In Advance, Highlight Affected Hilly Areas Network Roads by Sun Glare

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Abstract: This studying aims to display on real time the affected roads of sun glares *in advance or real time* when traveling on the 3D national transportation networks, and present them on roads or navigations digital maps layers, by calculating the directions and azimuths of roads and Sun position and test if they were close enough or almost parallel in 3D model where the sun glare direct or indirect reflected the drivers eyes.

The study would apply on cities that constructed on hilly or mountains areas were no absolutely flat areas found, have mid topographic surface and crowded with people and vehicles, and the roads had constructed on valleys, foothills and tops.

Keywords*:* Transportation networks, 3D, DTM, GIS, Sun position, Azimuth angle, Elevation angle, accuracy.

1. INTRODUCTION

Designing and analysis the 3d transportation networks helps the decision makers in strategic management, roads designing and increasing the roads services levels, displaying the affected roads will improve the 3d transportation networks and achieves several goals the designing the geographic layers, increasing driving performance and protection from sun glares which reduce Traffic accidents and reduce eyes harming and etc.

In previous research's [1] [2] they did not concerns in first designing and calculations of the 3D transportations data and ignored the topographic surface second NOT in advance but they were interested in sun glare on that effected traffic accidents analysis, by inspection**-** on google earth **-** the area of Chiba Prefecture, Japan [1], it was not absolutely hilly area and have not big change in elevation topographic surface. The traveling of the earth around the sun and the rotation around its axis with a tilt angle are change the sun position in the sky, sunrise and sunset directions on earth and varies because of time, date and observer's geographic location[3][4].

Within employing modern technologies software even hardware of geographic information systems (GIS) in designing and analysis the 3D transportation network that obtained from digital cadastral maps and digital elevation maps(models) owned by Department of Lands and Surveys(DLS) of the pilot area, this indicates the useful of legal cadastral maps of DLS warehouse in many fields of GIS systems.

2. SUN POSITION CALCULATIONS

2.1 GENERAL EQUATION

As shown in Figure 1, the solar position is represented by solar zenith angle (θ) and azimuthal angle (χ). The solar zenith angle is measured from a vertical line to the direction of the sun, and the solar azimuthal angle is measured from the North Pole direction to the direction of the sun [1].

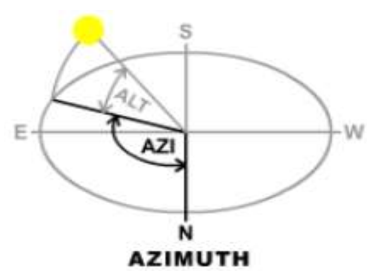

Figure 1. Solar position

Formulae for calculating the solar zenith angle and azimuthal angle are explained here, this method was showed by Murakami, T. (2010) [5]. Solar declination (δ) and hour angle (t) are indices representing the solar position on the celestial sphere. The north celestial pole is expressed as +90 degrees and the south celestial pole is expressed as -90 degrees in solar declination (δ). Hour angle (t) is the angle between the celestial meridian and the great circle that includes solar position and both celestial poles. The position of the sun relative to the earth was estimated by calculating solar declination (δ) and hour angle (t). The solar zenith angle (θ) is determined by latitude and longitude, and the solar zenith angle (θ) was calculated in order to use the solar declination (δ), hour angle (t) and latitude and longitude at the accident spot, as shown in Formula (1). The solar azimuthal angle (θ) at the accident spot is also determined by latitude and longitude, so as a first step in calculating the solar azimuthal angle (θ), the sine and cosine of χ were calculated using solar declination (δ), hour angle (t) and solar zenith angle (θ) from Formulae (8) and (9). The values of sine and cosine of χ are then:

$$\cos\theta = \sin\delta\sin\varphi + \cos\delta\cos\varphi\cos t \quad (1)$$

Where

θ : solar zenith angle (rad)

δ : solar declination (rad) φ : latitude (deg., at accident spot)

λ : longitude (deg., at accident spot)

t: hour angle (deg.)

Where,

$$\delta = 0.006918 - 0.399912\cos A + 0.070257\sin A - 0.006758\cos(2A) + 0.000907\sin(2A) - 0.002697\cos(3A) + 0.00148\sin(3A) \quad (2)$$

$$A = 2\pi/365 \quad (3)$$

Where,

J: day of the year (Julian day)

$$t = 15\,\pi\,180\,(TST - 12) \quad (4)$$

$$TST = MST + ET \quad (5)$$

$$MST = GMT + \lambda\,15 \quad (6)$$

$$ET = (0.000075 + 0.001868\cos A - 0.032077\sin A - 0.014615\cos(2A) - 0.040849\sin(2A))12\,\pi \quad (7)$$

Where,

TST: true solar time MST: mean solar time (local time) GMT: Greenwich Mean Time ET: equation of time

$$\sin\chi = \cos\delta\sin t\ \cos\theta \quad (8)$$

$$\mathrm{Cos}\chi = -\cos\varphi\sin\delta + \sin\varphi\cos\delta\cos t\ \ \sin\theta \quad (9)$$

The calculated values of sinχ and cosχ are classified into cases, and χ1 and χ2 are calculated as follows. Cosχ<0, χ1=2π－χ Cosχ>0 & sinχ<0, χ1=3π+χ If cosχ and sinχ do not fit the two above-mentioned conditions then χ1=π+χ where, χ1>2π χ2＝χ1－2π

If $\chi 1$ is less than 2π, then the calculated $\chi 1$ is the solar azimuthal angle. If the calculated $\chi 1$ is more than 2π, then the solar azimuthal angle is $\chi 1 - 2\pi$, which is equal to $\chi 2$. Therefore, either of the calculated $\chi 1$ or $\chi 2$ is the solar azimuthal angle.

2.2 NOAA SOLAR CALCULATOR[6]

2.2.1 GENERAL

The calculations in the NOAA Sunrise/Sunset and Solar Position Calculators are based on equations from Astronomical Algorithms, by Jean Meeus[7]. The sunrise and sunset results are theoretically accurate to within a minute for locations between +/- 72° latitude, and within 10 minutes outside of those latitudes. However, due to variations in atmospheric composition, temperature, pressure and conditions, observed values may vary from calculations.

The following spreadsheets can be used to calculate solar data for a day or a year at a specified site. They are available in Microsoft Excel and Open Office format. Please note that calculations in the spreadsheets are only valid for dates between 1901 and 2099, due to an approximation used in the Julian Day calculation. The web calculator does not use this approximation, and can report values between the years -2000 and +3000.

Day NOAA_Solar_Calculations_day.xls
Year NOAA_Solar_Calculations_year.xls

2.2.2 DATA FOR LITIGATION

The NOAA Solar Calculator is for research and recreational use only. NOAA cannot certify or authenticate sunrise, sunset or solar position data. The U.S. Government does not collect observations of astronomical data, and due to atmospheric conditions our calculated results may vary significantly from actual observed values.

2.2.3 HISTORICAL DATES

For the purposes of these calculators the current Gregorian calendar is extrapolated backward through time. When using a date before 15 October, 1582, you will need to correct for this.

The year preceding year 1 in the calendar is year zero (0). The year before that is -1.

The approximations used in these programs are very good for years between 1800 and 2100. Results should still be sufficiently accurate for the range from -1000 to 3000. Outside of this range, results may be given, but the potential for error is higher.

2.2.4 ATMOSPHERIC REFRACTION EFFECTS

For sunrise and sunset calculations, we assume 0.833° of atmospheric refraction. In the solar position calculator, atmospheric refraction is modeled as:

Solar Elevation	Approximate Atmospheric Refraction Correction (°)
85° to 90°	0
5° to 85°	$\frac{1^\circ}{3600''}\left[\frac{58.1''}{\tan(h)} - \frac{0.07''}{\tan^3(h)} + \frac{0.000086''}{\tan^5(h)}\right]$
-0.575° to 5°	$\frac{1^\circ}{3600''}\left(1735'' - 518.2''h + 103.4''h^2 - 12.79''h^3 + 0.711''h^4\right)$
< -0.575°	$\frac{1^\circ}{3600''}\left(\frac{-20.774''}{\tan(h)}\right)$

The effects of the atmosphere vary with atmospheric pressure, humidity and other variables. Therefore the solar position calculations presented here are approximate. Errors in sunrise and sunset times can be expected to increase the further away you are from the equator, because the sun rises and sets at a very shallow angle. Small variations in the atmosphere can have a larger effect.

3. Area of study

3.1 Geography

The area of study located in Jordan which lies on the continent of Asia between latitudes 29° and 34° N, and longitudes 35° and 40° E (a small area lies west of 35°). It consists of an arid plateau in the east, irrigated by oasis and seasonal water streams, with highland area in the west of arable land and Mediterranean evergreen forestry, the highest point in the country is at 1,854 m above sea level, while the lowest is the Dead −420 m.

3.2 Topography

The highlands of Jordan separate Jordan's main topographical feature is a dry plateau running from north to south. This rises steeply from the eastern shores of the Jordan River and the Dead Sea, reaching a height of between 610 and 915 meters This plateau area includes most of Jordan's main cities and towns' the Jordan Valley and its margins from the plains of the eastern desert. This region extends the entire length of the western part of the country, and hosts most of Jordan's main population centers.

3.3 Sun position accuracy determination of area of interest (AOI) extents.

The table 1, shows the differences of the sun position at extents of AOI (10.00 AM Aug 1 2014, (15 km *15 km)).calculated by the spreadsheet of NOAA Solar Calculator [6].

(°) degrees	latitude	longitude	Sun Elevation	Sun Azimuth
Left lower corner	31.9	35.9	50.9	100.8
Right top corner	32.1	36.1	51.0	101.2
Changing			0.2	0.4

Table 1: Sun position of AOI extents

As shown in the figure 2, The angular diameter of Sun, when seen from Earth is approximately 32 arcminutes (1920 arcseconds or 0.5 degrees)[8] and While differences in elevation and azimuth is less than 0.4° in 15 km lengths , as illustrated above It could be to use the average of corners of AOI extent, Latitude = 32.0 and longitude = 36.0 for the following calculations related to sun position.

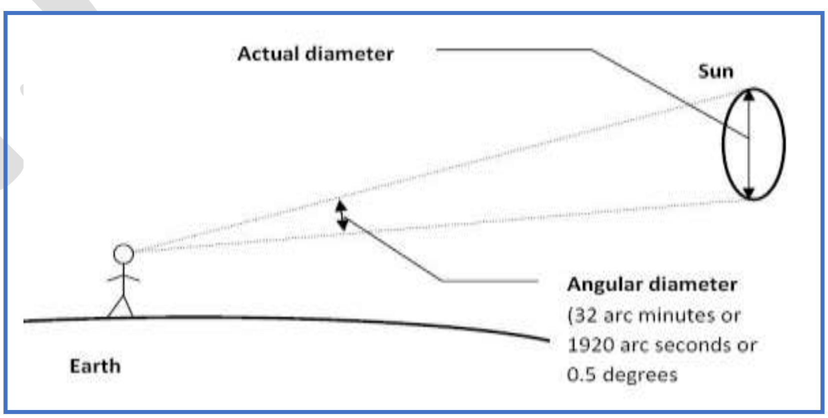

Figure 2: The angular diameter of Sun

4. Azimuth and zenith calculation of transportation.

To do further analysis on transportation networks layer and sun position it is recommended to add fields and field's values this layer in the GIS model, Azimuth, Zenith (elevations) of roads and sun position and do the calculation of each record of roads.

The main layers used in these calculation the transportation networks that derived from with high accuracy digital cadastral of DLS and the digital terrain model (DTM) derived from aerial photography shown in figure 3.

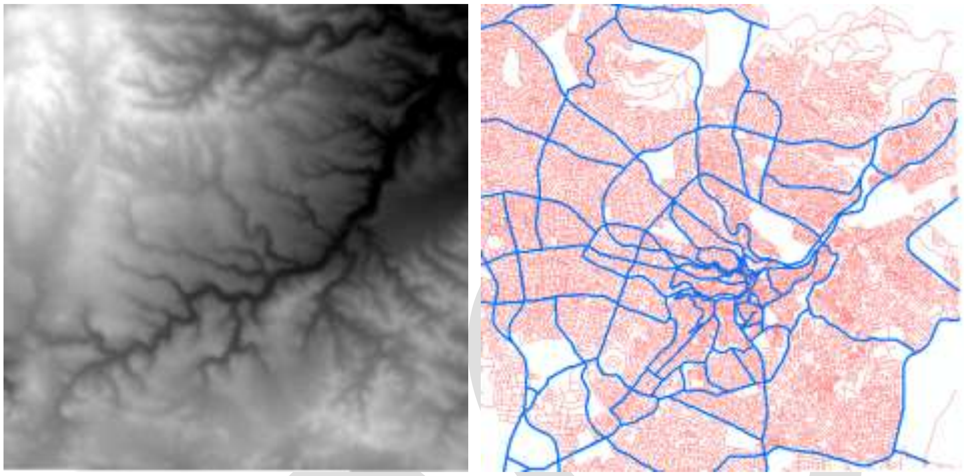

Figure 3: left DTM, right transportation network of AOI

The figure 4, shows the GIS presentation of transportations network that derived from the cadastral maps with high accuracy, The (DLS) owns reliable, comprehensive and accurate digital information which serves the objectives of comprehensive national development and is available to clients by easy, equitable and transparent means, to satisfy their needs.

Figure 4: Roads segments and cadastral boundaries.

4.1Azimuth(direction):

By definition, the azimuth of a line is the direction given by the angle between the meridian and the line measured in a clockwise direction either from the north or south branch of the meridian [9] (Anderson & Mikhail, 1998).

The geometry of a straight line can be described using a direction and a distance this can be used by the function Adding COGO attribute to a feature class and update COGO attribute[10] Shown in figure 5, and table 2.

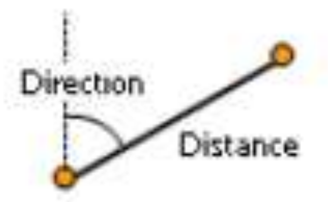

Figure 5 direction and distance

ZMainroads

OBJECT	Direction	Distance	Layer
19	69.0797	200.587	MAIN
20	69.5850	116.861	MAIN
21	69.0097	125.786	MAIN
22	9.8306	169.822	MAIN
23	[illegible]	[illegible]	[illegible]

Table 2: results of COGO attributes.

Other way of calculation the azimuth.

Azimuth formula is:

$$\text{Azimuth} = \text{ATAN}\ \Delta Y/\Delta X \quad (11)$$

Where

$$\Delta Y = YB - YA \quad (12)$$

$$\Delta X = XB - XA \quad (13)$$

By adding the fields of Start(x,y) and End(x,y) of road segments to attribute tables and calculate the above formulas. [11] [12]

4.2Zenith

Convert 2D features to 3D features by deriving the height value from a surface. There is a geoprocessing tools that allow you to obtain 3D properties from a surface: Interpolate Shape which Interpolates z-values for a feature class based on elevation derived from a raster, triangulated irregular network (TIN), or terrain dataset [13]as shown if figure 6 and table 3.

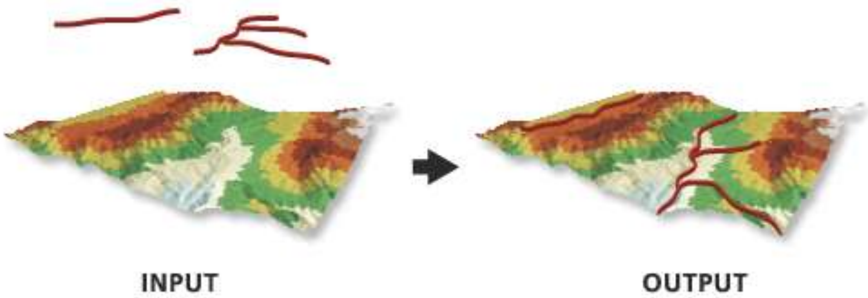

Figure 6: interpolation method.

Zf	Zt	Zdelta	Elevation	Distance	Direction	ElevAng
836.0034	834.1553	1.8481	0.06	30.566	99.9250	3.4586
832.5464	830.1634	2.383	0.04	67.823	99.6694	2.0115
782.0558	780.8045	1.2513	0.06	22.073	98.9314	3.2432
849.0919	851.4408	2.3489	0.04	67.02	98.7148	2.0065
942.3719	942.1184	0.2535	0.05	5.129	98.7135	2.8286
849.1185	848.6219	0.4966	0.01	40.578	98.5950	0.7009
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3: interpolation method tabular results.

Zenith formula is:

$$Zenith = ATAN(\Delta Z / D) \quad (14)$$

Where

$$\Delta Z = ZB - ZA \quad (15)$$

$$D = (\Delta X2 + \Delta Y2)^{1/2} \quad (16)$$

By adding the fields of Start (Z) and End (Z) of road segments to attribute tables of the transportation layer and calculate their values by the above formulas.

5. Data analysis

5.1 Sun position analysis

The purpose of this part is to determine how sun position angles vary with season and time of day, NOAA spread sheet [7] was used to analyze the elevations and azimuth of the sun of AOI (32, 36) in the year 2014.

The results of this analysis are shown in Table 4, The changing of sun position (elevation, azimuth) during changing the dates and times, The lowest sun elevations are obviously in morning and evening of days, and decreasing in winter season, it is said that sun elevation is lowest in winter more than any other season, The changing of Azimuth was obviously minimum values in the morning, and was maximum values in evening in the summer, while the winter had maximum values in the morning and was minimum values in evening. The negative sign (red) in the table indicates that the sun below the horizon plans.

The changing of sun position means that the affected roads of sun glares also vary with season and time of day, the effected next month will not be the same of the effected of today , so affected can be expected and present in advance.

date	sun elevation						sun Azimuth					
	Clock (hrs)						**Clock (hrs)**					
	6	**7**	**8**	**17**	**18**	**19**	**6**	**7**	**8**	**17**	**18**	**19**
01/01/2014	~~-19.90~~	~~-7.83~~	3.75	7.12	~~-4.08~~	~~-16.01~~	~~105.30~~	~~112.26~~	120.02	237.29	~~245.42~~	~~252.59~~
15/01/2014	~~-20.25~~	~~-8.03~~	3.77	9.35	~~-1.81~~	~~-13.89~~	~~102.87~~	~~109.94~~	117.71	237.91	~~246.27~~	~~253.65~~
01/02/2014	~~-19.25~~	~~-6.79~~	5.28	12.67	1.45	~~-11.02~~	~~98.61~~	~~105.95~~	113.86	240.45	249.09	~~256.76~~
15/02/2014	~~-17.22~~	~~-4.58~~	7.68	15.56	3.89	~~-8.63~~	~~94.49~~	~~102.10~~	110.16	243.91	252.70	~~260.57~~
01/03/2014	~~-14.26~~	~~-1.39~~	10.92	18.34	6.29	~~-6.35~~	~~90.16~~	~~98.00~~	106.19	248.40	257.21	~~265.20~~
15/03/2014	~~-10.68~~	2.30	14.68	20.88	8.52	~~-4.18~~	~~85.87~~	93.84	102.07	253.60	262.29	~~270.32~~
01/04/2014	~~-5.99~~	6.75	19.37	23.59	10.99	~~-1.59~~	~~80.87~~	88.83	96.95	260.32	268.70	~~276.65~~
15/04/2014	~~-2.26~~	10.25	22.91	25.55	12.88	0.67	~~76.99~~	84.82	92.71	265.74	273.76	281.56
01/05/2014	1.46	13.55	26.18	27.55	14.92	2.72	72.92	80.52	88.03	271.27	278.83	286.40
15/05/2014	3.54	15.58	28.11	29.14	16.61	4.51	69.83	77.20	84.36	275.16	282.33	289.68
01/06/2014	4.94	16.82	29.21	30.83	18.41	6.44	66.95	74.11	80.92	278.26	285.07	292.16
15/06/2014	5.12	16.89	29.20	31.90	19.51	7.59	65.55	72.65	79.32	279.27	285.91	292.88
01/07/2014	4.39	16.12	28.41	32.51	20.09	8.12	65.28	72.44	79.14	278.64	285.31	292.26
15/07/2014	3.16	14.93	27.29	32.28	19.78	7.69	66.32	73.62	80.51	276.67	283.55	290.61
01/08/2014	1.29	13.14	25.63	30.80	18.19	5.93	69.18	76.71	83.95	272.90	280.21	287.53
15/08/2014	~~-0.54~~	11.53	24.14	28.53	15.86	3.51	~~72.72~~	80.44	88.02	269.10	276.80	284.38
01/09/2014	~~-3.05~~	9.53	22.18	24.67	11.99	~~-0.28~~	~~78.13~~	86.03	94.03	264.14	272.24	~~280.08~~
15/09/2014	~~-4.93~~	7.81	20.39	20.85	8.26	~~-4.49~~	~~83.20~~	91.18	99.48	260.02	268.32	~~276.28~~
01/10/2014	~~-7.08~~	5.71	18.06	16.24	3.87	~~-9.01~~	~~89.23~~	97.22	105.75	255.41	263.78	~~271.73~~
15/10/2014	~~-9.04~~	3.70	15.73	12.39	0.48	~~-12.62~~	~~94.34~~	102.24	110.85	251.49	259.81	~~267.62~~
01/11/2014	~~-11.60~~	1.11	12.59	8.52	~~-3.52~~	~~-16.07~~	~~99.80~~	107.51	116.05	246.97	~~255.11~~	~~262.65~~
15/11/2014	~~-13.83~~	~~-1.51~~	9.91	6.35	~~-5.48~~	~~-17.82~~	~~103.29~~	~~110.77~~	119.15	243.55	~~251.55~~	~~258.85~~
01/12/2014	~~-16.35~~	~~-4.31~~	7.06	5.23	~~-6.34~~	~~-18.45~~	~~105.80~~	~~113.01~~	121.12	240.28	~~248.19~~	~~255.28~~
15/12/2014	~~-18.29~~	~~-6.31~~	5.09	5.45	~~-5.90~~	~~-17.86~~	~~106.48~~	~~113.50~~	121.41	238.27	~~246.21~~	~~253.26~~
01/01/2015	~~-19.88~~	~~-7.82~~	3.76	7.09	~~-4.11~~	~~-16.04~~	~~105.33~~	~~112.29~~	120.06	237.29	~~245.42~~	~~252.58~~

Table 4: sun position analysis results

The results of this analysis are shown in Table 5, the statistical summary of the above tables 4 of Sun Position analysis shows the interval of elevation angles and their azimuth intervals for the months around sharp clocks intervals.

	Clock (hrs)					
	6	**7**	**8**	**17**	**18**	**19**
Elevations angles	1-5	2-17	4-30	7-33	0-20	1-8
Azimuths angles	65-73	72-107	79-12	238-270	257-285	281-292
months	May-Aug	March-Nov	all year	all year	Feb-Nov	Apr-Sep

Table 5. The changing of sun position in different times of a year

The results of this analysis are shown in Table 6, the statistical summary of the previous table 4, Where the Sun Position is less than 10 degrees which may effects and analysis the transportation network.

	Clock (hrs)					
	6	7	8	17	18	19
Elevations angles	Less than 10					
Azimuths angles	65-120			237-292		
months	Jan-Apr , Sep-Dec					

Table 6 the changing of sun position less than 10° during a year

5.2 Transportation layer analysis

The table 7, shows the result of ArcGis spatial analysis of the transportation layer, there are a lot of roads segments exists have the ranges of sun elevation and azimuth that analyzed in previous section of sun position analysis.

	Clock (hrs)					
	6	7	8	17	18	19
Elavations angles	1-5	2-17	4-30	7-33	0-20	1-8
Azimuths angles	180±(65-73)	180±(72-107)	180±(79-102)	180±(238-270)	180±(257-285)	180±(281-292)
months	May-Aug	March-Nov	All year	All year	Feb-Nov	Apr-Sep
roads segments	918	2953	1726	991	2559	1549

Table 7: roads segments counts effected by sun glare in different times.

While the table 8, shows the result of ArcGis spatial analysis of the transportation layer, the elevation of sun and roads less than 10° have the same ranges of time, azimuth and months.

	Clock (hrs)					
	6	7	8	17	18	19
Elavations angles	less the 10					
Azimuths angles	65-120			237-292		
Months	Jan-Apr , Sep-Dec					
roads segments	4370					

Table 8 roads segments counts less than 10°.

6. Final results

6.1 Determine the angle of views.

The front windshields of vehicle is the most important factor of determining the angle of views of the driver eyes where the driver face sun glare.

The figure 7, shows the vertical angle of view approximately equal to 12.5 ° calculate by sin rule which equal to half of horizontal angle of view measured from the straight sightline parallel to road segment of driver eyes to the left side of front windshields shown in the figure 8.

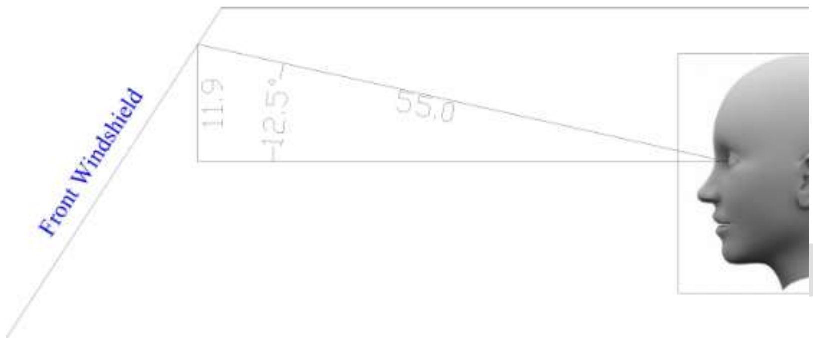

Figure 7 angle of vertical view near the front windshields.

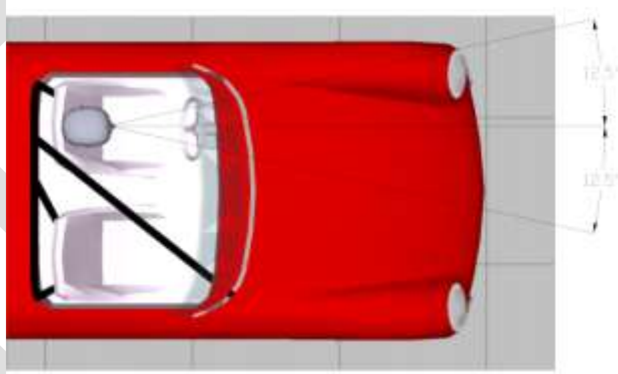

Figure 8 the horizontal angle of view

6.2 Calculate and Symbolizing Effected by Sun and

So in this study the precision of vertical angle of view will be 12.5 ° and the range of horizontal angle of view will be two times (25.0 °) that will be used in calculation of the affected roads by the sun glare, the only condition of effected roads will:

Road elevation equal to the sun elevation - 12.5°, and

Road azimuth equal sun azimuth ±12.5°

Calculation the sun position in the attribute table of transport using model builder ESRI[14],ESRI's Model Builder application with which a model, or geospatial data processing workflows, can be created to streamline or automate geospatial processing tasks, Model Builder uses a geographical user interface (GUI) which is a graphic interface that looks like a workflow with which many people are familiar figure 9, One advantage of Model Builder is that computer programming is not required to create a fully functional model; and thus opens up the application to be used by more people. [15]

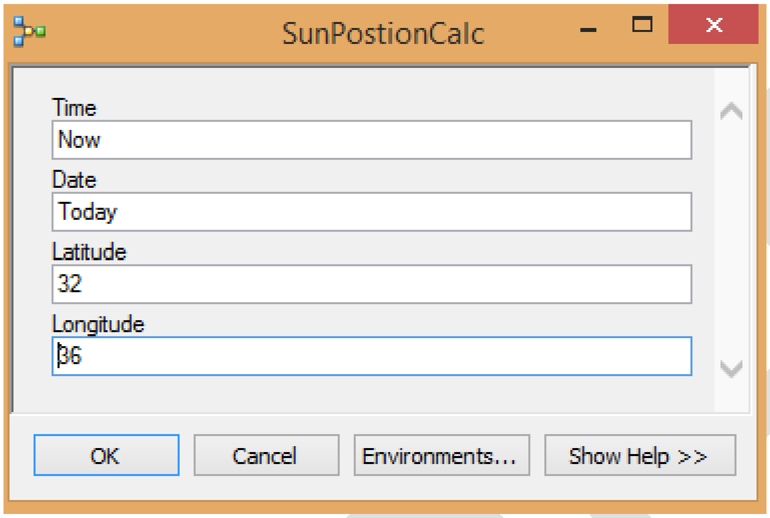

Figure 9: interface Sun position application
By Model builder

The figure 10, shows the procedure of sun position application done by model builder ESRI, the calculation of sun elevation and sun azimuth in moment of execute the model.

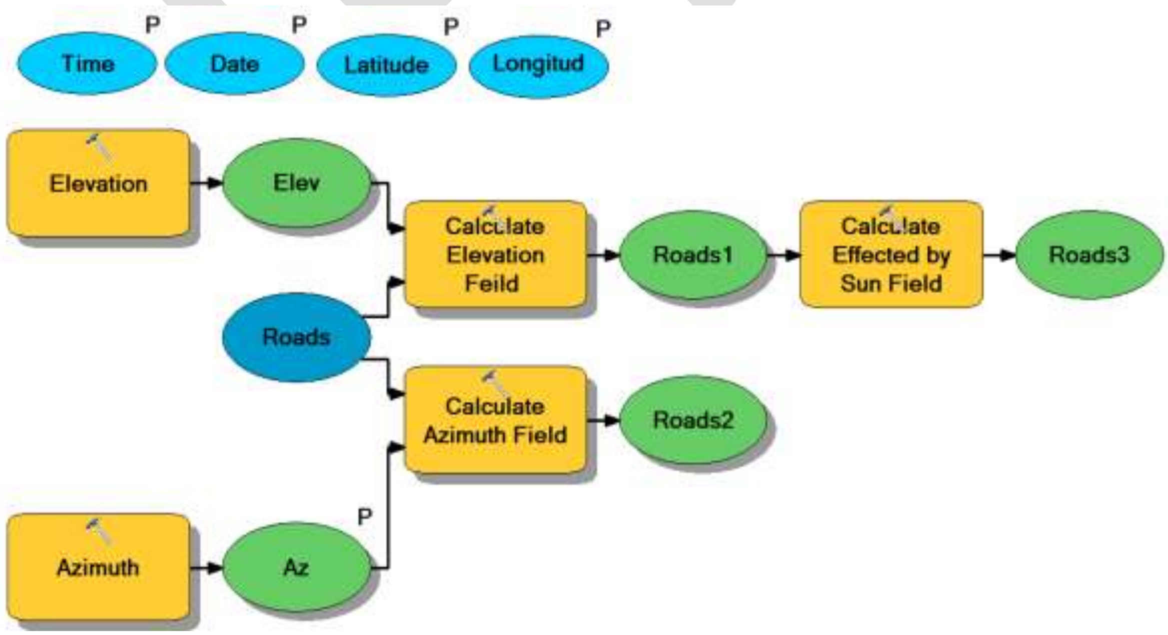

Figure 10 model builder procedures

The table 9, shows the real values the sun position of all roads segments records that calculated by model builder before, the values of effected roads by sun glare and the roads segments azimuth and zenith (elevation) values.

Sun_Elevat	RoadZen	SunAzimuth	RoadAz	Effected by Sun
8.568876	11.66	100.389832	219.79	NO
8.568876	12.52	100.389832	243.44	NO
8.568876	12.52	100.389832	2.00	NO
8.568876	13.07	100.389832	89.22	NO
8.568876	8.64	100.389832	102.80	YES
8.568876	10.62	100.389832	102.58	YES
8.568876	10.19	100.389832	104.30	YES
8.568876	7.56	100.389832	97.56	YES
8.568876	6.68	100.389832	98.85	YES
8.568876	5.10	100.389832	101.00	YES
8.568876	5.75	100.389832	98.05	YES
8.568876	8.87	100.389832	97.44	YES

Table 9: final result attributes value of Sun Position.

Figure 11, shows the GIS presentation of transportations network in 2D view of the affected roads by sun glares at specific time of Model Builder execution and symbolizes them.

Figure 11:2D road map of affected roads by sun glare.

Figure 12, shows the GIS presentation of transportations network ws 3D view of the best route sample of traveling to destination place using navigation system applications, and symbolizes the affected road of sun glare with special symbol.

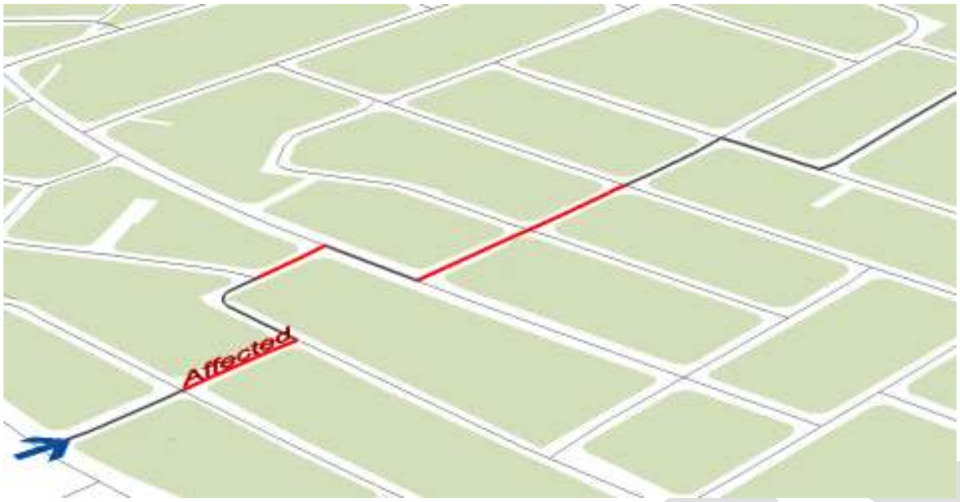

Figure 12: 3D view of the affected roads of sun glares.

7. Conclusions

The analyses show the affected roads by sun glare and Adding special symbol on transportation maps or navigations maps that have been effected on real time on the digital maps of the transportation network or on navigation maps systems, to reach this approach each transportation layer prepared in 3D model means have the elevation and azimuth attributes and values of all features of the GIS data.

This study was applied for big area (15km*15km) and it may be used for a specific or single and important road to analysis the effect of sun glare of each segment of the road in different times and dates and in advance .

The changes of sun position changes in seasons in the hilly areas and more effected the transportation network when the sun elevation in is lowest in winter and affected more roads than summer days in the north part of earth.

The useful of this study are showing messages on the intelligent traffic signs shows the following road affected by Sun glare, controls the speed on effected roads, reducing eyes harming, reducing car accidents , drivers can determined the time of travel, and Drivers change the route of travel.

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