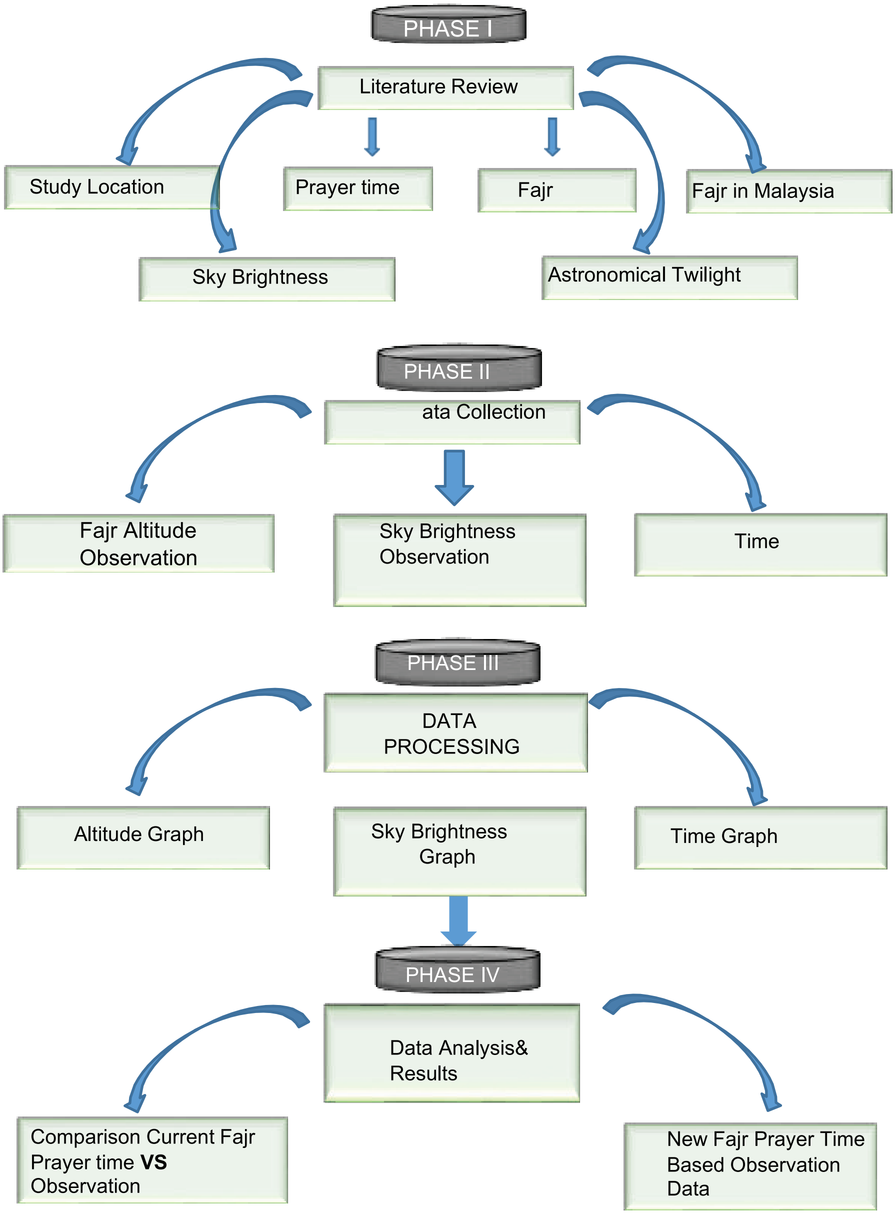
$$RMSE = \left(\sum_{i=1}^{n} \frac{(y_i - \hat{y}_i)^2}{n-u} \right)^{0.5} \qquad (6)$$

Wheres, $\hat{y}_i$ represent sky brightness estimated data (calculated); yi represents sky brightness observation data (original physical data); n represents the amount of data in one window; u represents the number of parameters in a polynomial model.

EQUIPMENT

No.	Equipment	Picture	Description
1.	Theodolite		Used to measure the altitude angle of the brightness of the sky
2.	Sky Quality meter		Used to measure the brightness of the sky
3.	Digital camera		Used to record the state of the sky during research
4.	Watch		Used to record times observation and the sky during research

METHODOLOGY



Sky Brightness Observation

Fieldwork was carried out at Balai Cerap, UTM. The survey was performed from April to May 2021. Observations were made from 4.58 am till 6.30 am in one morning by using Sky Quality Meter. The SQM-LU is very simple to use. The system is designed to measure the brightness of the night sky in magnitudes per square arc second unit. To get the best position for the SQM device, therefore the observer has prepared the instrument namely Topcon Digital Theodolite (Model: Topcon DT-205), as the base station. There are several reasons why SQM-L is established at the "base"; a) the optical drop ensures the theodolite is placed almost vertically above the survey point, b) the internal bubble level ensures the device is horizontal, and, c) the instrument level is key to success af the survey which can improve accuracy and precision. Since the instrument is flattened to the horizon, SQM-L will be directed directly to the light radiating on the eastern horizon near the position of the rising sun.

As for the SQM-LU, it will automatically activate the detector and then wait for a few seconds to obtain a reading. Under urban skies, reading will be displayed almost immediately meanwhile, under the sky darkest conditions (no moon in the sky, far from civilization), the meter may take up to a minute to complete its measurement. The observer must ensure that SQM-LU maintains the meter's orientation until the reading is displayed. The SQM-LU's reading is indicative of the sky brightness within its field of view. There must be no direct illumination or shading of the sensor by a terrestrial light source. The sky brightness value was observed using SQM-LU device and recorded directly into the PC. The observation was carried out at Balai Cerap UTM as shown in Figure 5.

Figure 5: The theodolite was attached on of the pillar at Balai Cerap UTM

RESULT AND DISCUSSION

The results obtained for each data are presented in this section. Table 1 shows the information on the morning twilight and the official time of Fajr. The data for the official time of Fajr was obtained from JAKIM. The data for sky brightness readings and altitude of sun's readings for each day of observation can also be seen on that table. This data has been taken at Balai Cerap, UTM from 27 April 2021 until 29 April 2021. All the observations were in good sky condition, even though there was some cloud movement and light pollution that might influence the results. Graphically the result in April is shown in Figure 6, 7 and 8. Based on Table 1 and Figure 6, SQM value for 27 April 2021 is 16.15 mag/ arcsec2 with the Altitude of Sun is -13o 46' 12" at 06:10 am compared to the official Fajr time whereby the SQM value is 16.17 mag/ arcsec2 with the Altitude of Sun is -17o 49' 12" at 5:48 am. Next the SQM value for 28 April 2021 as shown in Table 1 and Figure 7 is 16.18 mag/ arcsec2 with the Altitude of Sun is -13o 42' 00" at 06:10 am compared to the official Fajr time whereby the SQM value is 16.18 mag/ arcsec2 with the Altitude of Sun is -17o 44' 53" at 5:48 am. Followed by Table 1 and Figure 8 on 29 April 2021 the SQM value is 16.11 mag/ arcsec2 with the Altitude of Sun is -13o 37' 12" at 06:10 am compared to the official Fajr time whereby the SQM value is 16.16 mag/ arcsec2 with the Altitude of Sun is -17o 55' 09" at 5:47 am.

Table 1 The results of the morning twilight in April

Date	Morning Twilight (The end of AstronomicalTwilight)		Official time of Fajr	
27 April 2021	6:10		5:48	
	SQM (mag/arcsec^2)	**Altitude of Sun**	**SQM (mag/arcsec^2)**	**Altitude of Sun**
	16.15	-13° 46' 12"	16.17	-17° 49' 12"
28 April 2021	6:10		5:48	
	SQM (mag/arcsec^2)	**Altitude of Sun**	**SQM (mag/arcsec^2)**	**Altitude of Sun**
	16.18	-13° 42' 00"	16.18	-17° 44' 53"
29 April 2021	6:10		5:47	
	SQM (mag/arcsec^2)	**Altitude of Sun**	**SQM (mag/arcsec^2)**	**Altitude of Sun**
	16.11	-13° 37' 12"	16.16	-17° 55' 09"

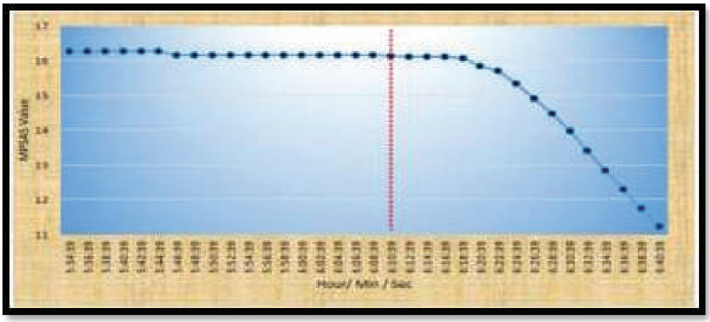


Figure 6 SQM values at Balai Cerap, UTM on 27 April 2021

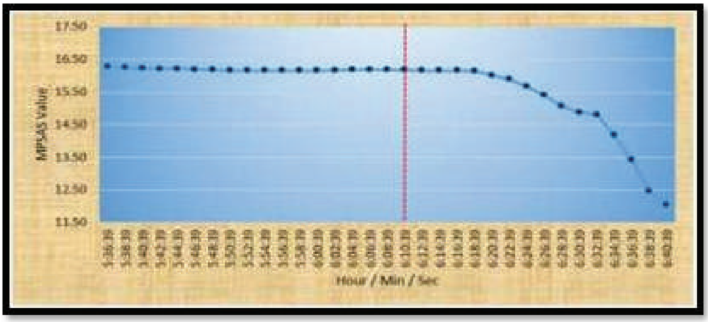


Figure 7 SQM values at Balai Cerap, UTM on 28 April 2021

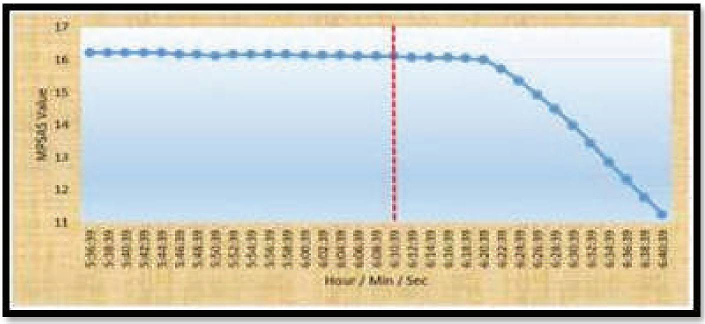


Figure 8 SQM values at Balai Cerap, UTM on 29 April 2021

Based on the results obtained, there is a difference of 20 minutes between the prayer time observed and the prayer time issued by JAKIM. The difference is because of the sun depression angle that has been used for the prayer time calculation.

From the observation, it was found that the sun depression angle from the observation is an average of -13.77o compared to -18o that has been issued by JAKIM. The result shows that the dawn time just occurs when the sun depression angle is -13.77o, and it is indicated that the dawn time is only 54 minutes. Therefore, an advanced study needs to be carried out at the exact location and other suitable locations to prove the differences in sun depression value. The difference may also be due to light pollution, which affects the SQM sensor reading during the observations. In addition, it may be due to the targeted observation east direction which is not at the exact location of the sunrise. Is justified using the smartphone compass rather than using the direction from the sun observation method. In this case, it will also affect the reading value because the value of the compass magnitude is constantly changing and not fixed. Therefore, in the future, it is necessary for the observance to consider all the things that could result in a difference in the observations at dawn.

CONCLUSION

Based on the analysis that has been made, the conclusion that can be made is to advance qualitative and quantitative understanding of sky brightness at dawn for morning twilight or fajr stages. It was found that there are strong relationships between the sun's position below the horizon the beginning of Fajr prayer time. From the evidence, SQM can assist in the process of determining the beginning of Fajr prayer time. Furthermore, SQM gives the numerical result (which has to be analysed), so this makes SQM more precise. At this point, the author can conclude that the SQM approach proved to be suitable for determining prayer times. The author proposed it is plausible that the value of the morning twilight angle is fluctuating for Fajr according to what is given by the instruments.

ACKNOWLEDGEMENT

The authors would like to express their deepest appreciation and gratitude to the Ministry of Education Malaysia and Universiti Teknologi Malaysia for the support and provision given to conduct this study under the Research University Grant Fund (GUP) (No. Vot: Q.J130000.2527.19H35).

REFERENCES

Abdul Kader M.Abed, (2015). Determining the beginning of the true dawn (al-Fajer al-Sadek) observationally by the naked eye in Jordan. *Jordan Journal of Islamic Studies, 11* (2), 2-12.

Al-Bakri, Z. M. (2019). *Bayan Linnas Khas: isu tambahan waktu 8 minit bagi permulaan azan subuh dan hukum solat subuh sebelum masuk waktu.* Diperoleh daripada http://muftiwp.gov.my

Aminnuraliff, M. (2019, November 29). *Kenapa solat Subuh di Selangor lewat 8 minit?*

Sinar Harian. Diperoleh daripada from https://www.sinarharian.com.my

Bernama. (2019, November 28). *Tambahan 8 minit waktu Subuh di seluruh Selangor mulai esok.* Astro Awani. Diperoleh daripada from https://www.astroawani.com

Goldstein, B.R. (1985). *Theory and observation in ancient and medieval astronomy.* London: Variorum Reprints.

Ismaail, Z., Yahaya, N., Kaspin, R., Sanip, Z., Husmin, E., Zaini, N. F. M. and Bakar, F. A. (2009). Computational calculations of Islamic prayer times: Issues and solutions. *Proceedings - 2009 International Conference on Future Computer and Communication, ICFCC 2009, pp. 301–305.*

JAKIM. (2019). Tambahan 8 minit bagi permulaan waktu solat subuh. *Dalam Muzakarah Majlis Kebangsaan Bagi Hal Ehwal Ugama Islam Malaysia Kali Ke-116, 20-21 November.*

Kassim Bahali, Abdul Latif Samian, Nazri Muslim & Nurul Shazana Abdul Hamid. (2019). Re-evaluation of Calculation of the Dawn Prayer Time in the Malay World. *International Journal of the Malay World and Civilization, 7(*2), 37-48.

King, D. A. (2004). *The call of the Muezzin: Studies in astronomical timekeeping and instrumentation* Dalam Medieval Islamic Civilization:(studies I-IX). Leiden: E.J. Brill.

Niri, M. A., Zainuddin, M. Z., Man, S., Nawawi, M. S. A. M., Wahab, R. A., Ismail, K. & Lokman, M. A. A. (2012). Astronomical determinations for the beginning prayer time of Isha. *Middle-East Journal of Scientific Research,12*(1), 101-107.

Nizam, N. K., Nawawi, M. S. A. M. and Man, S. (2018). Kaedah penentuan waktu solat di Malaysia: Satu Sorotan literatur. *Dalam Penyelidikan Serantau Islam dan Alam Melayu: Pendidikan, Kewangan, Kehartaan, Kenegaraan dan Isu Kontemporari.* Kuala Lumpur: Akademi Pengajian Islam Universiti Malaya, pp. 202–215.

Noh, N. C. (2019, November 28). *Waktu Subuh di Selangor lewat 8 minit bermula esok.* Berita Harian Online. Diperoleh daripada from https://www.bharian.com.my/

Noor, U. M. M. (2020). *Al-Kafi #1638: Pasca perubahan waktu subuh; Adakah waktu syuruk dan imsak berubah?* Diperoleh daripada from https://muftiwp.gov.my

Nor, S. A. M., & Zainuddin, M. Z. (2012). Sky brightness for determination of Fajr and Isha prayer by using sky quality meter. *Muslim World, 15,* 15-30.

Nur Nafhatun. (2013). Background theory of twilight in Isha and Subh prayer times, ed. Saadan Man, Mohd dalam *Dimensi Penyelidikan Astronomi Islam.* Saiful Anwar Mohd Nawawi, Raihana Abdul Wahab & Nurul Huda Ahmad Zaki. Kuala Lumpur: Jabatan Fiqh dan Usul, Akademi Pengajian Islam, Universiti Malaya, pp 25.

Raihana, A., Hazwan, M. M. & Norihan, K. (2016). Issues on determination of-accurate Fajr and Dhuha prayer times according to Fiqh and Astronomical Perspectives in Malaysia. *Dalam Conference Proceeding, Bali Indonesia Oct 13- 14, 2016,18 (10)5, pp. 675–680.*

Sadali, H. M. (2011). *Kajian penetapan takwim Solat Pulau Pinang menurut Ilmu Falak.* Universiti Sains Malaysia.

Sadali, H. M. (2019). *Taudhih Alahkam. Tajuk: Penjelasan Tambahan Waktu Subuh 8 Minit.* (video file). Diperoleh daripada https://www.youtube.com/watch?v= cwSDm_tMOW4&ab_ channel=JabatanMuftiNegeriSelangor

Semeida M.A. & Hassan A. H. (2018). Pseudo dawn and true dawn observations by naked eye in Egypt. *Journal of Basic and Applied Sciences, 7*(2018), 287.

Shariff, N. N. M., Muhammad, A., Zainuddin, M. Z., Hamidi, Z. S., & Ibrahim, Z. A. (2011). Investigation of Twilight Using Sky Quality Meter for Isha' Prayer Time. *7th Mathematic and Physical Science Graduate Conference 2011. National Universiti of Singapore. Singapore*

Shariff, N. N. M., Muhammad, A., Zainuddin, M. Z., & Hamidi, Z. S. (2012). The Application of Sky Quality Meter at Twilight for Islamic Prayer Time. *International Journal of Applied Physics and Mathematics, 2*(3), 143.

Tono Saksono. (2019). *Awal Subuh di Indonesia. Seminar Falak Kontemporari Peringkat Kebangsaan 2019.* Dewan Besar Pusat Islam Iskandar, Johor Bahru, Malaysia, Julai 3, 2019.

Unihedron (2012, April 2). *Sky Quality Meter.* Diperoleh daripada http://www.unihedron.com/projects/sqm-l/