A STUDY OF FAJR AND ISHA PRAYER TIMES AT HIGH LATITUDE REGIONS BETWEEN 48° TO 67°

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ABSTRACT

Study of prayer times was done at selected high latitude regions. Research is focusing on the night prayer times which is Subh and Isha Prayer times. Study included selected cities locate at 48°N until 67°N latitude. Studies is to ensure the existing way to determine the prayer times at high latitude regions (higher than 48°) can be adopted or need to be adjusted to the alternative way. Thus the existence alternative ways which are nearest latitude, nearest day, middle of night and seventh part of night been discuss in physic perspective. Research is focusing on the standardizing the alternative way. Research covers the perspective of physic (astronomical view) which explains that abnormality in these regions by focusing in the sun‟s altitude. The method used in this research is by using prayer time software Accurate Times and astronomical software which is The Sky Sixth. The used of this software is to simulate prayer time and simulate the sun path. The sun altitude pattern then is analyzed to see the effect of the latitude to the starting of the astronomical twilight and starting of Subh and Isha prayer times.

Research finding shows that for cities locate at 48°N until 51°N still could determine starting of Fajr and Isha prayer times by using Accurate Time software. For cities locate above than 51°N until 65° latitude where prayer times undetermined by compute the software thus need to be calculate by alternative way. Research found that by dividing the night by two gives the prayer time start late but gives the more time for the sun to go deeper below horizon where it is most fitted the requirement of fiqh. The changing pattern in the sun‟s altitude will shift the times of prayer.

ABSTRAK

Kajian waktu solat telah dilakukan di kawasan-kawasan latitud tinggi terpilih. Penyelidikan menumpukan pada waktu solat malam iaini Subuh dan Isyak. Kajian telah memilih beberapa bandar yang terletak pada 48 °U hingga 67 °U latitud. Kajian dilakukan adalah untuk memastikan cara yang sedia ada untuk menentukan waktu solat di kawasan latitud tinggi (lebih tinggi daripada 48 °) boleh diguna pakai atau perlu disesuaikan dengan cara alternatif. Justeru itu perbincangan ke atas cara alternatif dalam aspek fizik ini telah dilakukan termasuk penggunaan waktu solat di latitud berhampiran, penggunaan waktu solat di hari berhampiran, pembahagian malam kepada separuh malam dan pembahagian malam kepada tujuh bahagian. Satu garis panduan harus ditentukan dalam menentukan cara alternatif yang sedia ada. Kajian meliputi dari sudut fizik (pandangan astronomi) bagi kawasan-kawasan yang mengalami keadaan tidak normal ini dengan memberi tumpuan dalam ciri ketinggian matahari. Perubahan corak dalam ketinggian matahari berubah mengikut latitud. Kaedah yang digunakan dalam kajian ini adalah dengan menggunakan perisian waktu solat iaitu Accurate Times dan perisian astronomi yang The Sky Sixth. Tujuan digunakan perisian ini adalah untuk mensimulasikan waktu solat dan simulasi pergerakan matahari. Perubahan ketinggian matahari kemudian dianalisis untuk melihat kesan latitud kepada permulaan senja astronomi dan permulaan dan Subuh Isyak waktu solat.

Dapatan kajian menunjukkan bahawa untuk bandar-bandar pada garis lintang 48 ° U hingga 51 ° U masih boleh menentukan permulaan Subuh dan Isyak dengan menggunakan Accurate Times. Untuk bandar-bandar di atas daripada 51 ° U hingga 65 ° latitud di mana waktu solat tidak dapat ditentukan dengan menggunakan perisian itu perlu mengira dengan cara alternatif. Penyelidikan mendapati bahawa dengan membahagikan malam itu dengan dua bahagian akan menghasilkan masa solat bermula

lewat tetapi memberikan lebih banyak masa untuk matahari untuk pergi lebih rendah di bawah garis ufuk di mana ia memenuhi fiqah.

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List of Symbols and Abbreviations

δ	:	Delta
$^\circ$	:	Degree sign
λ	:	lamda
ϕ	:	phi
θ	:	theta
α	:	alpha
$\pm$	:	plus minus sign
sin	:	sin function
cos	:	cos function
tan	:	tan function
Sin^{-1}	:	Sin inverse function
Cos^{-1}	:	Cos inverse function

CHAPTER 1

1.0 Introduction

For Muslims, it is obligatory to perform prayers five times per day. Five times prayers are known as Subh (Fajr prayer), Zuhr (Midday prayer), Asr (Evening prayer), Maghreb (Sunset prayer) and Isha (Night prayer). Fajr prayer is the prayer that must be performed when the sky begins to lighten, sometime before the sun itself appears. Zuhr prayer is performed when the sun appears in its highest position in the sky during its journey from sunrise to sunset. There are two opinions that define Zuhr prayer which are Shia and Sunni. In Shia opinion, Zuhr prayer starts once the sun has crossed the celestial meridian called true noon. This is when the sun is at the highest point in the sky. The difference in Sunni opinion is that when the sun is transit after reach its highest point.

Meanwhile, Asr prayer is also defined differently by the two main Islamic sects. According to Sunni point of view, Asr prayer begins when the length of any object‟s shadow equals the length or twice the length of the object itself plus the length of that object‟s shadow at noon. In Shia, there is a different point of view for determining the Asr prayer time. The Asr prayer begins when the Zuhr prayer has been recited.

Maghrib prayer is performed when the redness in the eastern sky appears after sunset has passed over the head. Sunset is defined as the disappearance of the sun below the horizon. Lastly, Isha prayer is the time at which darkness falls and there is no scattered light in the sky. Determinations of Isha differ upon several opinions. The differences are based on the angle such as in the table 1.0 below. However, this research focus upon the method determination of each prayer times according to the Sunni perspective.

Table 1.0: Solar depression angle for the beginning of Fajr and Isha according to the various conventions

Convention	**Fajr (beginning of morning twilight)**	**Isha (ending of evening twilight)**
Shia Ithna Ashari (Jaafari)	16	14
Islamic Society of North America(ISNA)	15	15
Muslim World League (MWL)	18	17
Umm al-Qura, Makkah	18.5	90 mins after maghrib
Egyptian General Authority of Survey	19.5	17.5
University of Islamic Sciences, Karachi	18	18
Malaysia	20	18

The above table is representing the twilight angle upon Isha and Fajr prayer times. It differs depending on the different opinion and jurisprudence. This angle is the sun position below the horizon after dusk and before dawn occurs. Some of the studies have used different terminology which can represent it in solar depression angle to determine starting of these two prayer times. According to Niri [1]“*Most of previous studies have used the measurement of solar depression angle to explain the disappearance of shafaq*”. Shafaq means the redness in the sky at evening twilight.

[1] M.A Niri. Astronomical Determinations for the Beginning Prayer Times of Isha". Middele-East Journal of Scientific Research 12(1):101-107,2012.

To calculate the prayer times for the regions that included in the study, some of the parameters needed are latitude (ϕ), local time zone, the longitude (λ) of the location studies, equation of time (EqT) and declination of the sun (δ). The equation of time is the difference between time as read from a sundial and a clock. While the declination of the sun represents the angle between the rays of the sun and the plane of the equator.

Zuhr time can be obtained through the calculation below:

Zuhr=12+Time Zone-$\frac{\lambda}{15} - \frac{EqT}{60}$

Asr time can be obtained by using the following equation:

Asr(k)=$\frac{1}{15}\cos^{-1}[\sin[\cos^{-1}(k+\tan(\lambda-\delta)) - \frac{\sin\lambda\sin\delta}{\cos\lambda\cos\delta}]]$

From the Asr equation, k represents the times of the length of the object. As mentioned in the definition of the Asr time above, there are two opinions on how to calculate it. The majority of the schools say it is at the time when the length of the object‟s shadow equals the length of the object itself plus the length of the object‟s shadow at noon. Only the Hanafi school of thought defined it as the length of any object‟s shadow is twice the length of the object plus the length of the object‟s shadow at noon. Thus the Asr time could be determined as in below equation:

Standard thought;

Asr=Zuhr+A(1)

When substitute the k is equal to 1

Hanafi‟s thought;

Asr= Zuhr+A(2)

When substitute the k is equal to 2

While Maghreb time can be obtained by considering two points of view which are Sunni‟s and Ja‟‟fary‟s (Shia). For Sunni, Maghreb is equal to sunset where the prayer time begins once the sun has completely set beneath the horizon while for Shia, it begins when the redness in the eastern sky passes overhead by assumed a twilight angle as equal to four.

The equation below is how to get the beginning time for Maghreb from the opinion in Shia.

Maghreb=Zuhr+T(4)

Where T is represented as the twilight angle.

In the regions of higher latitude, twilight may persist throughout the night during some months of the year. To overcome this abnormal period in determination of Isha and Fajr prayer times, some modifications are needed on the formulas mentioned. In this study, the proposed solutions are by calculating the period of day and night for regions that include in the abnormality. The period from sunset to sunrise is divided into two halves. The first half will be considered as day and the other half will be night. Fajr and Isha in this method are assumed to be at the midnight during this abnormal period.

In Muslim countries, the prayer times will usually be announced through Athan that comes from mosque nearby. Unfortunately, in Non-Muslim countries, there is no call for Athan coming from the mosque. Thus, Muslims who live in such countries need the prayer time table to alert themselves for the prayer times. It is common for those Muslims who live in regions of higher latitude use the prayer time table of the nearby cities which are situated at the normal latitude which is below 48°.

Generally, this prayer time table is not precise enough to be used by the residents living in countries located in latitude between 48° and above up to the Arctic Circle. So, this study will come up with an alternative solution to calculate prayer times in these regions by using the software that needs some modification which is explained further in the methodology.

1.1 Problem statements

Previous studies have proved that there is no standard and accurate method to determine prayer times at high latitude areas (latitude higher than 48°). Thus, this research is to improve the prayer times table that have less disadvantages compared to the existing method. Muslims living in these areas (latitude higher than 48°) have difficulties to perform prayer in precise (fixed) time. [2] „*In some Muslim countries and in most Non-Muslim countries, the above-mentioned tables are just for big and major cities and villages in non-Muslim countries don't have that's. ' (Aghighi, 2008)*. So, the residents living in these areas need to refer to prayer times used by nearby countries. This matter will lead to late performing of the prayers by Muslims living in these areas.

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[2] Aghighi, H. & Alimohammadi, A. & Ghahareh, M.S. 2008. Prayer Times Modeling With GIS: A Case Study for Iran and Its Surrounding. *Journal of Computer Science 4 (10):* 807-814.

It absolutely contradicts the Muslims" belief where it is stated in Holy Quran (4:103) to perform the prayer on stated times (precise). Allah most High says: Then there succeeded them a generation which neglected prayers and followed lusts. They will meet with destruction (Ghayy), except the one who repents and believes and acts righteously. (Quran 19:59-60) And Ibn Abbas (RAA) explained that it does not mean that they completely abandoned prayers, but that they delayed them to the end of their prescribed times.

1.2 Significance of study

The importance of this research is to provide scientific documentation on the most appropriate method to determine the prayer times in areas having the latitude higher than 48°. Abnormality occurs in the regions which are beyond the 48°. The duration of the night and day is not equal. It occurs during winter and summer seasons where day time is longer during summer and the night time is longer than the day time during the winter. In the astronomical terminology, it can be explained as [3]"*The solstice is an astronomical event that occurs twice each year as the sun reaches its highest or lowest excursion relative to the celestial equator on the celestial sphere. On the day of the solstice, the sun appears to have reached its highest or lowest annual altitude in the sky above the horizon at local solar noon"*. Thus, some modification should be made to standardize the time which is called daylight saving time. This study will lead to improve the knowledge about this abnormality that happens in these regions.

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[3] Philip&Deborah Scherrer. Solstice and Equinox("Suntrack")Model,page3. http://solar-center.stanford.edu/AO/Sun-Track-Model.pdf

Furthermore, the study of twilight is also looked at in this research because the regions situated beyond 48° have different phenomenon of twilight. The definition of dawn and dusk might be different in these regions because in some countries, the twilight might persist throughout the day. The solar elevation is defined differently in these abnormal regions.

Also, the position of the sun is different in these high latitudes regions. This study improves the knowledge of the behavior of the sun altitude throughout the year in these regions as well. Thus, it will give the people who live in these regions to implement this knowledge to make their daily activity easier. This study also approaches an alternative solution to calculate the precise prayer times in the regions having latitude higher than 48°.

1.3 Objectives

The objective of this research is to investigate the effect of the latitude on starting the prayer times. Due to the abnormalities that occur in the regions situated in latitude of 48° and above, research needs to be done to know how this latitude affects the sun altitude for a certain time. This research must be carried out to find out whether the existing way is suitable to determine prayer time for these regions or some modifications need to be applied upon the method and to see which is the most convenient to be used. Thus, the research will focus more on the abnormalities that occur in these regions by focusing on the case of twilight and also the sun motion for the certain period of time when these abnormalities happen.

1.4 Scope/ limitation of study

The limitations of the study cover the countries which are at latitude higher than 48°. The timing of sunrises varies throughout the year, as determined by the viewer's longitude and latitude of the reference. In the summertime, the days get longer and sunrises occur earlier every day until the day of the earliest sunrise, which occurs before the summer solstice. In the Northern Hemisphere, the earliest sunrise does not fall on the summer solstice around June 21, but occurs earlier in June. Sunset is the daily disappearance of the sun below the horizon. The timing of sunsets varies throughout the year, as determined by the viewer's longitude and latitude of the reference.

In the summertime, the days get longer and sunsets occur later every day until the day of latest sunset, which occurs after the summer solstice. In the Northern Hemisphere, the latest sunset does not fall on the summer solstice around June 21, but occurs later in June or in early July. In addition, for some regions, sunset and sunrise are not occurring at all. These regions in which the latitude is higher than 48° will be covered in this study because the full darkness would not occur for some times which lead to the problem in the determination of Fajr and Isha times. But the limit of the research will stop at the 67° latitude. It is because the latitude above this limit will be treated to the same way as in the case in 67° latitude. Phenomenon of no true darkness occurs starting from latitude 66.5° and above. [4] *"This latitude is the Arctic Circle which the sun does not set for one day at summer solstice on 21st June and does not rise for one day at winter solstice on 21st December".*

[4] Paula Messina, Geology 103. „Day and Night in Alaska".

1.5 Methodology

The method that will be used in this research is software computation method. The Accurate Times 5.3 software version is used to calculate the prayer times for a year of this study. Then research will use The Sky Sixth software to implement the time of this prayer time to generate the sun motion for two prayer times which are Fajr and Isha. Then the abnormalities which appear from the data will be analyzed. Later on, the research will be done a comparison method of determining the Isha and Fajr prayer times by using several alternative methods that are proposed to be used in high latitude countries. A few cities have been selected for this purpose. The reason of choosing these cities will be explained in chapter 3. The comparison will be made upon the existing method in determining the prayer times at high latitude regions. Comparison will be made upon these three methods to the reading of prayer time that has been computed by using Accurate Times. These four methods include:

a) Nearest Day
b) Nearest Latitude
c) Middle of the Night
d) Seventh Part of the Night

Comparison should be made to determine which is the most convenient to be used and also which one is most accurate. Then the research also will find out the changing of the sun altitude during the abnormal periods in the selected regions which are used to investigate the effect of the latitude in determining the prayer times.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter discusses the title of the research, previous studied and the parameters that involve in this research. The title of this research is a study of prayer times at selected regions that are higher than 48° latitude. In regions that are higher than 48° latitude, the determination of prayer times differ from countries located in regions that are below 48° latitude. It is because the sun appears at different times in the regions which are higher than 48°latitude. This abnormality will affect the determination of prayer times. The definition of each prayer time in terms of astronomical is discussed in this chapter as well.

2.1 Twilight

Twilight is the time between dawn and sunrise or between sunset and dusk during which sunlight scattered in the upper atmosphere illuminates the lower atmosphere, and the surface of the earth is neither completely lit nor completely dark. Because it is below the horizon, the sun itself is not directly visible.

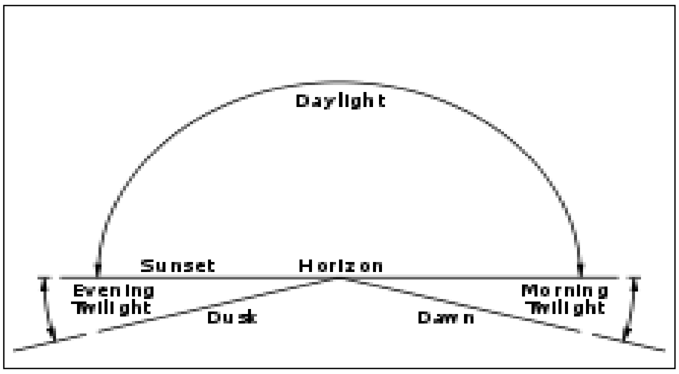

Figure 2.0 Description on twilight

There are three types of twilight which are civil twilight, nautical twilight, and astronomical twilight. Twilight is defined based on the solar elevation which refers to the position of the center of the sun relative to the horizon. Civil twilight is known as the brightest while the astronomical is the darkest. The description of the twilight based on the solar elevation is given in the following table.

Table 2.0 Twilight Angle

Types of twilight	**Solar elevation angle**
Civil twilight	$-6° \leq \theta < 0°$
Nautical twilight	$-12° \leq \theta < -6°$
Astronomical twilight	$-18° \leq \theta < 12°$

2.1.1 Civil Twilight

Civil twilight is roughly equivalent to lighting up time which the brightest star is visible and the horizon is clearly visible at the sea. Morning civil twilight begins when the center of the sun is 6° below the horizon which is known as civil dawn and ends at the sunrise. While the evening civil twilight begins at the sunset and ends when the center of the sun reaches 6° below the horizon which is known as civil dusk. Civil twilight can also be described as the limit at which twilight illumination is sufficient under clear weather conditions where terrestrial objects can be distinguished. At the beginning of morning civil twilight or end of evening civil twilight the horizon is clearly defined and the brightest stars are visible under clear atmospheric conditions.

2.1.2 Nautical Twilight

Nautical twilight is the time when the center of the sun is between 6° and 12° below the horizon. The horizon at the sea ceases to be clearly visible and it is impossible to determine altitudes with reference to the horizon. During nautical twilight, sailors can take reliable star sighting of well-known stars using horizon for reference. The end of this period in the evening or its beginning in the morning is also the time at which traces of illumination near the sunset or sunrise point of the horizon are very difficult if not impossible to discern where this is often being referred to as the first light before civil dawn and nightfall after civil dusk. At the beginning of nautical twilight in the morning known as nautical dawn or at the end of nautical twilight in the evening known as nautical dusk under good atmospheric conditions and it occurs in the absence of other illumination. In this case, the general outlines of ground objects may be distinguishable but detailed outdoor operations are not possible and the horizon is distinct.

2.1.3 Astronomical Twilight

Astronomical twilight is the time when the sun is between 12° and 18° below the horizon. From the beginning of astronomical twilight in the evening to the beginning of astronomical twilight in the morning, the sky is dark enough for all astronomical observation. It is the condition where truly dark and no perceptible twilight remains. Astronomical twilight is when the sun is geometrically 18° below the horizon. It is completely dark when this astronomical twilight ends. It is suitable to start the astronomical observation. According to Goldstein, [5] *"Astronomical twilight is the time from sunset to the disappearance of the twilight glow on the western horizon (and similarly in the morning)"*.

2.1.4 Effect of Latitude on Twilight

At latitude higher than 48°, the length of twilight after sunset and before sunrise is influenced by latitude of the observer. In the Arctic and Antarctic regions, twilight can last for several hours. There is no civil twilight at the poles within a month on either side of the winter solstice. At the poles, civil twilight can be as long as two weeks while at the equator the conditions where day change into night is just takes twenty minutes. This is because at lower latitudes, the sun"s apparent movement is perpendicular to the observer"s horizon. The sun"s disk moves toward the observer"s horizon at a lower angle when one gets closer to the Arctic and Antarctic circles.

In the polar circles, twenty four hour daylight is encountered in summer and in regions very close to the poles, twilight can last for weeks on the winter side of the equinoxes. Meanwhile, at the outside of the polar circles, the angular distance from the polar circle is less than the angle which defines twilight as above. Twilight can continue

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[5] Bernad.R.Goldstein, Ibn Mucadh"s Treatise on Twilight and the Height of Atmosphere, Communicated by A.Aaboe, pg 98.

through local midnight near the summer solstice which is occurring in June at the Northern Hemisphere and December in the Southern Hemisphere. The following diagram can simplify the relation on the latitude and sun height that occurs during equinox and summer solstice.

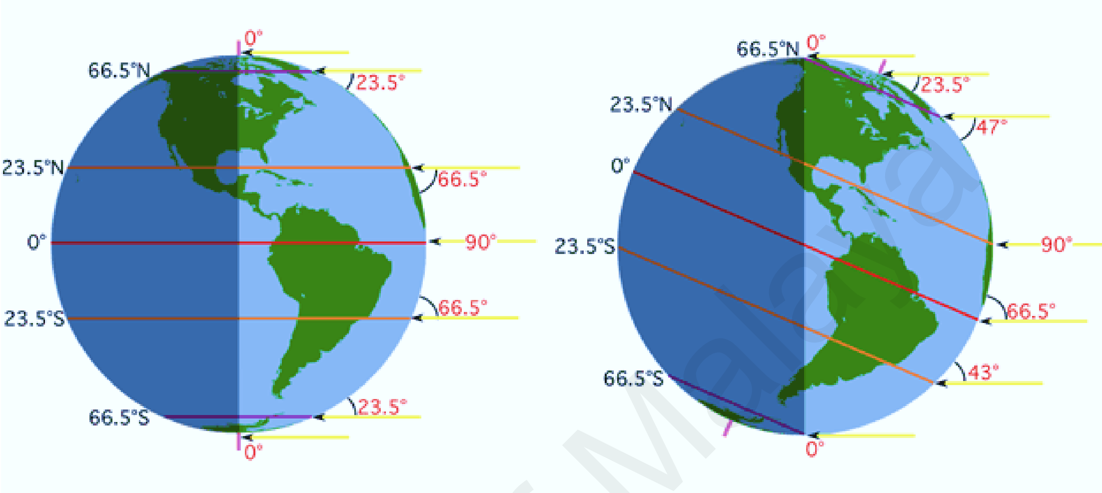

Figure 2.1: Diagram on the Maximum sun rays on Equinox and Summer Solstice.

The above diagram is representing the relationship of the sun height to the latitude for two types of situations which are during equinox and summer solstice. The red numbers on the right of the globe are the maximum solar altitude at solar noon while the blue numbers on the left indicate the location of the Equator, Tropic of Cancer at 23.5°N, Tropic of Capricorn at 23.5°S, Arctic Circle at 66.5°N and Antarctic Circle at 66.5°S.

As seen in the diagram, it is noted how the latitude is effected by the sun height. As the position moves from the equator to the north of the globe, the sun height is declining.

2.2 Prayer Times as In Astronomical View

For Muslims, it is obligatory to perform five prayers throughout the day and night. There are five types of it such as Subh which is also known as Fajr prayer, then Zuhr or Midday prayer, Asr or evening prayer, Maghrib and the last at night is known as Isha or night prayer. According to Hajewaming [6] *"the most of islamic prayer times correspondence with astronomical phenomena such as the time of Zuhr starts when sun passes its zenith, Asr begins when the length of the shadow of a vertical rod is equal to the length of the rod plus its shadow at noon. Maghrib begins immediately after sunset while Isha begins when the sky is completely dark and Subh begins before sunrise".* These all five prayer times can be defined according to the astronomical changing.

According to Alnaser [7], *"the prayer time varies according to the latitude and all depend on the position of the sun"*. As stated in previous paragraphs, twilight may differ according to the latitude which is explained in the twilight part. There are two types of prayer times that are related to the astronomical twilight which are Subh and Isha times. Meanwhile, the daylight prayer times is just referring to the shadow which relates to the sun appearing. The definitions of each prayer times are given below.

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[6] Hajewaming, N. 2002. Astronomucal Calculation of Islamic Times and Qilat Direction. 33rd Congress on Science and Technology of Thailand. Available online: http://repo.unnes.ac.id/dokumen/astrodb/pdf/astroomical-calculation.pdf. 1-6.

[7] Alnaser, WE & Alnaser, NW. 2009. The Solar Connection in the Muslim Community. ISESCO Science and Technology Vision Vol 5 (7): 41-44.

2.2.1 Subh Prayer

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

Fajr= Transit-t_s (1)

From the trigonometry,

$$t_s = cos^{-1}\left[\frac{cosZs-sin\delta s-sin\Phi}{cos\delta scos\Phi}\right] \quad (2)$$

t_s represents the angle of the sun at the Fajr .

Z_s represents the position of zenith at Fajr.

δ_s represents the sun declination at Fajr.

Φ represents the latitude at location studies.

2.2.2 Zuhr Prayer

The beginning of Zuhr prayer time is when the sun passes the Meridian and moves to the west. The following diagram shows the position of the sun slip to the west.

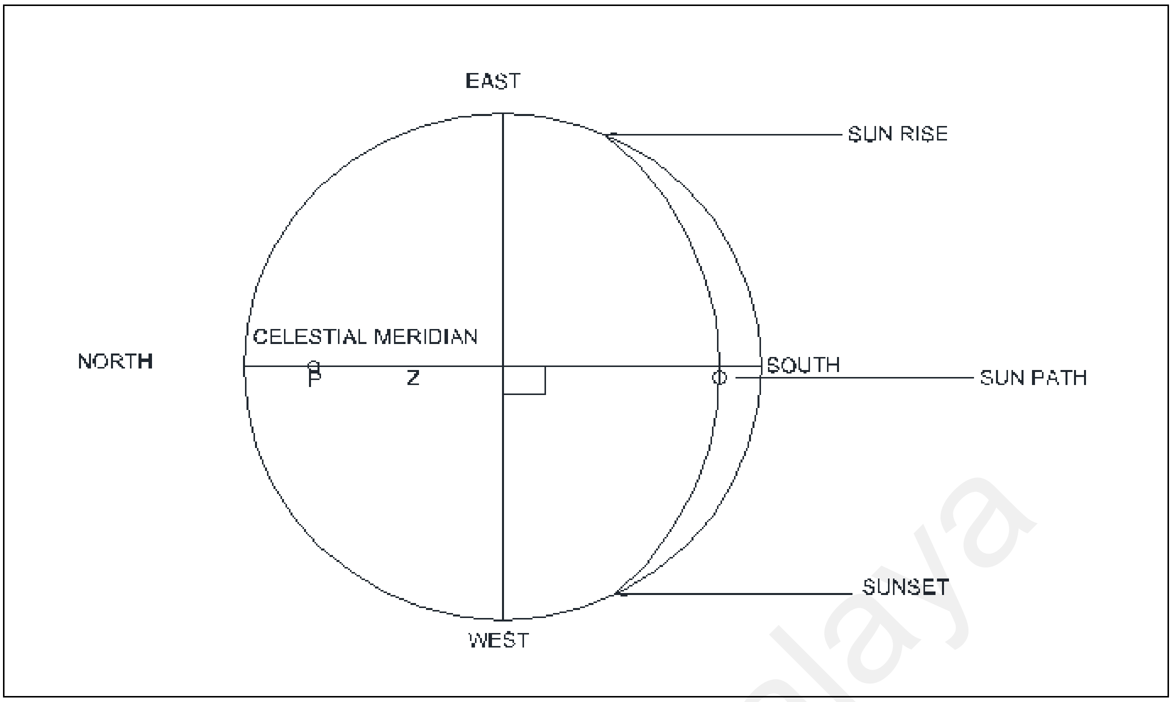

Figure 2.2: Diagram of the sun position slip to the west.

Transit occurs when the center geometric of the sun is at the Local Meridian. Thus the formula for Zuhr prayer time is as below:

$$\text{Zuhr prayer time} = \text{Transit} + t_{sd} \quad (3)$$

t_{sd} represents the time taken by the sun which passes through the Local Celestial Meridian. The duration of the time taken is 1min and 4sec. The diagram below shows the side view of the sun passing the Meridian.

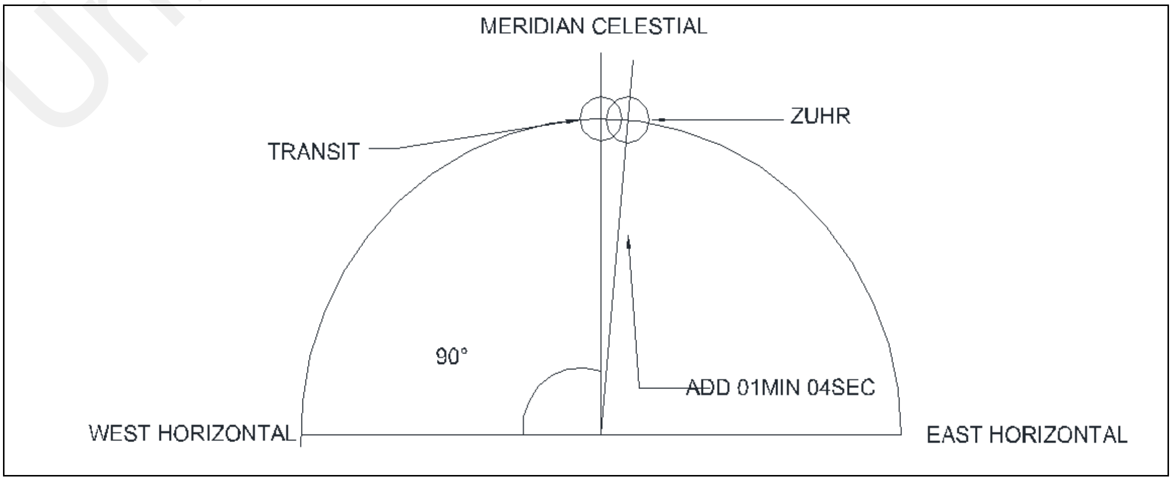

Figure 2.3: Position of the sun slip and transit

2.2.3 Asr Prayer Time

Asr prayer time begins when the length of any object‟s shadow equals the object itself plus the length of that object‟s shadow at noon. Diagram 2.2 explained the object‟s length as mentioned above.

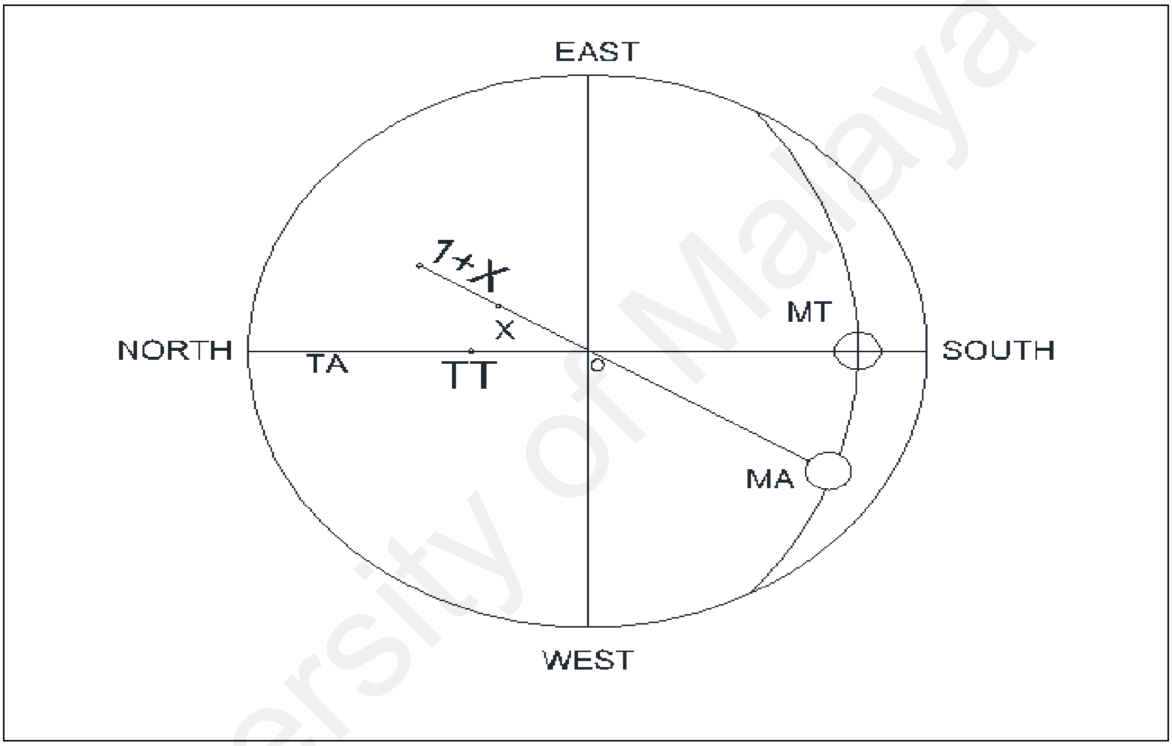

Figure 2.4: Diagram of the sun during transit and zenith

The diagram above shows the length of the shadow when the sun at the transit which is M_t is OT_t= X and let‟s say the length of the object is 1 unit. When the length of the shadow is (1+X) unit, the location of the sun is at M_t. This is when the Asr prayer time begins. The diagram below shows the view of the observer from the west.

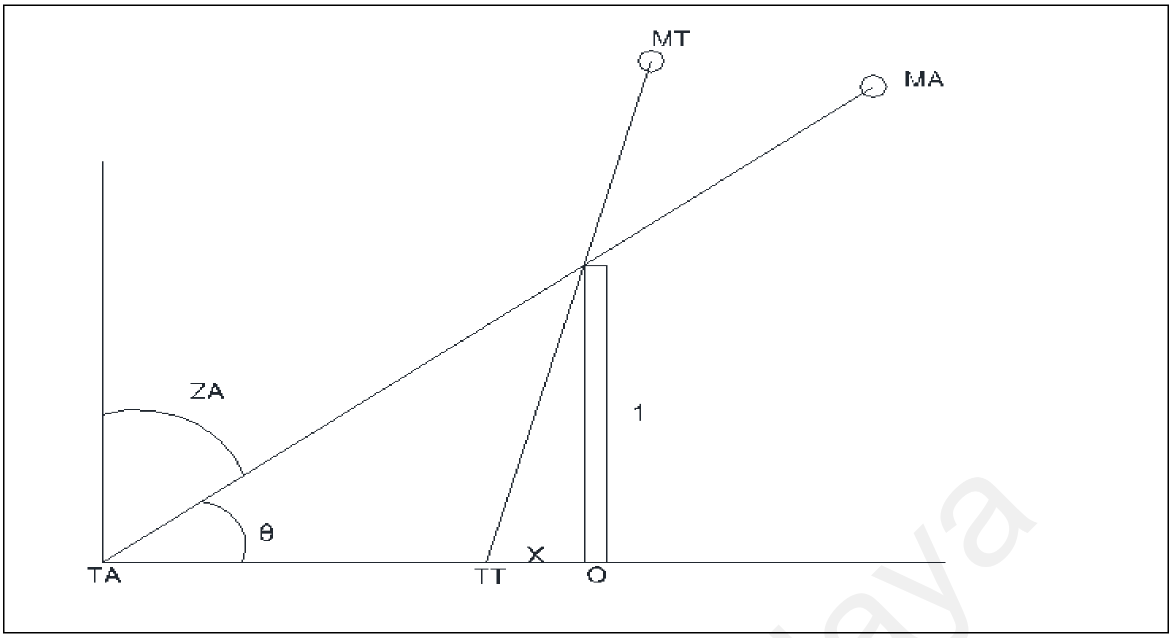

Figure 2.5: Diagram of the shadow when Asr prayer begins

Thus the calculation is as shown below:

$$\text{Tan } \theta = \frac{1}{1+X} \qquad (4)$$

Where θ is the altitude of the sun, Asr prayer begins.

And X is the length of the shadow during transit.

2.2.4 Length of the Shadow at the Sun Transit, X

Figure 2.6 shows the position of the sun during transit from the view of observer at the west.

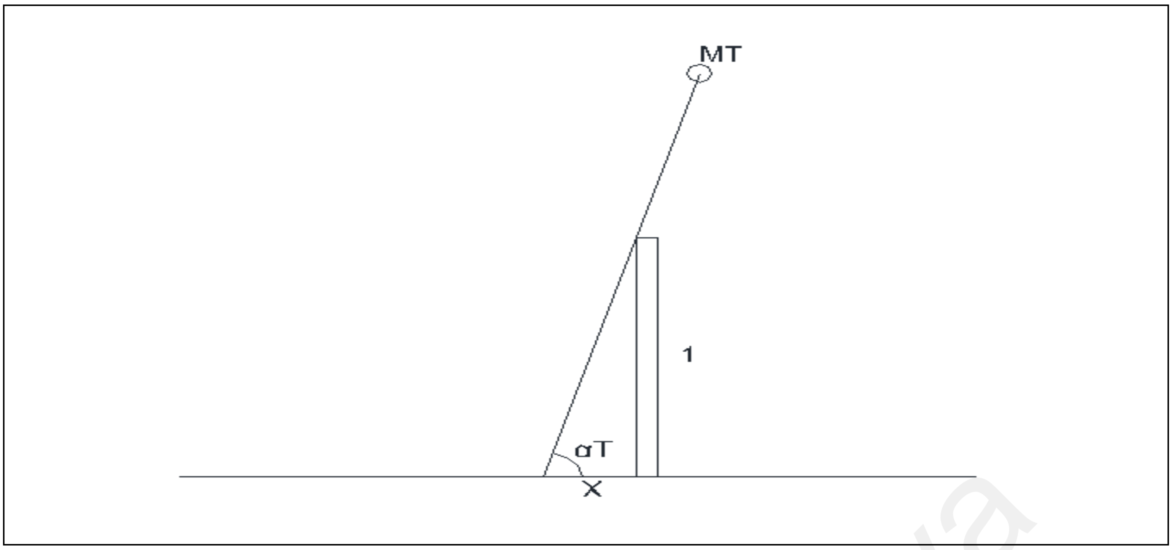

Figure 2.6: Length of the shadow during the sun's transit,X

The above diagram shows that:

$\tan \alpha_T = 1/X$ (5)

Where α_T is the altitude of the sun during transit

The relation between the sun"s positions during transit with the position of the observer at the earth is shown in diagram 2.7.

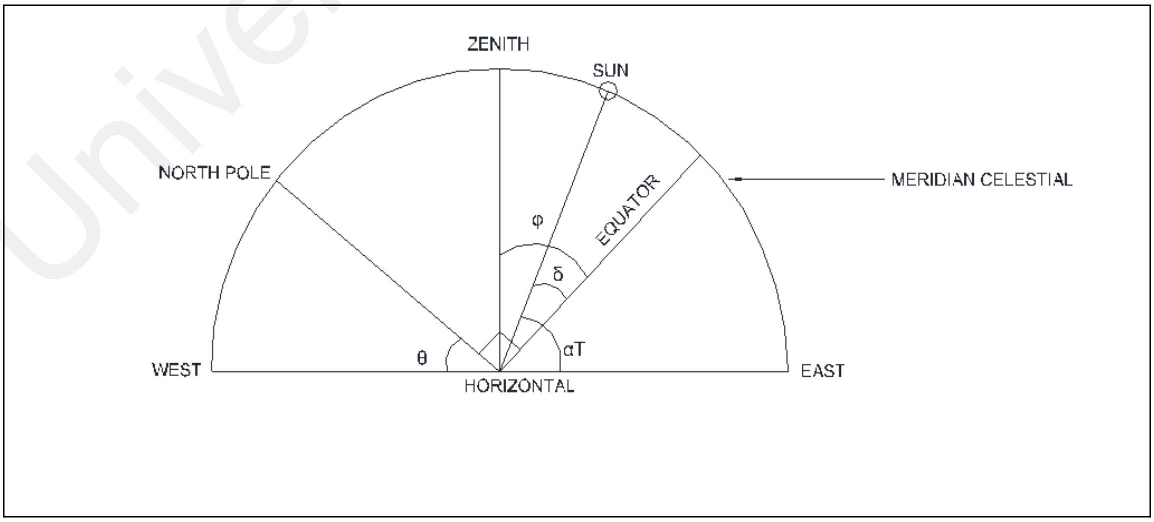

Figure 2.7: Position of the observer at O in the System Sphere Celestial.

From the 2.7 diagram:

$$\alpha_T = 90-(\varphi-\delta) \qquad (6)$$

From the equation number one and two:

$$X = 1/ \tan (90-(\varphi-\delta) \qquad (7)$$

Thus:

$$\Phi = \tan^{-1} [1/(1+\tan(\varphi-\delta))] \qquad (8)$$

By substituting the $\varphi = 90-Z_A$, where Z_A is the distance of zenith (complement angle to the altitude) from the 2.4 diagram:

$$Z_A = \tan^{-1} [1 + \tan (\varphi-\delta)] \qquad (9)$$

The value of $(\varphi-\delta)$ is changing depending on the position, thus it must always be in positive. Thus,

$$Z_A = \tan^{-1} [1 + \tan | (\varphi-\delta)|] \qquad (10)$$

From the equation in (6), shown that the value of the zenith change with the different location along the year depends on the sun declination,(δ) which can be found in Almanac.

2.2.5 Angle of sun at Asr Prayer Time

This section discusses about the relation between the sun altitudes and the determination of Asr Prayer time itself.

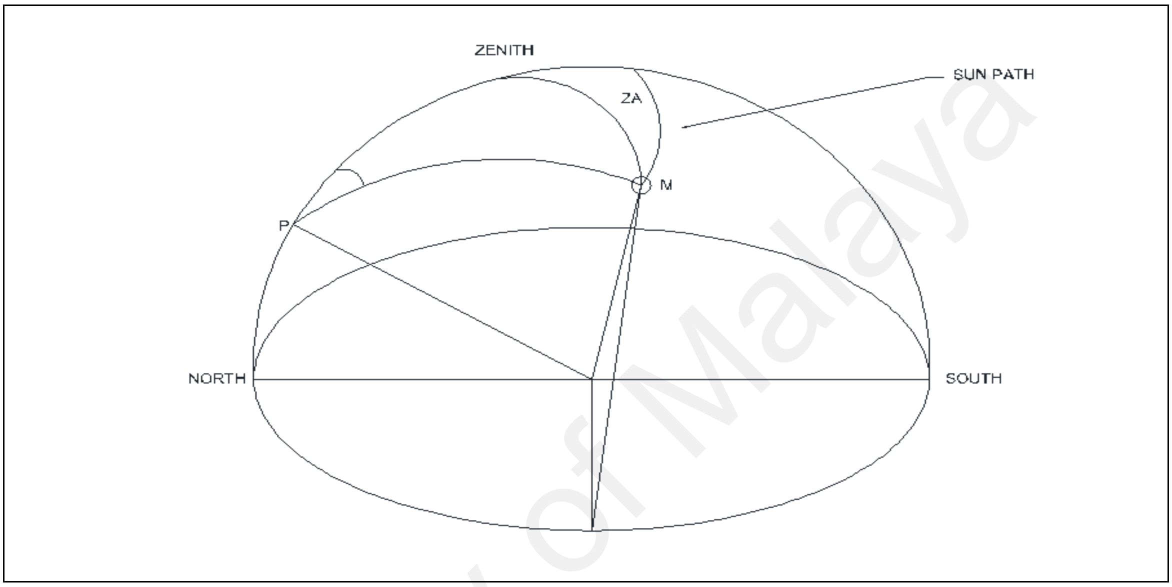

Figure 2.8: Diagram of Sun altitudes at Asr Prayer Time

In the diagram 2.8, M is representing the sun position while ZA is the vertical position of the reference at Asr time.

From the trigonometry of the sphere:

$t_A = \cos\text{-}1\ [(\cos Z_A - \sin\delta_A \sin\varphi)/(\cos\delta_A \cos\varphi)]$ (11)

From the equation in (11) Z_A is the vertical position of reference during Asr

δ_A is the declination of the sun at Asr prayer time

φ is the latitude at the point of reference

Thus, the the Asr prayer time can be show as the equation below:

$$Asr = Transit + t_A \quad (12)$$

t_A represents the angular of the sun‟s time during Asr

2.2.6 Maghreb Prayer Time

In Sunni‟s point of view, the Maghreb prayer time begins when the sun is completely beneath the horizon. While in Shia‟s viewpoint the precaution must be taken and as long as the redness in the eastern sky has not passed overhead after sunset then it is not the beginning of the Maghreb prayer time yet. The twilight angle which is at 4 must be taken into consideration. The diagram below shows the position of the sun at the beginning of Maghreb prayer time.

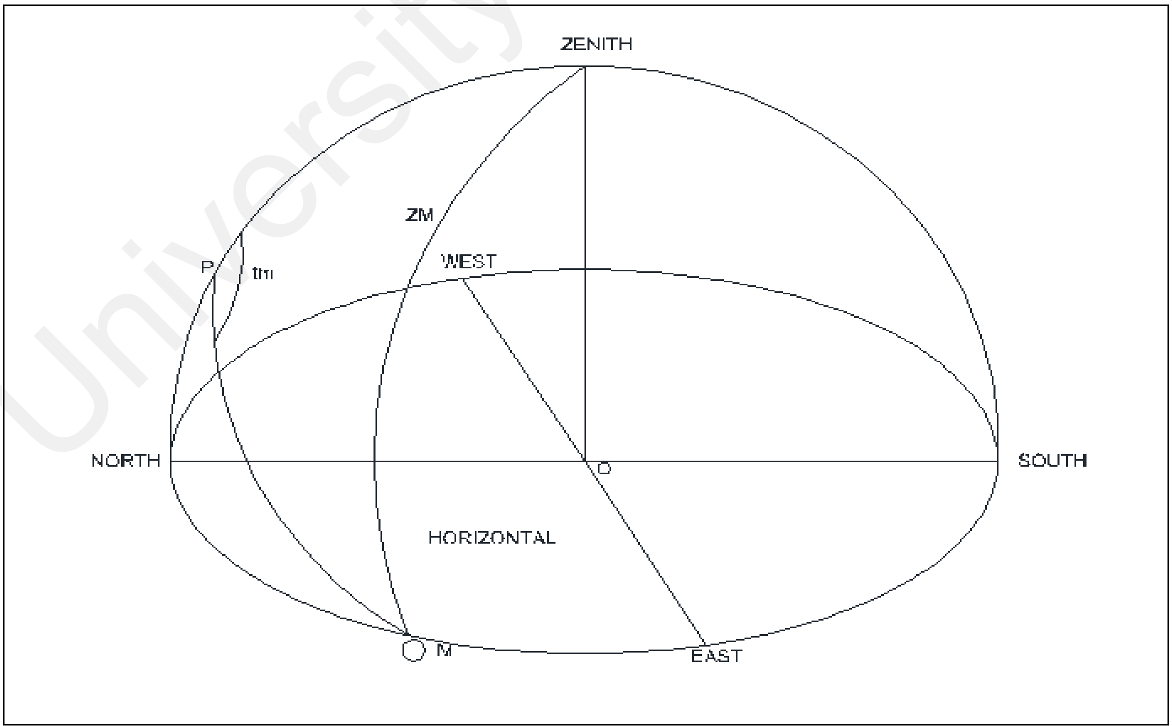

Figure 2.9: Diagram of the sun position when Maghreb prayer time begins.

In the above diagram, t_M is the sun angle at the sunset while Z_M is the distance of zenith at Maghreb time. By taking into the consideration the factor of semi diameter of the sun and atmosphere refraction, then:

$Z_M = 90° + SD + Refraction$

Average SD = 16‟ and Refraction = 34‟, then:

$$Z_M = 90° + 16'' + 34'' = 90°50'' \quad (13)$$

Then;

$$t_M = cos^{-1} \frac{(\cos ZM - \sin\delta_M \sin\phi)}{(\cos\delta cos\phi)} \quad (14)$$

t_M represents the angular of the sun‟s time during Maghreb

Z_M represents the vertical position of the reference point at Maghreb

δ_M represents the sun‟s declination during Maghreb

ϕ is the latitude on reference point

Thus,

$$Maghreb = Transit + t_M \quad (15)$$

The ending of Maghreb prayer time is when the Isha prayer time begins.

2.2.7 Isha Prayer Time

Isha prayer time begins when the darkness falls and there is no scattered light in the sky. The time taken when all the scattered light disappears is called the astronomical twilight. The astronomical twilight occurs when the solar elevation is at 18° under the west horizon. This was shown in the diagram 2.8.

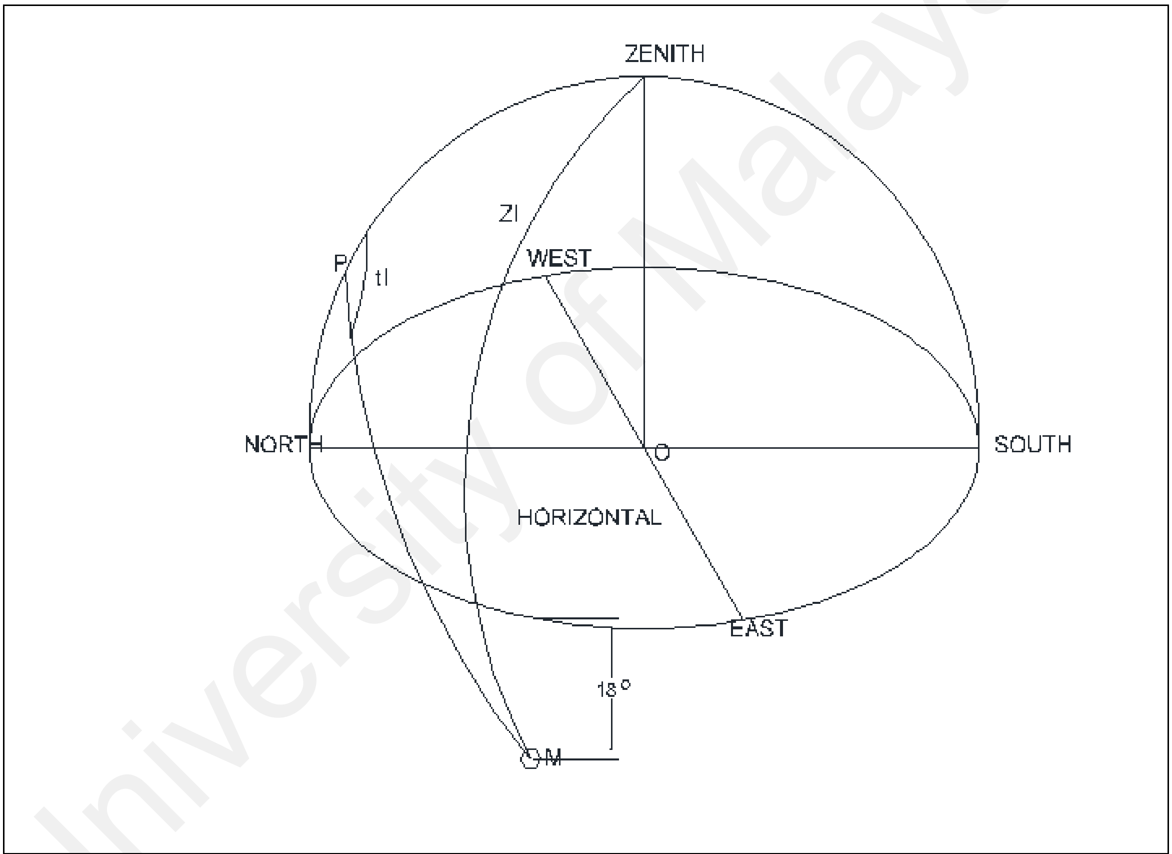

Figure 2.10: Diagram of the sun position is at 18° below the horizon

Thus, the distance of the zenith when the Isha prayer time begins is as below:

$$Z_I = 90° + 18° = 108° \quad (16)$$

Z_I is representing the vertical position of reference at Isha time.

Then the solar angular when the Isha prayer begins is:

$$t_I = cos^{-1}\frac{(\cos ZI - \sin\delta_I \sin\phi)}{(\cos\delta_I cos\phi)} \quad (17)$$

Z_I represents the vertical position of reference at Isha time

δ_I is the declination of the sun during Isha time

ϕ is the latitude of the reference

Thus:

$$\text{Isha} = \text{Transit} + t_I \quad (18)$$

t_I represents the angular of the sun‟s time at Isha time

2.3 Latitude

Latitude refers to the geographic coordinate that specifies the position from north to south on the earth surface. Latitude can be noted in the range of angle between 0° to 90° to the North or to the South Pole. Latitude can be distinguished by terminology into five categories which are geodetic, geocentric, spherical, and geographic and latitude itself. In this research, most of the terminology used refers to the geographical latitude or alternatively called astronomical latitude. The astronomical latitude (Φ) refers to the angle between equatorial planes to the true vertical at the point of the surface. This true vertical can be defined as the direction of the gravity field to that point. The astronomical latitude can be obtained by measuring the angle between zeniths to celestial pole or else can be obtained by measuring the angle between the zenith and the sun when the elevation of the latter has been obtained from almanac.

2.4 Previous Studies

Study on determination of prayer times at high latitude regions is an ongoing discussion. Many studies came up with the alternative method to improve this type of problem. Muslims who live in this region need to refer to prayer times of the nearby countries. It is because the twilight may persist throughout the night during some of the months. This needs some modification to divide daylight and night equally. Also, countries in these regions perform the daylight saving time during spring and autumn. Typically, clocks are adjusted one hour during the spring and adjusted to minus one hour during the autumn. This fact needs to be considered in this study so that the calculation on determination of prayer times would not be wrong and becomes more precise. According to Muneer[8], *"it must be borne in mind that during the "abnormal" period there is room in the jurisprudence to follow the alternative ways to determine the limit time for Fajr and Isha"*. The alternative could be the solution to determine the prayer time so that Muslims can perform the prayer at precise time.

Hamid Zarrabi Zadeh[9] who has studied this issue states that:

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[8] Muneer, T. 2007. The Islamic Prayer Times – Computational Philosophy with Particular Reference to the Lack of Twilight Cessation at Higher Latitudes. Available online: http://www.islamicity.com/prayertimes/Salat.pdf. 1-6.

[9] Zadeh, HZ. 2010. Prayer Times Calculation. Available online: http:/tanzil.info/prayertime/doc/calculation. 1-5.

there are some adjustment has to be made in the way to calculate the prayer time at higher latitude regions where twilight may persist throughout the night in several months along the year.. The third and the last method are called angle based method. In this case, let a be the twilight angle for Isha and let t = a/60. The period of sunset until sunrise will be dividing into t parts. The Isha prayer will begin after the first part.

The other method proposed by Zarrabi Zadeh is the same as the one proposed by Muneer which is the middle of the night and the seventh part of the night.

2.5 Description on the Software

There are a few types of software that can be used to determine prayer times. This software includes Athan Pro 4.2, Prayer Time PC Pro and Salaat Time. Athan Pro 4.2 has many features such as Automatic Athan (Azan) at every prayer time. Another feature is minute‟s adjustment to make the prayer times more precise according to local Mosque. Qiblah direction is also available in this software in graphical format. But this software is not suitable to be used in this research because it cannot calculate prayer times at high latitude regions.

Other software available is Prayer Time PC which can be used to calculate the prayer times. The special feature in this software is that it can adjust the prayer times by individually each prayer time. Unfortunately, it is not suitable to be used because it does not have adjustment for summer time. Lastly, the software that is suitable to calculate the five daily prayer times is Salaat Times software. It can both calculate the period of the middle of the night or the last one third of the night and it has additional precision for longitude and latitude. This features help to calculate night prayer.

In this research, the software that has been used is Accurate Times for determination of prayer time. This software manages to do the calculation for prayer times at high latitude cities. Also, it can do some adjustment for summer time. This research focuses on the extreme periods of time which are during summer time on 21^{st} of June and winter time on 21^{st} of December. Comparison has to be made later on the alternative way that has been proposed in the previous study on calculating prayer time at high latitude.

The other software used in this research is The Sky Sixth. It is an astronomical software that is used to simulate many astronomical events. It has been built and developed by Software Bisque. It is used here to simulate the sun Path. The data is accurate and it can capture a good image as well.

CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter discusses how the research has been done. The research used the software called Accurate Time to calculate the prayer times at high latitude regions for the selected cities. Later, the findings have been compared to the alternative way of determination of prayer times in the high latitude regions. The alternative ways proposed:

a) Nearest day
b) Nearest Latitude
c) Middle of night
d) Seventh part of night

An experimental comparison should be made to find out which way is the easiest to carry out and also the applicability to use which will give the precise time. Analysis will be carried out upon the effect of increasing the latitude on the determination of prayer time. This will focus on the atmospheric effect to do the analysis. Research will focus on the extreme periods of time when the abnormalities occur which are during the summer solstice and the winter solstice.

3.1 Description on Accurate Times

The software is used to compute the prayer times at high latitude regions at some selected cities. The research is carried out by using Accurate Time because of its ability to generate the prayer time at high latitude regions. This software is used by the Jordanian Ministry of Islamic Affairs to calculate prayer time for Jordan. The program runs under Windows, and it is written by Mohammad Odeh[10], the chairman of the Islamic Crescents' Observation Project (ICOP).

One reason why this software has been used is because of its accuracy compared with the Astronomical Almanac [11]. The result shows that it is almost precise to the existence value which is within an accuracy of about one second. This is exceptional for Zuhr prayer where the error is within the range of 0.03 second at maximum.

Figure 3.0: Diagram of the components in Accurate Times.

[10]Accurate Times 5.3.9 released on 17 October 2014,Mohammad Odeh ,Islamic Crescents' Observation Project (ICOP). Copyright (C) 2000-2014 ICOP.

[11] Moh'd Odeh, 2014 Islamic Crescents' Observation Project (ICOP),2014, http://www.icoproject.org/accut.html?&l=en

3.2 Description on The Sky 6 software

The Sky sixth is generated and developed by software Bisque. It was used in many observatories around the world. It has good features that make it suitable to be used for many studies and observations. It is suitable for this research because it could be used to generate the sun path at the required locations. Thus, for certain locations in this study where it needs to see the sun position; the path can easily be simulated here. Therefore, it makes the results so clear and the study so easy to understand.

Also, the images captured are in a very good condition and magnification. This program can operate in Windows 98/Me/2000/XP Home/XP Professional and others. The most important thing is to identify the exact location of the study and time need to change relative to the position studies.

This software manages to be used to learn basic astronomy concepts as well. Users can also use it to view simulation of astronomical events. The most important part is to generate and export customs reports of astronomical data.

3.3 Determination of Prayer Time by Using the Accurate Time Software

This study uses the software to calculate some measurement such as prayer times and sun position. This software is the official program adopted by the Jordanian Ministry of Islamic Affairs to calculate the prayer times in Jordan. Accurate Times calculates the following astronomical events and the following list is a component that relates to this study;

i) Islamic prayer times (Fajr, Zuhr, Asr, Maghreb, and Isha).

ii) Sun times (Beginning and end of twilight, sunrise, sunset, and Sun transit).

Components that have been used in this software are Prayer Time, Location and Preferences. Accurate Times can used to calculate the prayer times at high latitude regions. The research focuses on the prayer times at Fajr and Isha times because abnormalities occur at high latitude regions when sun does not set below the horizon. Therefore, the twilight may persist throughout the night. The components can be used in Accurate Times to indicate the beginning and ending of twilight.

There are four main components that are used in this software program. First is Prayer time component which shows the result daily, monthly and yearly. The Prayer time component can be used after assigning the input in the preferences component. It can be shown in flow chart below.

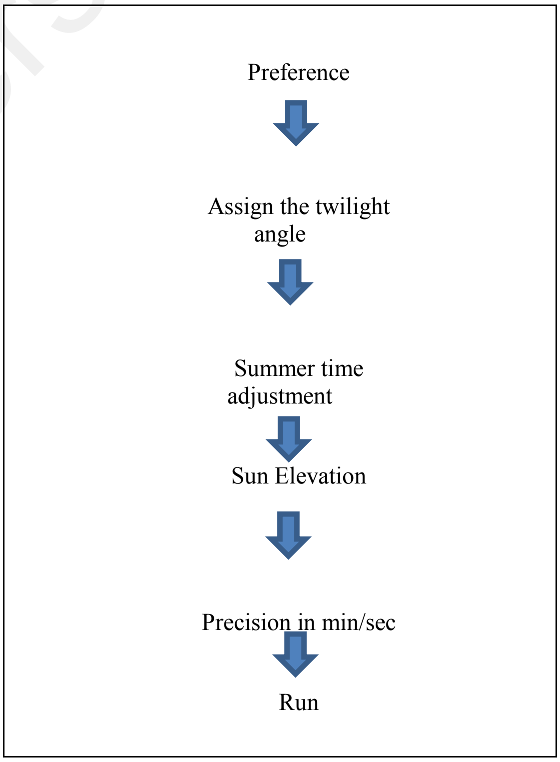

Figure 3.1: Flow Process for Assigning Input

In the preferences part, some data is needed such as twilight angle, summer time adjustment and addition in time, precision and language used. For the twilight input data, the angle used for countries studied need to be kept in. This depends on the scholars and their opinion which vary from 14° up to 18°. While in the summer time adjustment, the countries using the daylight saving time, additional time of one hour during summer or subtraction of one hour in the winter needs to be done. For the precision, data need to be assigned in minute or second. The next part used in this study is location. Location needs to be chosen in this software. In this research, the countries chosen are at the high latitude regions. This research chooses to study four cities from high latitude regions at 48° up to 67°. While in date part, user needs to decide whether to assign the data in yearly, monthly or daily. Also, this research focuses on changes of sun altitude and the relation to the prayer times.

This research focuses on the cities in high latitude regions which include twenty cities in different latitude. There are cities in latitude at 48° up to 67°. These cities have abnormality in twilight present. The selected cities have been chosen because a lot of Muslims are living in these areas. Research starts at 48° because "*the abnormalities begin here when the duration of night and day is not equal*" [12]. Comparison needs to be made for these four different cities as the latitude increases. The highest is at 67° where these cities have habit here and they are included in this research because there are Muslims living there. It is also the upper limit in this research because cities in this latitude are situated in the Arctic Circle.

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[12] Philip & Deborah Scherrer, Solstice and Equinox ("Suntrack") Model, pg3, Standford Solar Center.

3.4 Sun Calculation

It is important to know the algorithm behind the research. Some calculations need to be made to find out the movement and the sun position at the specific prayer time. The pattern of the sun movement along the earth is the main focus in this research. That is the way to find out the effect of increasing the latitude on the indication of prayer time. The parameter that is important to use in this research includes declination angle (δ), AST (Local Solar Time), hour angle (H) and solar altitude (β).

Declination angle represents the angular distance of the sun from north or south to the earth‟s equator. It can be calculated by the following equation;

$$\delta = 23.45° sin \left[\frac{N+284}{365} \times 360°\right] \quad (1)$$

Where N is the number of the day

As earth is divided into latitude and longitude, the equator is at latitude of 0°. While the North Pole is at +90° and South Pole is at -90°. Tropic of Cancer is at +23.45° and Tropic of Capricorn is at -23.45°. The longitudes is described in terms of how many degrees they lie to the east or west of the prime meridian. A 24 hour day has 1440 minutes which when divided by 360°, it means that it takes 4 minutes to move each degree of longitude. The apparent solar time, AST (Local Solar Time) in the western longitudes is calculated from

$$\text{AST}=\text{LST}+\left(\frac{4min}{\text{deg}}\right)(LSTM - Long) + EqnT \quad (2)$$

Where

LST= Local standard time or clock time for that time zone (may need to adjust for daylight savings time, DST, which is LST=DST-1hour

Long= Longitude of position of interest

LSTM= Local Longitude of standard time meridian

$$LSTM=15° \times \left(\frac{Long}{15°}\right) \tag{3}$$

The difference between the true solar time and the mean solar time is the continuous changes of day to day with annual cycle. The quantity is known as the equation of time. The equation of time, EqnT in minutes is approximated by equation 4.

$$ET= 9.87\sin(2D) - 7.53\cos(D) - 1.5\sin(D) \tag{4}$$

Where $D= 360° \frac{(N-81)}{365}$

The hour angle, H is the azimuth angle of the sun"s rays caused by the earth"s rotation, and H can be computed from 3.

$$H= \frac{(No\ of\ minutes\ past\ midnight, AST)-720mins}{4min/deg} \tag{5}$$

The hour angle as defined here is negative in the morning and positive in the afternoon (H=0° at noon)

Solar altitude,β is the apparent angular height of the sun in the sky if you are facing it. Then the zenith angle,θ and its complement the altitude angle,β are given by equation 6.

$$Cos\theta_Z= \sin\beta= \cos(L)\cos(\delta)\cos(H)+\sin(L)\sin(\delta) \tag{6}$$

Where

L= Latitude

δ= declination angle

H= hour angle

The noon altitude is $\beta_N = 90°-L+\delta$

The sun rises and sets when its altitude is 0° and not necessarily when its hour angle is $\pm 90°$.

All the above equation is important to be implemented in this research where the changes of the sun motion can be seen and analyzed in relation to the changes of the latitude.

CHAPTER 4

RESULT AND ANALYSIS

4.0 INTRODUCTION

This chapter discusses the results from the research and analyzes the data taken. Discussion is made upon two of the prayer times which are Subh and Isha. The prayer times have been determined using Accurate Times Software. Then they have been compared with other alternative ways of calculation of the prayer times at high latitude cities. The alternative ways proposed are:

a) Middle of night
b) Seventh part of night
c) Nearest latitude
d) Nearest day

The comparison made would examine the easiest way to use, the accessibility to use and the most convenient way to be used.

4.1 Time of Data Taken

There are two periods of time where the research has focused on which are on winter and summer time. During this period of time, the abnormalities could occur on the pattern of the sunset and sunrise. The exact time is upon 21^{st} of June 2012 and 21^{st} December 2012. Discussion is made upon these two cases of time periods. Summer solstice is taken on the 21^{st} of June while winter solstice has been taken on 21^{st} December 2012. This research focuses on the changing of the sun motion that occurs depending on the changing of the latitude. The reason of selecting the above mentioned date is because 21^{st} December is known as winter solstice when the shortest day and longest night occur. While 21^{st} June is known as summer solstice when the longest day and the shortest night is occurs. This research focuses on the extreme cases for both of these two periods of time.

4.2 Latitude of Studies

The cities that are located at latitude of 48° up to 67° to the North Pole are the main focuses of this research. Ten cities are included in this study. The list of cities and their location are mentioned in the following table.

Table 4.0: Latitude of cities' Studies

Latitude	Longitude	Time Zone
48°(Paris)	2°	1
49°(Reims)	4°	1
50°(Koln)	6°	1
51°(Bochum)	7°	1
52°(Berlin)	13°	1
53°(Hamburg)	9°	1
54°(Gdansk)	18°	1
55°(Moscow)	37°	3
56°(Halmstad)	12°	1
57°(Aalborg)	9°	1
58°(Arendal)	8°	1
59°(Oslo)	10°	1
60°(Helsinki)	24°	2
61°(Mikkeli)	27°	2
62°(Joensuu)	29°	2
63°(Keflavik)	-22°	0
64°(Kajaani)	27°	2
65°(Oulu)	25°	2
66°(Rovaniemi)	25°	2
67°(Sondre Stron	-50°	-3

Table 4.0 is the table of cities that are examined in the research. There is a considerable number of Muslims living in these cities. Some of these cities are located in the Tropic of Cancer to the North and some are located at Arctic Circle which is at 67°. It should be the limit of the study because no real darkness occurs at this circle of latitude during summer and there is no sunrise during some specific period of time when winter comes. Thus, only one city that is located at the Arctic Circle should represent the circle of this latitude where more regions above that could use these findings in the future.

4.3 Duration of Day and Night on summer 2012

To begin the analysis, one should look at the beginning of the sunset and sunrise of each city. This is needed in order to know the duration of the night and day for each season either for summer or winter. Table 4.1 shows the duration of the night and day for 21st June 2012 that occurs on summer.

Table 4.1: Duration of Day and Night on 21st June 2012

Latitude	Sunset	Sunrise	Day	Night
48°(Paris)	21:55	5:52	16.05	7.95
49°(Reims)	21:45	5:46	15.98	8.02
50°(Koln)	21:49	5:33	16.27	7.73
51°(Bochum)	21:43	5:24	16.32	7.68
52°(Berlin)	21:24	4:55	16.48	7.52
53°(Hamburg)	21:46	5:05	16.68	7.32
54°(Gdansk)	21:16	4:23	16.88	7.12
55°(Moscow)	22:07	5:00	17.12	6.88
56°(Halmstad)	21:54	4:33	17.35	6.65
57°(Aalborg)	22:13	4:38	17.58	6.42
58°(Arendal)	22:25	4:34	17.85	6.15
59°(Oslo)	22:30	4:21	18.15	5.85
60°(Helsinki)	21:40	3:11	18.48	5.52
61°(Mikkeli)	22:39	3:47	18.87	5.13
62°(Joensuu)	22:44	3:27	19.28	4.72
63°(Keflavik)	23:23	3:36	19.78	4.22
64°(Kajaani)	23:45	2:43	21.13	2.47
65°(Oulu)	0:23	2:21	22.37	1.63
66°(Rovaniemi)	up	up	-	-
67°(Sondre Stromfjord)	up	up	-	-

Table 4.1 shows the duration of day and night upon changing of latitude. The above table can be illustrated in graph to clearly show the changing pattern of the period of day and night upon latitude. There are two cities from two different latitudes of 66° and 67° which do not have the time of sunset and sunrise. Both cities are located on the Arctic Circle. This data shows that sun is always up on this date which is 21st of June 2012. Therefore, the period of day and night is unidentified only for this certain period of summer. This phenomenon can be explained more clearly after it is depicted in the graph below.

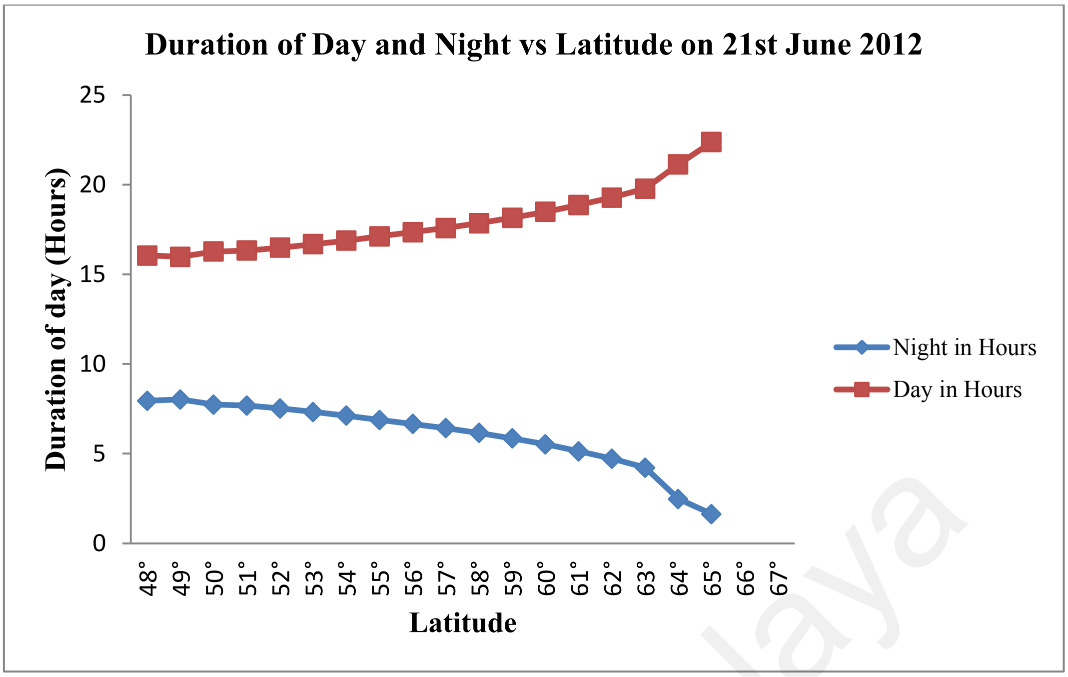

Figure 4.0 Graph of Duration of Day and Night vs Latitude on 21st June 2012

Figure 4.0 shows the changing pattern of a period of day and night during summer on latitude. The blue line represents the duration of night while the red line is the duration of day in hours. As seen in the graph above, as the latitude increases the duration of day increases as well while the duration of night gets shorter. This could occur because of the period of earth moving around the sun is particularly different compared with other seasons. At this Arctic Circle which is at 66.7° latitude on 21st June, every location in north of the Arctic Circle is illuminated for 24 hours and this is called the Land of the Midnight sun. It is because the sun does not rise or set on the solstice but just circulates around above the horizon. By simulating the Sky 6 software, one can see the sun path on this Arctic Circle. The following diagram shows the sun paths on 21st June 2012 at 66°30'N latitude.

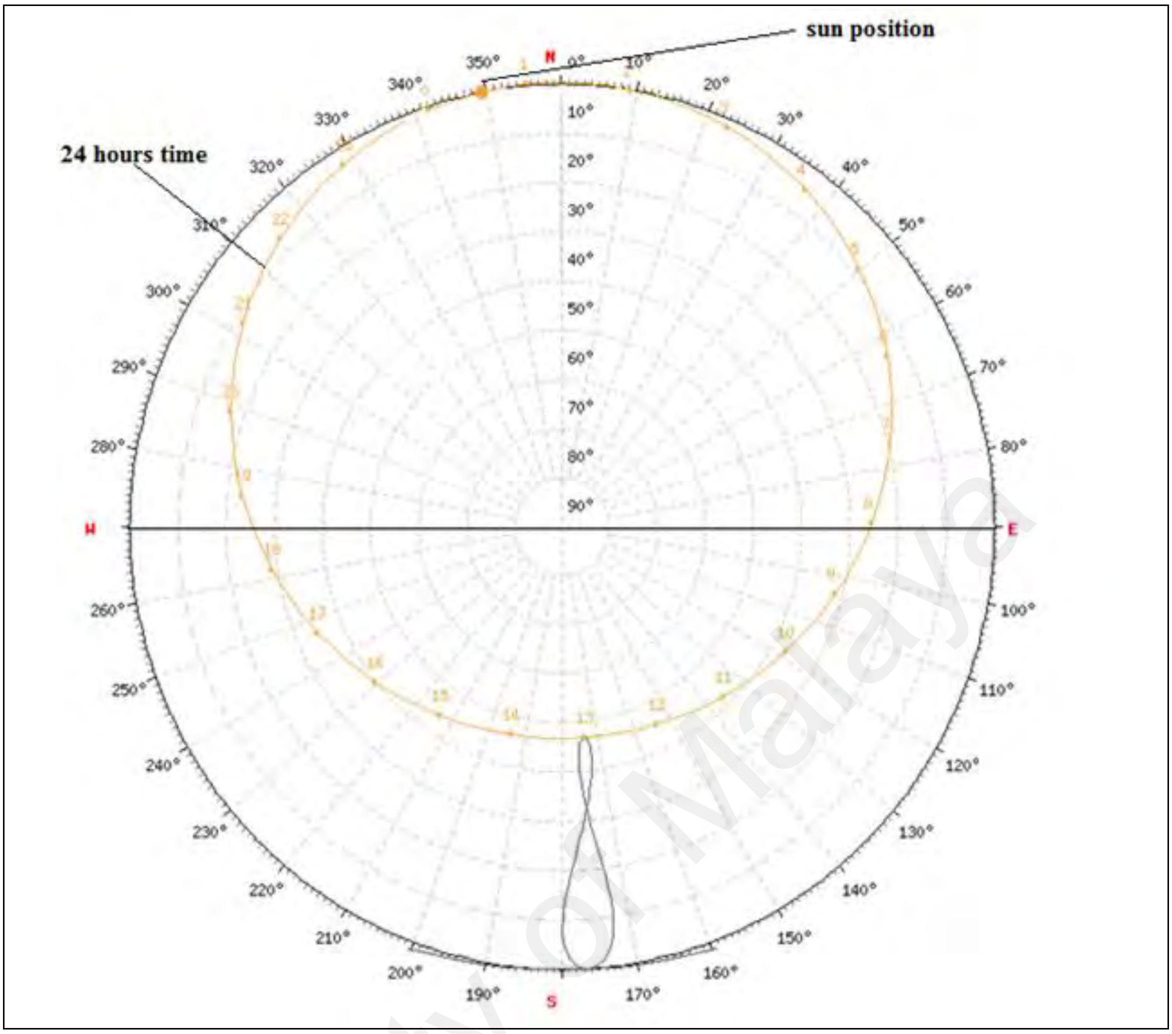

Figure 4.1: Sun Path on 21st June 2012 at Rovaneimi, Finland (66°30'N)

Figure 4.1 shows the Sun Path on 21st June at this Arctic Circle city. The circle inside is the sun motion for a period of twenty four hours at latitude 66°30‟N. The times in the circle show the position of the sun at a certain position. It has not risen in the east and set in the west. Thus, there is no specific time to determine the duration of night and day for this particular day. This could occur because of the earth tilt on its orbit towards the sun at maximum axial tilt at 23°26‟ for twice each year. In this case, it occurs on June between 20th until 22nd and towards northern hemisphere where the sun reaches its highest position in the sky. The above diagram is also the example of the phenomenon called midnight summer that occurs at Arctic Circle during summer when the sun is visible at full twenty four hours. In the above diagram, the highlighted number in degree is the sun altitude at each time. The lowest the sun can go is at 0.95° above the horizon.

The previous diagram shows the sun movement for a period of twenty four hour on 21st June 2012. The location of the sun at 0:30am~01:00am can be assumed as its lowest position below horizon. Looking at the alphabets E and W which stand for the east and the west, it is the point where the sun starts to rise and then set in west. However, in this abnormal case, the sun does not set and rise. Thus, the research focus on the deepest point of the sun can go below the horizon at the time which can be considered as night in a normal case. Thus, for determining Subh and Isha prayer times, we should use the alternative method that has been proposed and it is when the sun could not reach 18° below horizon in normal cases and at 15° below horizon in the extreme cases at high latitude cities.

4.3.0 Determination of Fajr and Isha during summer 2012

As discussed earlier in the previous chapter, we need to use an alternative way in order to determine the Fajr and Isha prayer time in some cities that lie in high latitude. The reason of propose this alternative ways is because of these cities do not have sunset and sunrise for a certain period of time. The alternative ways proposed are:

a) Middle of night
b) Seventh part of night
c) Nearest Latitude
d) Nearest day

However, the way to select which way is the most appropriate way to be used is discussed in this part. Nearest day is suitable to be used for cities that do not have ending of twilight for a certain period of time. Hence, the last day of twilight that appears for those cities can be used. While for the nearest latitude define as when the differences between starting of twilight until sunrise at latitude 48° have been calculated. The same value was used to implement these differences for these cities in order to evaluate the beginning of Fajr. Then, for Middle of the night is when the specific time starting from sunset until sunrise has been divided into two halves when the first half is considered as night and the other half as daybreak and the midpoint is considered as the limit to stop the Sahur and begin the Fajr time. Lastly, is the seventh part of night that is when the period between sunset and sunrise has been divided into seven parts. The last one seventh part of the night will be considered as beginning of Subh.

Thus, these alternative ways best fit for the certain period of time for the certain cities that experience the abnormal period. The following table is the table of prayer times for Subh and Isha which is computed by Accurate Times for cities that include in this research.

Table 4.2 Table of Fajr and Isha Times on 21st June 2012 for Cities of the Study

	Accurate Times				Middle of night				Seventh part of Night				sun at deepest		
Latitude	Subh	Altitude	Isha	Altitude	Isha	Altitude	Subh	Altitude	Isha	Altitude	Subh	Altitude	position	Sunset	Sunrise
48°	3:22	-11.16	0:23	-18.22	23:55	-17.35	3:53	-8	23:03	-14.4	4:44	-1.88	-18.55	21:55	5:52
49°	3:08	-10.88	0:23	-17.38	23:51	-16.54	3:43	-7.46	22:53	-13.30	4:38	-1.00	-17.55	21:45	5:46
50°	2:18	-13.24	0:50	-16.5	23:45	-15.63	3:29	-7.31	22:55	-13.12	4:27	-0.74	-16.55	21:49	5:33
51°	1:49	-13.71	0:17	-15.46	23:38	-14.55	3:29	-6.13	22:48	-12.01	4:19	-0.59	-15.55	21:43	5:24
52°	Bright	-	Bright	-	23:17	-13.68	3:02	-5.66	22:28	-11.35	3:51	-0.41	-14.55	21:24	4:55
53°	Bright	-	Bright	-	23:39	-12.89	3:15	-5.16	22:49	-10.73	4:03	-0.21	-13.55	21:46	5:05
54°	Bright	-	Bright	-	23:03	-11.90	2:36	-4.65	22:17	-10.02	3:22	-0.09	-12.55	21:16	4:23
55°	Bright	-	Bright	-	23:50	-11.00	3:17	-4.12	23:06	-9.35	4:01	0.07	-11.55	22:07	5:00
56°	Bright	-	Bright	-	23:34	-10.11	2:53	-3.65	22:51	-8.64	3:36	0.26	-10.55	21:54	4:33
57°	Bright	-	Bright	-	23:50	-9.20	3:02	-3.08	23:08	-7.91	3:43	0.49	-9.55	22:13	4:38
58°	Bright	-	Bright	-	23:55	-8.23	3:02	-2.47	23:18	-7.19	3:41	0.66	-8.55	22:25	4:34
59°	Bright	-	Bright	-	23:58	-7.41	2:53	-1.82	23:20	-6.58	3:31	1.22	-7.55	22:30	4:21
60°	Bright	-	Bright	-	23:03	-4.86	1:48	-4.86	22:27	-3.10	2:24	-3.10	-6.55	21:40	3:11
61°	Bright	-	Bright	-	22:56	-4.10	2:30	-1.15	23:23	-4.93	3:03	1.12	-5.55	22:39	3:47
62°	Bright	-	Bright	-	23:55	-4.52	2:16	-0.65	23:24	-4.15	2:47	1.34	-4.55	22:44	3:27
63°	Bright	-	Bright	-	0:27	-2.67	2:48	-2.16	1:25	-3.55	3:15	-1.06	-3.55	23:23	3:36
64°	Bright	-	Bright	-	0:22	-2.53	2:06	0.17	0:06	-2.54	2:22	0.98	-2.55	23:45	2:43
65°	Bright	-	Bright	-	0:52	-1.08	1:54	0.35	0:37	-1.50	2:07	0.76	-1.55	0:23	2:21
66°	Bright	-	Bright	-	-		-	-	-	-	-	-	-	up	up
67°	Bright	-	Bright	-	-		-	-	-	-	-	-	-	up	up

Table 4.2 shows a comparison on determination of Subh and Isha prayer times by using three methods which are by using software and calculative method. The time of starting the Subh and Isha time have been computed from Accurate Time software. Software then computes only for the cities at latitude 48° up to 51°. It is because when assigning the twilight angle for both prayers at 15° as used for ISNA in table 1.0, time for Subh and Isha cannot be detected and the sun position is read as above the horizon. Other cities that locate beyond 52° and above do not have the exact time for both prayer times. The "bright" in the above table brings the meaning that the sky is always bright. But, fortunately, the sunset and sunrise can be calculated for the whole cities except for latitude that lie on Arctic Circle which are 66°~67°. Therefore, the alternative way of determination Subh and Isha prayer times should best be implemented here. The computed prayer times that appear in the table above can be used for the cities from 48° up to 51°. While for the cities that are located at 52° up to 65°, the calculation for Subh and Isha prayer times can be done either by using middle of the night or seventh part of the night. Both of these ways have been calculated and shown in table 4.2. The two ways of the alternative methods show that the middle of the night gives a value in which

the sun is in its deepest position below horizon. The example of the calculation is shown below.

<u>For Middle of Night at cities 52°N</u>

Duration of time from sunset till sunrise= 7.52 hours

Two halves of the night= $\frac{7.52}{2} = 3.76\text{hours}$

Thus, for day break midpoint is between = $\frac{3.76}{2} = 1.88\text{hours}$

Convert to hour and min= 1hour 53min

Subh= middle of night+1hour 53min

Subh= 3:02am

Isha= middle of night-1hour 53min

Isha= 23:17pm

<u>For Seventh of the Night at cities 52°N</u>

Duration of time from sunset till sunrise= 7.52hours

One-seventh of night= $\frac{7.52}{7} = 1.08\text{hours}$

Convert to hour and min= 1hour 5min

Fajr=time of sunrise (4:55am)-1hour 5min

Fajr= 3:50am

Isha=first one-seventh of night

Isha=22:28pm

For cities that lie at 66°~67°N latitude, there is no sunrise and sunset on 21st June every year. Thus, these two methods would not match and would not be suitable to use because the duration of night is undefined. Therefore, the second method shall be used. The method is called nearest day. The last day of sunset at the cities shall be used as the time of sunset for 21st June when the sun just circulates above the horizon. Sunset on 20th June can be used then.

4.4 Duration of Day and Night on winter 2012

After looking at the sun movement pattern on summer, one should look into sun movement pattern on winter as well. This movement should be looked upon and discussed because the research needs to focus on the effect of changing of the solstice that might affect the determination of prayer times especially on Fajr and Isha prayers. Solstice is the astronomical phenomenon which occurs twice each year where the sun reaches the highest and lowest point on its excursion that is relative to the celestial equator on its celestial sphere. In both cases, for the differences on the duration of night and days for summer and winter, one should see the table 4.3.

Table 4.3: Duration of Day and Night on 21st December 2012

Latitude	Sunset	Sunrise	Day	Night
48°(Paris)	16:55	8:46	8.15	15.85
49°(Reims)	16:43	8:42	8.02	15.98
50°(Koln)	16:30	8:39	7.85	16.15
51°(Bochum)	16:21	8:40	7.68	16.32
52°(Berlin)	15:52	8:22	7.5	16.5
53°(Hamburg)	16:02	8:43	7.32	16.68
54°(Gdansk)	15:20	8:13	7.12	16.88
55°(Moscow)	15:58	9:04	6.9	17.1
56°(Halmstad)	15:31	8:51	6.67	17.33
57°(Aalborg)	15:35	9:10	6.42	17.58
58°(Arendal)	15:31	9:22	6.15	17.85
59°(Oslo)	15:14	9:23	5.85	18.15
60°(Helsinki)	15:08	9:37	5.52	18.48
61°(Mikkeli)	14:45	9:37	5.13	18.87
62°(Joensuu)	14:24	9:41	4.72	19.28
63°(Keflavik)	16:41	12:08	4.22	19.78
64°(Kajaani)	15:16	11:04	4.2	19.8
65°(Oulu)	15:06	11:31	3.42	20.58
66°(Rovaniemi)	14:42	11:55	2.22	21.78
67°SondreStromfjord	down	Down	-	-

Table 4.3 shows the duration of day and night during winter on 21st December 2012. This day is called winter solstice. The reason of using this day is because the sun is at lowest point on its celestial sphere. This is called the shortest day and longest night as well. As the latitude gets higher, sunset occurs earlier and sunrise is delayed. It also shows that the day get shorter as the latitude increases and also, as the latitude get higher, the period of the night gets longer. There is one city at 67°N which is located at Arctic Circle that does not have sunrise and sunset. It shows that the sun is located just below the horizon. This data can be transformed into a graph where the analysis could be seen clearly. See figure 4.2 for the graph.

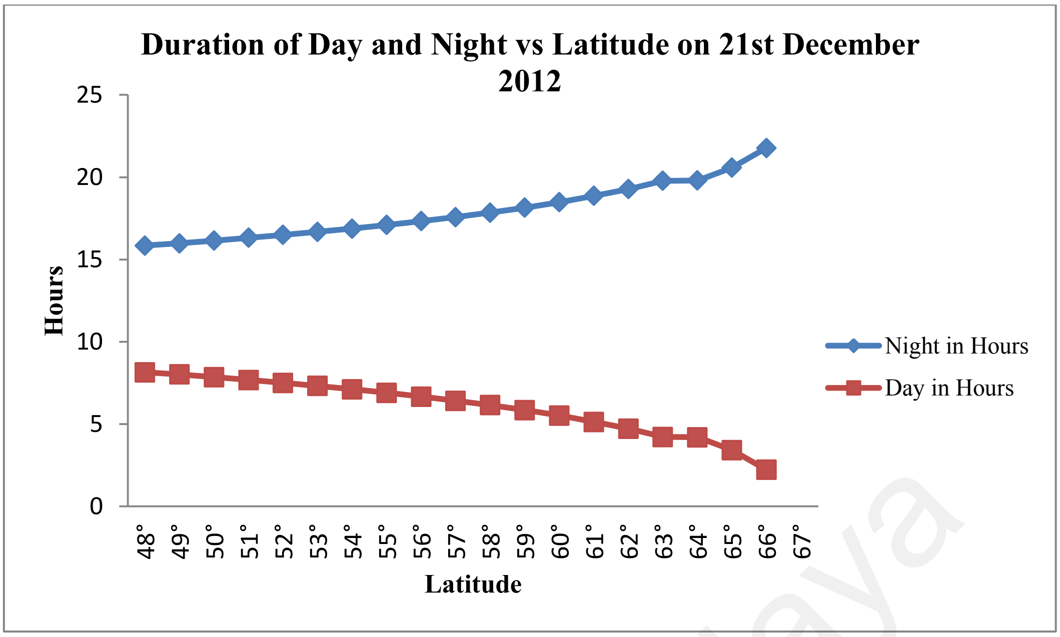

Figure 4.2: Graph of Duration of Night and Day vs Latitude on 21st December 2012

The graph shows in figure 4.2 is the duration of night and day on 21st December 2012. The blue line represents the changing of night in hours and the red line is for day length in hours in winter. As the latitude gets higher, the length of night increases while it is vice versa for the length of day; that is, the length of day gets shorter as the latitude increases. This occurs during winter.

4.4.0 Determination of Fajr and Isha Prayer on winter 2012

The research then examines whether the latitude would affect the time of starting the Fajr and Isha prayer in winter. The date of data taken is on 21st December 2012. This is also known as winter solstice. It is called midwinter as well when this day is the shortest day and the night is the longest night. Table 4.4 shows the Fajr and Isha prayer times on 21st December 2012. It also shows the time of starting sunset and sunrise on this date for every city in the study. How should the prayer times for Fajr and Isha be determined in the case of 67° latitude?

In this case, no sunset and sunrise occur on 21st December 2012. The best way to be implemented here is by using the Nearest Day method. This method proposed by using the last day of sunset of this city where it could be used to determine the sunset for this city. Then, the time of starting of Fajr and Isha can be determined by calculating the duration of the night. The following table is the table of prayer times computed by using Accurate Times for the cities studied at winter 2012.

Table 4.4: Prayer times of Fajr and Isha on 21 December 2012

Latitude	Subh	Altitude	Isha	Altitude	Sunset	Sunrise
48°	7:04	-15.06	18:34	-14.55	16:55	8:46
49°	6:58	-15.07	18:26	-14.88	16:43	8:42
50°	6:50	-15.38	18:11	-14.13	16:30	8:39
51°	6:50	-15.11	18:09	-14.77	16:21	8:40
52°	6:28	-15.13	17:41	-14.51	15:52	8:22
53°	6:44	-15.45	17:53	-14.28	16:02	8:43
54°	6:11	-15.35	17:16	-14.48	15:20	8:13
55°	6:59	-15.13	17:57	-14.42	15:58	9:04
56°	6:40	-15.33	17:33	-14.25	15:31	8:51
57°	6:53	-15.53	17:44	-14.47	15:35	9:10
58°	7:02	-15.23	17:45	-14.46	15:31	9:22
59°	6:58	-15.09	17:33	-14.34	15:14	9:23
60°	7:02	-15.44	17:35	-14.48	15:08	9:37
61°	6:58	-14.88	17:21	-14.63	14:45	9:37
62°	6:51	-15.14	17:08	-14.46	14:24	9:41
63°	8:25	-14.45	18:32	-14.85	15:33	11:20
64°	7:05	-15.26	17:10	-14.63	15:16	11:04
65°	7:17	-14.85	17:16	-14.84	15:06	11:31
66°	7:23	-15.08	17:08	-14.5	14:42	11:55
67°	7:31	-14.77	17:12	-15.28	down	-

The above table shows the prayer times for high latitude regions for cities of this study. Also, it provides the sun altitudes at each prayer time. The sun altitude has also been defined for Subh and Isha prayer times. The sun altitude reaches the angle of 15° below the horizon. This is fulfilling the condition of the sun elevation angle for the cities at high latitude.

4.4.1 Effect of Latitude and Longitude to the Prayer Times

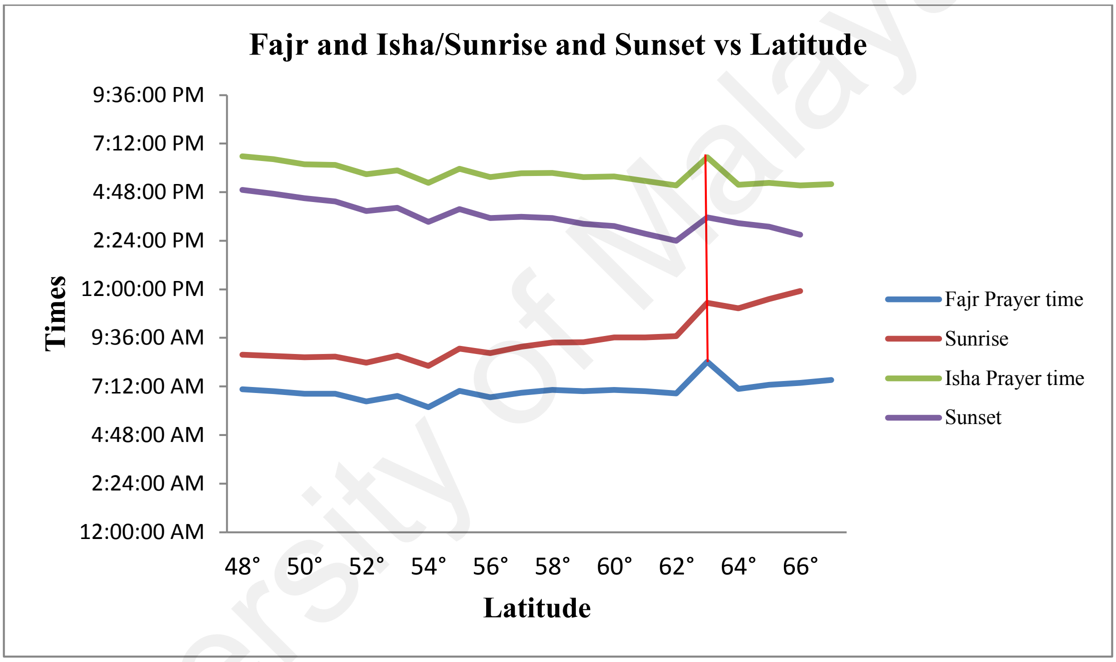

Figure 4.3: Graph of Fajr and Isha / Sunrise and Sunset vs Latitude at winter

The graph in figure 4.3 shows the starting time of sunset, sunrise, Fajr and Isha prayer times versus latitude. The blue line represents the Fajr prayer time and the red line represents the starting of sunrise. While the purple line represents the starting of sunset and the green line represents the starting of Isha prayer times. The first part focuses on the sunset and Isha times. This part shows that sunset starts earlier during winter as the latitude increases. The sunset and the prayer time of Isha start earlier as the latitude increases.

On the second part, the time of sunrise changes when latitude increases. The time of Fajr starts earlier as the latitude moves upward. This occurs because of the fact that longitude and the latitude do effect the starting of sunrise and sunset. This is because of the region of sky visibility as the location of the observer will set the horizon. The horizon moves parallel to the observer. Because of the earth tilt, the latitude determines the duration of day and night throughout the year. As latitude moves upward, the duration of day gets longer in summer and shorter in winter. As the observer moves towards the pole either to the north or south, the sun‟s path makes lower angle relative to the observer‟s horizon. Thanks to this reason, as the latitude gets higher, the sun path takes a longer time to move between twilight. Thus, at the nearest to the Pole, the civil twilight might occur for more than one week.

Furthermore, the vertical red line intersects the graph to shows the time of sunset, sunrise, Fajr and Isha for cities at 63°N latitude (Keflavik) which are located in Iceland. How should this difference in time compared to other cities in the high latitude regions be explained? As latitude gets higher, the sunset sets earlier in winter. In this case, not only the latitude should be focused on but also the time zone plays an important role in explaining why the sun sets earlier. Keflavik is located in time zone 0 and longitude of -22° to the west. Because of the earth steady rotation, the longitude is affecting the timing of many events such as sunrise and sunset. The earth rotates 15° for every an hour. Whether it moves earlier or later depends on its move to the west or to the east. The sun moves later an hour if it moves to the west and vice versa. That is the reason why the sunrise and sunset of the city of Keflavik is later compared to the other cities nearby.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.0 Introduction

This section discusses about the factors that mostly affect the starting of prayer times for Fajr and Isha at high latitude regions. In an early discussion in the previous chapter, the research discusses that latitude plays a role in determination of prayer times of Fajr and Isha. The research needs to find out whether or not the change of the latitude effect the starting of prayer times of Fajr and Isha at cities located in high latitude.

5.1 Conclusion on Factors in Determination of Night Prayers

In conclusion, the results show that change of latitude does effect the determination for starting Fajr and Isha prayer times. It also shows two different findings in two main seasons. In summer, the sun sets later and rises earlier which would result in short nights for cities in high latitude. As latitude gets higher, the period of night gets shorter. Some cities at extreme case occur at 66°N to 67°N which do not have sunset and sunrise. This occurs on 21st June 2012 or it can be called summer solstice where the sun does not set below the horizon. These cities belong to the Arctic Circle where the extreme cases occur.

Results show that, at winter, as the latitude increases, the sun sets earlier and the sunrise occurs later. This leads to the longer period of night which occurs as latitude increases. At 67°N of latitude, the sun does not appear at all on 21st December 2012. The sun does not rise above the horizon. This can be called midnight winter where night appears longer.

The research also finds out that there are other reasons or factors in determination of starting Fajr and Isha prayer times. As seen in result and analysis chapter, it shows that longitude and time zone define the starting of prayer times as well. In this research, the cities which are located at 63°N, the sunset, sunrise and the beginning of both prayer times start late because the cities are located at the longitude more to the west compared to other cities which are located at the east.

5.2 Conclusion on Implementing the Alternative Way in Starting Night Prayers

There are four alternative ways to define the starting of Fajr and Isha prayer times. These are nearest day, nearest latitude, middle of the night and seventh part of the night. Which way is the best to be used and easiest to be implemented in daily usage? It depends on the situation. As in normal case, the angle of beginning of the Isha and Subh prayer is at 18° below horizon. But at the high latitude case where the sun could not reach at 18°, several opinions are proposed to use 15° as starting the both prayers. The results show that in summer, some cities at high latitude regions, the sun does not reach

15° below the horizon to start the Fajr and Isha prayer time. Refer to table 4.2 in chapter on result and analysis. But the sun can still set and rise at a certain period of time. Thus, for cities located at 48°N up to 51°N there is still a way which can determine starting of Fajr and Isha prayer times by using computer software. For cities located above 51°N up to 65° latitude where prayer times are undetermined by computer software, it needs to be calculated by an alternative way. There are two ways of calculating it either by middle of the night or seventh part of the night. During summer where sun does not set 18° below the horizon, one should select which is the easiest way to calculate the night prayer. The research found out that by dividing the night by two, the Middle of the Night method gives the prayer time start, late but it gives more time for the sun to go deeper below horizon where it is most fitted with the requirement of fiqh. According to Katiya[13] *In summer, at latitudes higher than 48.5° (extreme northern regions), the sun does not go 18° below the horizon and at the latitudes higher than 51.5°, the sun does not go 15° below horizon, for example Manchester England and Edmonton Canada, in summer, the sun hardly goes beyond 13.5° below the horizon thus full darkness does not occur, in such cases several alternative methods are suggested by the leading scholars.(Katiya,2007)*

For cities at Arctic Circle, no sunset and sunrise occur at summer solstice where the sun does not set below the horizon. These cities could use the nearest day method where the last day of sunset at the cities can be used as the time of sunset for 21st June 2012. Then same goes here where the period of the night can be calculated.

Meanwhile, for the winter discussion, it is easier to calculate the prayer times here. As agreed by most experts, the sun angle 15° when starting the Fajr and Isha prayer

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[13] Aisha Charitable Support Services Montreal Canada Siddique Katiya, 15 September 2007 ,www.as-sidq.org

time is suitable in most cities at high latitude. Refer to table 4.4 to see the prayer times for fajr and Isha on 21st December 2012. The cities at 67°N latitude does not have sunset and sunrise where sun does not rise for a certain period of time. But by using 15° angle as the limit of starting the Fajr and Isha prayer times, the software can still used to compute the time.

5.3 Recommendation

Table 5.0: Sun Altitude for Fajr and Isha by Using Seventh Part of Night and Middle of Night Method

			seventh part of night				middle of night			
Latitude	Longitude	Time zone	isha	Altitude	Subh	Altitude	isha	Altitude	Subh	Altitude
48°	2°	1	23:03	-14.4	4:44	-1.88	23:55	-17.35	3:53	-8
49°	4°	1	22:53	-13.30	4:38	-1.00	23:51	-16.54	3:43	-7.46
50°	6°	1	22:55	-13.12	4:27	-0.74	23:45	-15.63	3:29	-7.31
51°	7°	1	22:48	-12.01	4:19	-0.59	23:38	-14.55	3:29	-6.13
52°	13°	1	22:28	-11.35	3:51	-0.41	23:17	-13.68	3:02	-5.66
53°	9°	1	22:49	-10.73	4:03	-0.21	23:39	-12.89	3:15	-5.16
54°	18°	1	22:17	-10.02	3:22	-0.09	23:03	-11.90	2:36	-4.65
55°	37°	3	23:06	-9.35	4:01	0.07	23:50	-11.00	3:17	-4.12
56°	12°	1	22:51	-8.64	3:36	0.26	23:34	-10.11	2:53	-3.65
57°	9°	1	23:08	-7.91	3:43	0.49	23:50	-9.20	3:02	-3.08
58°	8°	1	23:18	-7.19	3:41	0.66	23:55	-8.23	3:02	-2.47
59°	10°	1	23:20	-6.58	3:31	1.22	23:58	-7.41	2:53	-1.82
60°	24°	2	22:27	-3.10	2:24	-3.10	23:03	-4.86	1:48	-4.86
61°	27°	2	23:23	-4.93	3:03	1.12	22:56	-4.10	2:30	-1.15
62°	29°	2	23:24	-4.15	2:47	1.34	23:55	-4.52	2:16	-0.65
63°	-22°	0	1:25	-3.55	3:15	-1.06	0:27	-2.67	2:48	-2.16
64°	27°	2	0:06	-2.54	2:22	0.98	0:22	-2.53	2:06	0.17
65°	25°	2	0:37	-1.50	2:07	0.76	23:34	-1.08	1:57	0.35
66°	25°	2	-	-	-	-	-		-	-
67°	-50°	-3	-	-	-	-	-		-	-

The above table shows the altitude of the sun for each prayer times calculated by two methods which are seventh part of the night and middle of the night. The results show that the sun altitude is higher in the method of seventh part of night. While the sun altitude at both prayer times calculated by method middle of the night gives deeper sun altitude below the horizon. This case shows that middle of the night gives more accuracy of starting the prayer times by fulfilling the conditions set by the most scholars which is using 15° for high latitude cities. The Accurate Times can still be used for cities between 48° up to 51° to get the Subh and Isha prayer times. The middle of the night method can fulfill the requirements at latitude of 52° up to 65° where Isha starting time would fulfill the fiqh requirements where the sun is still below the horizon. But it still does not fulfill the requirement or the condition for Subh prayer time where at latitude 63°, the sun just raises which it does not fulfill the requirement of performing the Subh before beginning the Shuroq or sunrise time. Thus, the recommendation here is to standardize the method of determination of Isha and Subh prayer time where at 48° up to 51° latitude, those cities can use the Accurate Times to get both prayer times. As for cities located between 52° up to 65° latitude, the method of Middle of the Night can be used where it shows the increasing of the sun altitude is stable as the latitude increases. For latitude of 65° and above, further studies need to be done to determine the Isha and Subh prayer times which can fulfill the fiqh requirements.

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