ISSN: 2008-5079 / EISSN: 2538-2365
DOI: 10.22034/AAUD.2020.132007.1537

A Review of the Definitions and Calculation Methods of Sky View Factor*

Abdolhossein ZarifianMehr[a]- Laala Jahanshahloo[b]- Bohloul Alijani[c]- Hossein Zabihi[d]**

[a] Ph.D. Candidate of Urban Development, Department of Urban Development, Science and Reasearch Branch, Islamic Azad University, Tehran, Iran.
[b] Assistant Professor of Urban Development, Department of Urban Development, Science and Reasearch Branch, Islamic Azad University, Tehran, Iran (Corresponding Author).
[c] Professor of Climatology, Faculty of Geography, Kharazmi University, Tehran, Iran.
[d] Associate Professor of Urban Development, Department of Urban Development, Science and Reasearch Branch, Islamic Azad University, Tehran, Iran.

Received 16 May 2018; Revised 09 February 2019; Accepted 16 February 2019; Available Online 21 September 2020

ABSTRACT

The city, as a multifaceted phenomenon, has various dimensions. One of its most important dimensions, which has always been one of the debates raised in urban design and planning, is its geometry. Urban geometry and the geometry of urban valleys, which are defined by changes in height, length, and distance of buildings, significantly affect energy exchanges and thereby the temperature of urban areas. Changes in urban geometry will lead to some problems and issues, one of which is climate change on micro and medium scales. The geometry of the city has always been of interest to climatologists due to its effects on the urban climate. One of the important parameters of it is the Sky View Factor (SVF). Although urban climatologists know this factor well, it has not been properly raised among urban planners. On the other hand, since this factor is related to other climatic variables, it can play a key role in urban decision-making. Therefore, in the present study, it is attempted to present and classify the methods and techniques used for calculating this factor, while examining the need to pay attention to it. Therefore, this study aims to identify and study the types of this factor and then to study and classify various calculation and estimation methods. The results of this study show that the calculation and estimation of SVF have started with photographic and analytical methods and increasingly expanded with software and GPS methods. Also, at the end of this study, a classification of the background of the topic, along with various calculation methods and techniques and related software, is presented in a table in detail.

Keywords: Urban Geometry, Sky View Factor (SVF), Method.

* The present study is derived from the first author’s doctoral dissertation entitled “Study and analysis of the effect of urban geometry on urban climate”, which was defended under the supervision of the second and fourth authors and the advice of the third author at the Islamic Azad University (Science and Research Branch), Tehran.

** E_mail: l.jahanshahloo@srbiau.ac.ir

1. INTRODUCTION

Given the increasing problems of urbanization, especially the phenomenon of heat islands, current cities need accurate and extensive planning for future development and maintaining the quality of their urban environment (Jusuf, Ignatius, Wong, & Tan, 2017; Unger, 2017). On the other hand, the geometry of urban valleys, which are defined by changes in height, length and distance of buildings, significantly affects energy exchanges and thereby the temperature of urban areas and urban microclimates (Grimmond, Potter, Zutter, & Souch, 2001; Fredrik Lindberg, 2005). But this temperature also depends on a number of geographical-geometric factors (such as SVF) and meteorological variables (Upmanis & Chen, 1999). A short literature review suggests that one of the most common indicators used for describing urban geometry is SVF (Chen, Ng, An, Ren, Lee, Wang, & He, 2012).

The SVF has become one of the most important predictors of the UHI intensity due to its application in urban climate and UHI patterns and its contribution to local-spatial data and available techniques (Drezner & Shaker, 2010; Jusuf, Ignatius, Wong, & Tan, 2017; Yamashita, Sekine, Shoda, Yamashita, & Hara, 1986).

Although the SVF is internationally well recognized in urban climatology and energy level analysis (Li, Putra, & Yang, 2004), it has not progressed well in Iran and there are no reliable references on it (Behzadfaz & Monam, 2012). Also, it has not been recognized as a geometric parameter widely accepted in urban planning and design. The followings can be mentioned as some reasons for this (Li, Putra, & Yang, 2004):

- Lack of knowledge and lack of communication with climatologists.
- Lack of sufficient evidence indicating the importance of the SVF in design.
- Lack of sufficient and efficient tools for assessing the quality of SVF or lack of interaction between SVF evaluation and design process.

The application of this factor and the necessity of its application in urban climate issues are very obvious. In climate studies, the SVF is considered as an important geometric parameter because it is correlated with local thermal performance and potentially important in the urban design process (Li, Putra, & Yang, 2004). Another reason for the importance of the SVF is that the obstruction of long-wave radiation is estimated using it (Gustavsson, 1995), because the nocturnal cooling (also called night sky cooling) process is mainly influenced by the emission of long-wave radiation (Unger, 2004). In other words, reduction in the SVF increases the absorption of short-wave radiation during the day and decreases the emission of long-wave radiation during the night, making urban areas warmer (Johnson, 1985; Park, 1987). Quoted from Oke (1981) and Park (1987), Eliasson (1996) stated that there is a relationship between maximum island heat intensity and the SVF for some cities in Australia, Europe, North America as well as Japanese and Korean cities. Therefore, it is clear that the SVF plays a key role in thermal comfort and urban climate (Bourbia & Boucheriba, 2010). In other words, since there is a relationship between the SVF and surface temperature (Eliasson, 1992) and surface temperature is also derived from MRT - one of the indicators affecting thermal comfort[1]- it is obvious that the SVF also plays an important role in thermal comfort. Although the SVF cannot determine or control the temperature (Matzarakis, Rutz, & Mayer, 2000), Matzarakis et al. considered it as a determinant parameter in the MRT prediction model (Li, Putra, & Yang, 2004). Also, one of the advantages of the SVF over other geometric parameters such as H/W is that its ability to much better describe a complex urban environment (Johnson & Watson, 1984; Unger, 2009).

The present study was carried out using library studies, review of documents, and articles related to urban climate in general and SVF in particular. According to the authors, the present study is review-translational research, because it reviews the definitions and calculation methods of the aforementioned factor and presents a classification of them. Also, due to the lack of Persian references, almost 100% of the references used were in the English language and this had a significant effect on the development of this study. Thus, significant parts of the present study include the translations of other studies. So, it was greatly attempted to carefully refer and observe fidelity.

The present study was organized into six main sections. The first section, i.e. introduction, describes the research topic and presents a short background of it and the research methodology. The theoretical literature of the topic is reviewed extensively. In this section, various definitions and calculation methods of the SVF are examined. The third section includes the research conclusion. An appendix containing acronyms or abbreviations is presented. In order to avoid repeat Latin phrases and sometimes long Persian equivalents, English abbreviations are used in the study. Finally, some notes (or postscripts) are presented to further explain some contents, and a list of references used is provided at the end of the article.

2. THEORETICAL FOUNDATIONS

In this section, in addition to the definitions of the SVF, its types are investigated in terms of dispersion and location of measurement. Also, SVF calculation methods are classified into four main categories: analytical, photographic, software, and GPS, and 10 types of techniques along with applications.

2.1. Definitions

SVF is a parameter used in urban climatology. It refers to the amount of sky visible from a point on the ground. It is a geometric ratio that expresses a fraction of the sky observable from the observer's viewpoint (De Souza & Da Silva, 2006). It is a quantitative, dimensionless

factor with values varying between 0 and 1 (Bottyán & Unger, 2003; Chapman, Thornes, & Bradley, 2001; Oke, 1988) and describes surface geometry. The value 1 represents the complete visibility of the sky, and as this value approaches zero, the sky is covered with artificial or natural elements. Therefore, this factor is examined to discover the effects of a complex urban surface on the climatic processes of urban built-up areas (Hämmerle, Gál, Unger, & Matzarakis, 2011).
In other words, taking a point on the (ground) surface, one part of the radiation from the point is absorbed by the surrounding surfaces (building, tree, etc.) and the remaining radiation is directed to the sky. The measure of this parameter is defined as SVF, which means that the value of SVF can be calculated by subtracting the sum of all the VFs calculated for the "seen" surfaces from 1 (Unger, 2009). The surface marked by SB on the hemisphere shows the shape of the building 'seen' from ΔA (Fig. 1). In this case, the SVF is:

$$SVF=1-VF_{Building\text{-}\Delta A}=1-VF_{S_B\text{-}\Delta A}$$

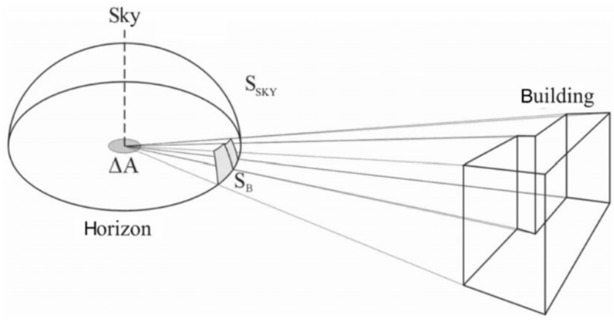

Fig. 1. Projection of the Seen Surface of the Building on the Assumed Hemisphere Surface
(Unger, 2009)

2.2. Types of SVF

There are two types of SVF in terms of the types of dispersion in the environment:
Discontinuous SVF (DSVF): This type of SVF is individually collected in urban environments and the data on them are not defined relative to each other. This type of measurement is usually performed with a limited number of points.
Continuous SVF (CSVF): When there are a large number of points collected or it is possible to connect them and provide an accurate and correct simulation of the areas between the points with collected SVF the continuous SVF is carried out. Today, various techniques such as IDW in ArcGIS software have the ability to do this (Fig. 2).

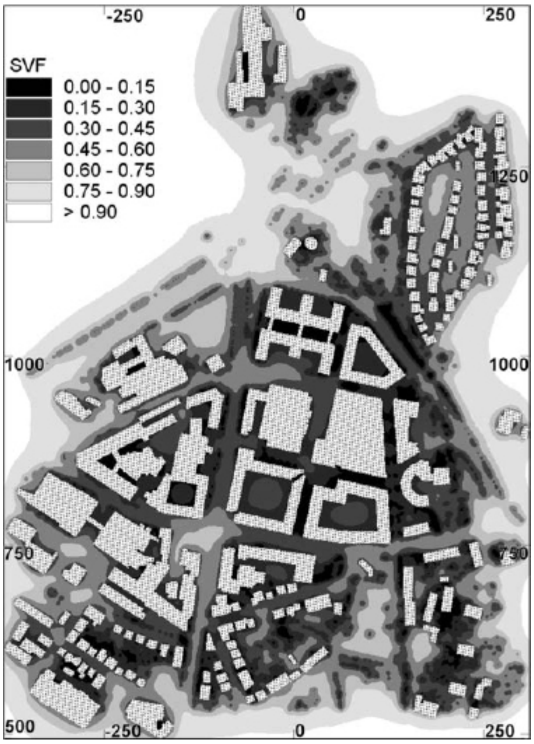

Fig. 2. An Example of a CSVF
(Matzarakis & Matuschek, 2011)

In addition, there are three types of SVF in terms of the measurement location (Chun & Guldmann, 2014):

• Ground SVF (SVF): it is a SVF measured at ground level and represents the pedestrian viewpoint.

• Roof SVF (RSVF): it is a SVF measured on the roof.

• Total SVF (TSVF): According to the map grid, TSVF can be calculated using the following equation:

$$TSVF=\sum_{i=1\rightarrow Ng} GSVF_i + \sum_{i=1\rightarrow Nr} RSV_{Fi}$$

Also in Figure 3, points 1, 2, and 3 are GSVF, and points 4 and 5 are RSVF.

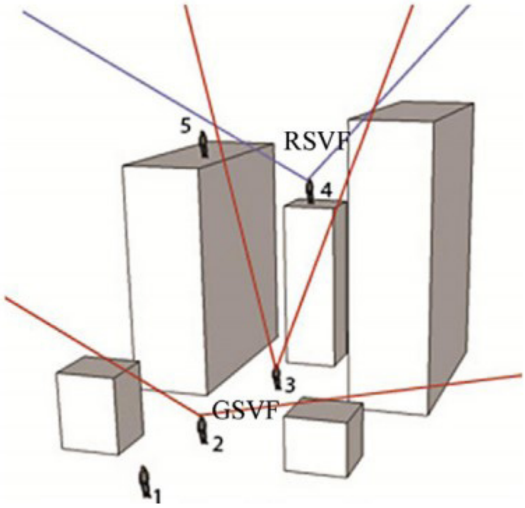

Fig. 3. SVF Types Based on Measurement Location

(Chun & Guldmann, 2014)

2.3. SVF Calculation Methods and Techniques

Up to now, various methods have been suggested for the calculation of the SVF considering different techniques, some of which are described in the following:

2.3.1. Analytical (Geometrical) Method

For the first time, Johnson and Watson (1984) have proposed a SVF calculation method. According to their method, the SVF is calculated only by "elevation" and "azimuth angles of a building" (Unger, 2009). In this method, the SVF estimation is based on the geometric characteristics and "radiation exchange model" of urban valleys (Chen et al., 2012). The pioneers of this method were Oke (1981) and Johnson & Watson (Johnson & Watson, 1984). In this method, SVF is calculated directly by the angle above the horizon and the corners of the surrounding buildings. Oke (1981) has presented the method for the urban symmetric valley along the infinite length, and Johnson & Watson (Johnson & Watson, 1984) have provided the same method for asymmetric valleys along the finite length (Watson & Johnson, 1987).

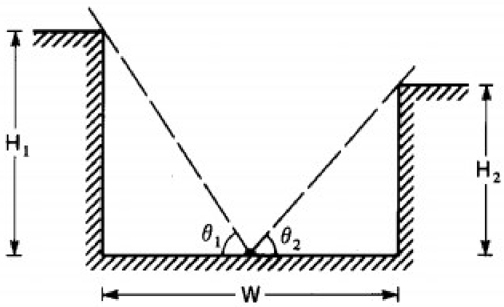

Fig. 4. Asymmetric Cross Section of an Urban Valley Surrounded by Buildings 1 And 2.

(Oke, 1988)

According to Figure 4, if it is assumed that the length of the urban valley is infinite, the VF of each wall (ψ_w), is calculated with the relation of ψ_w=(1-cos θ)/2 where θ=$\tan^{-1}$(H/0.5W). Accordingly, SVF is equal to: ψ_S = 1- (ψ_{w1} + ψ_{w2}), and for symmetric cross-sections, the relation will be simpler: ψ_s = cos θ (Oke, 1988).

This type of method (i.e. analytical)[2] provides a theoretical framework for determining the SVF of a particular point in different urban structures. This type of method is suitable for simple structures and can be used for algorithm testing and parametric analysis (Chen et al., 2012).

2.3.2. Photographic Method

Anderson (1964) was probably the first person who applied the "view factor" through a photographic approach when using photographic calculations to estimate the distribution of sunlight in forest canopy studies. However, since the 1980s, photographic methods have been sufficiently considered to determine the SVF in urban climate studies (Chen et al., 2012). Steyn (1980) has introduced a method to determine a geometrically correct SVF using FE images (Fig. 5) for complex urban environments (Unger, 2009). Steyn's "Equiangular Projection" (1980) is the most commonly used method. He has divided the images into concentric rings of equal width, then summed up all the circular sections- that represented the sky- and obtained the SVF based on the following equation (Chen et al., 2012):

$$\psi_{\text{sky}} = \frac{1}{2n}\sum_{i=1}^{n}\sin\left[\frac{\pi(i-1/2)}{2n}\right]\cos\left[\frac{\pi(i-1/2)}{2n}\right]\alpha_i$$

The Where n is the total number of rings. i represents the ring number and αi denotes the angular width of the sky in the ith ring. Johnson & Watson (1984) also later proposed the modified version of Steyn's method (Chen et al., 2012):

$$\psi_{\text{sky}} = \frac{1}{2\pi}\sin\frac{\pi}{2n}\sum_{i=1}^{n}\sin\left[\frac{\pi(2i-1)}{2n}\right]\alpha_i$$

To complete this method, Steyn et al. (1986) have proposed another technique for measuring the SVF. To apply this technique, a video image taken using the FE lens was required. They have also compared the results of their studies with the technique supposed by Johnson & Watson (Johnson & Watson, 1984). The results of their study on three case studies showed very little difference between the two aforementioned methods. To calculate the SVF using this type of method, first, images printed on the "Polar Coordinate Graph Paper" were analyzed manually and traditionally. Being time-consuming and the presence of error were the disadvantages of this method. Some experiments were then carried out to make this method automatic (Bärring, Mattsson, & Lindqvist, 1985) which resulted in the digitization of FE images with video cameras and then the direct collection of images using a video camera adjusted with FE lens (Steyn, Hay, Watson, & Johnson, 1986).

Fig. 5. An Example of FET Images
(Chen et al., 2012)

In the evolving process of this method, Grimmond et al. (2001) used digital cameras with FE lenses. These cameras provided an accurate estimation of the SVF, which was written with the Fortran Program (Unger, 2009). Svensson (2004) has also measured the SVF at two elevations (ground level and 2 m above the ground level) and with FET. The results indicated it is better to use FE photos taken at the ground level. Holmer (1992) also evaluated FE images in small sectors using a digitalizing tablet connected to a computer (Unger, 2009). Grimmond et al. (2001) have also proposed two simple techniques that objectively and rapidly estimate the SVF. Both techniques are based on FET. The first technique was to apply a digital camera (with a spherical lens) and the second one was to apply the "LI-COR LAI-200 Plant Canopy Analyzer" to automatically measure "Diffuse Non-Interceptance Light" using an optical sensor. In both techniques, data collection and processing are rapid and data storage is simple. In addition, Chapman et al. (2001) have developed a fully automated digital approach to distinguish the sky from non-sky. This method is applied using gray digital numbers on "converted fisheye images". They have developed the calculation of SVF based on Steyn's (1980) work (Unger, 2009). Moreover, one of the calculation methods of the SVF is to use "thermal fish-eye photography ", which accurately estimates the values of SVF. The reason for this accuracy is the fact that thermal images clearly distinguish the cold sky from warm barriers such as buildings (Chapman, Thornes, Muller, & McMuldroch, 2007; Debbage, 2013).

According to this theoretical framework, the photographic method was developed by expanding it to unequiangular angles and using stronger hardware and software. However, some environmental limitations in basic data collection using this method made it an unsuitable method for analyzing large areas (Chen et al., 2012). Moreover, collecting essential data in cities with complex skylines can be tiresome using this method (Johnson & Watson, 1984).

However, the method of photography of the environment and analysis of it has been developed based on newer techniques. Accordingly, Liang and his study team in a study entitled “Automatic Estimation of Sky View Using Street View Photos - Metadata Approach 2 Automatic Sky View Factor Estimation from Street View Photographs A Big Data Approach” pointed out that FET is one of the appropriate approaches to estimate the SVF. Also, high-resolution urban models such as LiDAR[3] (Light Detection and Ranging), and “Oblique Airborne Photogrammetry” can well estimate CSVF in large urban areas. However, such data are not always available and there are problems to obtain them (Liang, Gong, Sun, Zhou, Li, Li, Liu, Liu, & Shen, 2017). In contrast, SVPs [4] are widely available in urban areas worldwide. Using street view panoramas, Liang et al. have estimated SVF values for Manhattan Island, New York. To check the accuracy of their study, they compared the results of their study with two independent sources - LiDAR which is based on the Digital Surface Model (DSM) and Oblique Airborne Photogrammetry which is based on 3D City Models (OAP3D). The results indicated the correlation coefficients of 0.863 and 0.987, showing that it is a reliable estimation (Liang, Gong, Sun, Zhou, Li, Li, Liu, & Shen, 2017).

2.3.3. Software Method

There are many methods of estimating the SVF value, including geometric models, fish-eye lens photograph analysis, image processing, and diagram or graphical determination. However, the SVF calculation using these methods is not straightforward and such methods usually require time and money. In addition, the main problem of these methods is the delineation of the sky from buildings (Souza, Rodrigues, & Mendes, 2003a). Moreover, perhaps the biggest challenge faced by climatologists in using SVF data is the limitation of image collection in non-ideal climatic conditions (Chapman & Thornes, 2004). Considering that in urban environments, the SVF is mainly determined by buildings as the main elements on the ground (Unger, 2009), Souza et al. (2003b) have developed a method for estimating the SVF value in urban environments using GIS. To validate this tool, they have compared the actual SVF values with the obtained results of the simulation. This comparison confirmed the validity of this tool for estimating the SVF value. Also, Unger (2009), in his study, has presented an algorithm based on Souza et al.’s work (De Souza & Da Silva, 2006; Souza, Rodrigues, & Mendes, 2003a, 2003b) and using Arc View 3.2. He investigated the proposed algorithm using two SVFbasin and SVFinfinite calculation methods and the results showed a slight difference between the calculated SVF and the other two SVFs (the differences were 0.04% and 0.01%, respectively). Also, the calculation radius of SVF was considered to be 200 meters.

Gal et al. (2008), in addition to the calculation of continuous SVF for the area of 75.26 km2, Szeged City, Hungry, have compared the two methods. One of these two methods was based on vector data and another one based on raster data. This study was performed using Arc View 3.2 software, based on Souza’s model (Souza, Rodrigues, & Mendes, 2003b). In this study, the city was divided into 103 cells and about 900,000 points were used to estimate the SVF. The approximate time considered to calculate the SVF per cell was 24 hours (in the vector method). In the raster method, the SCA technique was used based on Ratti’s studies (Ratti & Richens, 1999). As shown in Figure 6, the results of the models indicated very high similarity between the two methods (correlation coefficient: 0.9827).

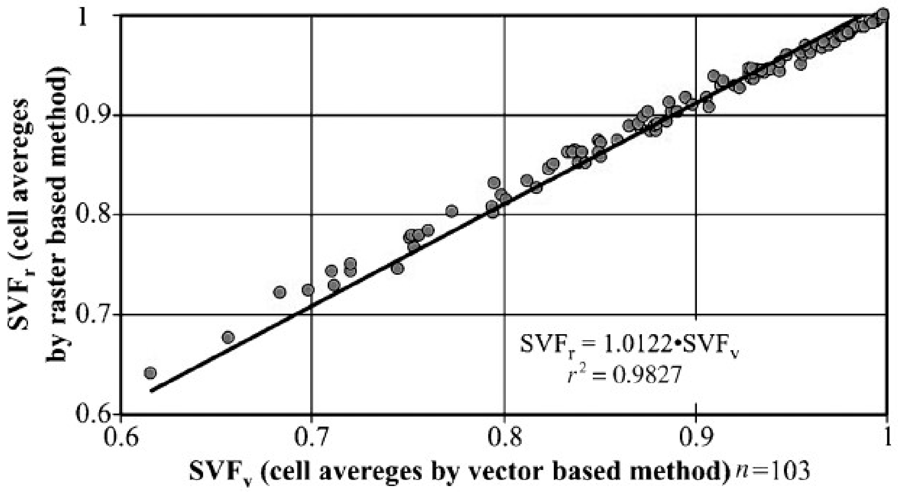

Fig. 6. Correlation between SVFr (Raster) and SVFv (Vector)
(Gál, Lindberg, & Unger, 2008)

In the application of software methods in general and the GIS system in particular, Thomas Gall et al. (2007), in their study entitled “Comparison between sky view factor values computed by two different methods in an urban environment”, have provided a method for SVF calculation by GIS, for which a 3D building database was essential. Besides, they have provided a basis for calculating the SVF based on FE. The comparison between the two methods indicated significant differences in the calculations, which were generally due to the presence of plants around the sites. Apart from the vegetation variable, there was a significant correlation between the two values. Therefore, the vector-based method can be considered a reliable method for the SVF calculation in urban environments. They also have pointed out that if a 3D building database is available, using the vector-based method takes a few days due to the high volume of computational operations (Gál, Rzepa, Gromek, & Unger, 2007).

Additionally, Chen et al. (2012) have proposed a rapid software method for calculating CSVF values. This method has been developed in a completely urban environment using a three-dimensional GIS database. For this purpose, a computer program was written in VBA programming language and run as Macro in ArcGIS. This mixed algorithm has the same geometric settings and theoretical basis as the vector method proposed by Gál et al. (2008). But it uses high-resolution DEM as input data. Chen at al. have combined the three-dimensional building database with a topographic database to create a DEM layer representing the height of the urban area. Figure 7 shows the illustration of this algorithm.

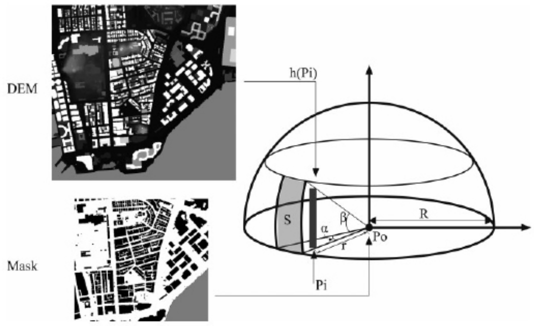

Fig. 7. Illustration of the SVF Calculation Algorithm
(Chen et al., 2012)

In another study, Chun & Guldmann (2014) have used three-dimensional and two-dimensional data to perform the spatial-statistical analysis and simulation of the heat island for the downtown of Ohio, and have stated that the results of changes in measured variables were consistent with previous studies. LST and TSVF were of variables they measured. Studies show that as TSVF increases LST decreases.

Although GIS, with its unique capabilities, has been successful in processing vector and raster data, Matuschek and Matzarakis (2011 and 2011), in their studies, have criticized the application of GIS in the SVF calculation, and states three problems: 1. GIS software and “3D Analyst extension” are expensive; 2. Specialized knowledge and a significant amount of time are required to provide the maps; and 3. GIS has difficulties in implementing some urban characteristics such as multiple surface reflection and tree modeling because GIS has not been basically designed for such a purpose. Accordingly, Matzarakis and Matuschek (2011), in their studies, have pointed out that there are powerful models and procedures for calculating the SVF value. However, they are sometimes very slow and complex to use for calculating different case studies. Finally, they have provided the “Skyhelios Model” for CSVF simulation and DSVF calculation in complex environments. Among other advantages of this model, one can mention short computing time, short development time, and low costs.

The Skyhelios model allows for modeling complex environments such as trees and non-flat roofs, while this is not possible using “raster-based” approaches. Also one of the advantages of this model is its higher accuracy without an increase in runtime (Matzarakis & Matuschek, 2011; Matzarakis, Mayer, & Chmielewski, 2010, pp. 534-539).

In addition to the application of the aforementioned software for the SVF calculation and estimation, other software has been used in combination with them or even separately. For example, Debbage (2013), in his studies, evaluated the spatial distribution of SVF values for different land use classes (downtown, commercial, residential, rural, and open areas) in Athens. Using the Magic Wand tool in Photoshop, he extracted the SVF values from the fisheye images and then estimated the SVF values for the downtown as well as the residential area by entering the coordinates of the points photographed in the ArcMap software and using the IDW tool.

In addition to using actual photos to calculate SVF values, those models with the ability to extract SVF values from digital environmental models have been developed, one of which is the RayMan Model. This model is based on digital data in both raster and vector forms and has the ability to quickly calculate SVF values for various areas (Matzarakis & Matuschek, 2011). Asawa et al. (2008) also have developed a “thermal design tool” for outdoor space planning. This tool has been developed by simulating the heat balance for urban surfaces (buildings, ground, and green surfaces) using a 3D-CAD system that can also be run on a personal computer. Besides, they have introduced the multiple tracing simulation method for calculating the SVF and radiative heat transfer. Vieira et al. (2003) have also compared the two variables of SVF and urban density using the multiple regression equation using IDRISI software. Jusuf et al. (2017) have designed a plugin (Screening Tool for Estate Environment Evaluation (STEVE Tool)) using the platform of Sketch Up software. This plugin has the ability to calculate the SVF and some other climatic factors.

There are two main approaches to examine software methods depending on the types of databases used: vector method and raster method (Chen et al., 2012). On the other hand, the " Shadow Casting" technique is one of the relatively new approaches to build a raster-based database for calculating the SVF. The output of this technique is a black and white image that shows the amount of light and shadow for each point. This method operates very quickly and can process large areas of a city in a limited timeframe, but the primary database must have a very high resolution (2MB/pixel) (Unger, 2009). This technique was introduced by Ratti (Ratti, 2001; Ratti & Richens, 1999, 2004). In the following, Lindberg (2005), in his study, has calculated the "sky view factor" in the area of about 2 square kilometers using SCA and DEM data. Also, in order to test the accuracy of the SVF, he has compared the obtained values with those calculated by the FET method. The results showed that if the data of 4 points in the parks of the city are removed, there will be a very strong relationship between the data of the two methods (R2 = 0.95), because the photos were taken in the seasons when the trees had green leaves and the SVF values were underestimated. Also in another study, Lindbergh and Grimmond (2010) estimated the CSVF value using DEM data, and through SCA. They have compared their method with previous methods based on "shadow casting", introduced by other researchers (Ratti, 2001; Ratti & Richens, 1999, 2004). They have stated that the "absolute mean difference" between the two methods was about 0.002. Besides, Hodul et al. (2016) have proposed a method for estimating the CSVF value. Their method used "Landsat 5 TM" satellite images and LiDAR data. The basis of this method was "shadow casting". The relationship between the SVF and Shadow Proportion (SP) has also been assessed in four US cities. The results indicated an inverse relationship and a correlation coefficient of 0.85 between SVF and SP.

Although the software methods are considered a class of methods, the software has been mainly developed to facilitate other methods or their input data are three-dimensional images or data. For example, in a study entitled " Comparison of models calculating the sky view factor used for urban climate investigations" in Hungary, six FET-based models were tested:

From the six models of 1. Steyn's model (Implemented in a GIS-Script) (Steyn, 1980), 2. Rayman model, 3. BMSkyView, 4. Skyhelios, 5. ArcView SVF Extension, and 6. SOLWEIG Model, the former three models operate based on images and the latter three models with the addition of a three-dimensional building database (Hämmerle, Gál, Unger, & Matzarakis, 2011).

2.3.4. GPS Method

Compared to the above methods, which are based on the direct SVF calculation, the GPS method was first developed using proxy data by Chapman et al. (2002). Accordingly, Chapman and Thornes (2004) have followed two issues regarding SVF data collection: 1. Despite numerous methods, no method has been proposed for calculating the "real time" SVF[5]; and 2. There was a need to expand the space of surveying in non-ideal conditions. Therefore, using three techniques of FET, GPS, and ANN model[6], they have provided an acceptable method for predicting the SVF. Chapman et al. (2001, 2002), in their studies, have also calculated the SVF value via GPS. To validate their research, they have compared their technique with FET and the results indicated that the correlation between data was 88% for urban areas, 72% for rural areas, and 52% for suburbs. The main changes were due to vegetation, tree canopy, and height. It should also be noted that the GPS method is commonly used in combination with FET. So Bradley et al. (2001), in their study in Birmingham City, have evaluated the SVF value for six various urban areas (including downtown, high-density and low-density residential, industrial and open areas) using FET and GPS and installing the digital camera on the car to record and capture photos per 20 meters. They stated that this method, in addition to being fast, is also economical and repeatable.

In conclusion, it should be noted that this method provides good results if used in urban environments, but does not have a good explanatory ability to be used in suburban and rural environments, because changes in tree coverage cause noise in signal processing. GPS is also combined with an FE lens to record and process images on a "mobile platform" to provide simultaneous real time SVF calculation and estimation. In addition, there are several features that make the GPS method more attractive than traditional methods:

(1) These methods are fast and relatively inexpensive; (2) This type of method, unlike photographic methods, does not depend on atmospheric conditions; (3) In this type of method, one can easily communicate with the GIS platform. However, there are some limitations to using this method: (1) It is not inherently accurate and is not an appropriate method where accuracy is required; (2) The prediction equation depends on GPS equipment, so it is impossible to obtain a global equation; and (3) This method has a suitable performance only when being used in urban areas (Chen et al., 2012).

3. CONCLUSION

In the present study, in addition to the definitions of SVF and the introduction of its types in terms of dispersion and location of measurement, various SVF calculation methods have been studied and analyzed. According to the literature review, the SVF is one of the geometric parameters of the city and refers to the amount of sky visible from a point on the ground. This factor has always been of interest to climatologists due to its various application in urban climate studies and also its relationship with the phenomenon of heat islands. It is also required and necessary to introduce this parameter to urban designers, planners, and managers.

According to the literature review, many methods have been developed for calculating and estimating the SVF values. The SVF estimation has been started with geometric and photographic methods and continued using software- and GPS-based methods. "Methods such as analytical methods are suitable for simple structures and can be used for algorithm testing and parametric analysis" (Chen et al., 2012). Due to some environmental limitations in basic data collection, the photographic method is not suitable for analyzing large areas and wastes a lot of time and money, although with new techniques such as "street view panoramas", this defect has been partially removed. In contrast, the development of various software and the application of them in the SVF calculation have played a key role in increasing the accuracy, and precision and reducing computing time, one of which was GIS. "GIS 3D tool" is a very useful tool not only for its ability to directly and quickly analyze urban geometry but also for its ability to predict the SVF given the buildings to be constructed in the future. Additionally, this ability, in addition to the elimination of the usual costs expended for the camera and image processing, is considered as its advantage (Souza, Rodrigues, & Mendes, 2003a). However, issues such as the expensiveness of related extensions and the difficulty it has in analyzing multiple surface reflection and tree modeling are of its disadvantages. "The GPS method is also straightforward and inexpensive" (Chapman, Thornes, & Bradley, 2001; Chapman, Thornes, & Bradley, 2002) and does not depend on atmospheric parameters. However, one of its disadvantages is its inadequate accuracy. In general, Table 1 presents a review of the SVF history, calculation methods and techniques, and the software used, along with more detailed information.

Table 1. Presents a Review of the SVF History

Environment	City	Area (KM2)	Type of SVF						Primary data								Year	Researcher	Row
			LSVF(m)	CSVF	MSVF	TSVF	GSVF	RSVF	DEM	satellite Data	Aerial photograph	3D Building	DSM	Infrared images	street view photo	Fish eye photo			
	G						❊										1981	Oke	1
																	1984	Johnson & Watson	2
Urban, densely built-up area	Malmo	8#	eye				❊									❊	1985	Bärring et al	3
urban and rural	Birmingham	20km long	1.4		❊		❊										1985	Johnson	4
SubUrban	5 Japanese cities	0.1 3.3	1.2				❊									❊	1986	Yamashita et al	5
							❊									❊	1986	Steyn	6
CBD	H						❊										1987	Park	7
																	1987	Watson & Johnson	8
							❊									❊	1992	Holmer	9
Different parts of a city	Goteborg	0.6					❊							❊		❊	1992	Eliasson	10
Different parts of a city	Goteborg	4#					❊									❊	1996	Eliasson	11
Urban Parks & built-up area	Goteborg	1.6					❊									❊	1998	Upmanis et al	12
Urban Parks & built-up area	Goteborg	3.3km long					❊									❊	1999	Upmanis et al	13
Urban	Birmingham	~7km long					❊									❊	2001	Bradley et al	14
																	2001	Chapman et al	15
	Bloomington	60km long	1.2,1.4				❊									❊	2001	Grimmond et al	16
Urban,SubUrban,Rural	Birmingham						❊										2002	Chapman et al	17
Urban	Szeged	24.25	1.5				❊										2003	Bottyán and Unger	18
	Braga						❊					❊					2003	Souza et al	19
Urban	Belo Horizonte	~2#					❊					❊				❊	2003	dos Santos et al	20
Urban	Lisbon	82.5، 7.2					❊					❊					2003	Vieira & Vasconcelos	21
urban and rural	Szeged	26.75	1.5				❊										2004	Unger	22
Urban dense canyons	Goteborg	3	2				❊									❊	2004	Svensson	23
urban and rural	Birmingham	110km long	1.5				❊									❊	2004	Chapman & Thornes	24
Urban	Goteborg	~2		❊			❊		❊			❊				❊	2005	Lindberg	25
Urban	Szeged	0.41					❊		❊			❊				❊	2007	Gál, Rzepa et al	26
urbanized area	Szeged	26.75		❊			❊		❊			❊					2008	T. Gál et al	27
urbanized area	Szeged	26.75		❊			❊		❊								2008	T. Gál et al	28
urban area	Szeged	26.75	1.4				❊		❊		❊	❊					2009	Unger	29
Urban,SubUrban,Rural	Greater London	1,572		❊			❊		❊								2010	Lindberg&Grimmond	30
CBD	Milwaukee	~2	0.1				❊									❊	2010	Drezner & Shaker	31
central parts of city	Constantine	12km long	1.5				❊									❊	2010	Bourbia & Boucheriba	32
Urban	Szeged	~1					❊					❊				❊	2011	Hämmerle, Gál et al	33
urban	Swabian	54		❊			❊		❊			❊					2011	Matzarakis&Matuschek	34
densely built-up area	Kowloon	22.4		❊			❊		❊			❊					2011	Chen and Ng	35
Urban park	Tehran	1.42	0.15				❊									❊	2012	Behzadfaz & Monam	36
densely built-up area	Hong Kong	3.2 & 3.6	1.5	❊			❊		❊			❊				❊	2012	Chen et al	37
urban and rural	Athens		Sh	❊	❊											❊	2013	Debbage	38
CBD	Columbus	46.5		❊		❊	❊	❊				❊					2014	Chun and Guldmann	39
urban	Vancouver	~120		❊			❊			❊			❊				2016	Hodul et al	40
CBD	Singapore						❊					❊					2017	Jusuf et al	41
densely built-up area	Manhattan	45					❊								❊		2017	Liang et al	42

Tools-Software																							Row
SOLWEIG	COT	SketchUp	FORTRAN	VB	EBBA	SkyHelios	BMSkyView	TOWNSCOPE II	RayMan	SVFMAKRO	IDRISI	ERDAS IMAGINE	C++	Matlab	ENVI	AutoCad	MapInfo	Adobe Photoshop	LAI	GPS	Arc GIS	Arc View	
																							1
																							2
					❊																		3
																							4
																							5
																							6
																							7
	❊																						8
																							9
	❊																						10
																							11
																							12
																							13
																				❊			14
			❊																				15
			❊																❊				16
																				❊			17
	❊																						18
																						❊	19
																❊	❊						20
									❊														21
	❊																						22
																							23
			❊	❊																❊			24
								❊													❊		25
							❊															❊	26
																						❊	27
											❊												28
												❊										❊	29
														❊									30
																							31
																							32
❊						❊	❊		❊													❊	33
						❊																	34
																					❊		35
										❊	❊												36
				❊			❊														❊		37
																		❊		❊	❊		38
																						❊	39
															❊								40
		❊																					41
													❊										42

Technique										Method				Row
STEVE Tools	ANN	RS	Lidar	SVP	GIS	STS	SCA	MST	FET	Software	GPS	Photographic	Analytical	
													❊	1
									❊			B	A	2
									❊			❊		3
						❊							❊	4
									❊			❊		5
									❊			C		6
									❊			❊		7
						❊							D	8
									❊			❊		9
						❊			❊			❊	❊	10
						❊			❊			❊	❊	11
									❊			❊		12
									❊			❊		13
									❊		❊	❊		14
									❊			❊		15
								❊	❊			F	E	16
									❊		❊	❊		17
						❊							❊	18
					❊					❊				19
									❊	❊		❊		20
										❊				21
						❊							❊	22
									❊			❊		23
	❊								❊		❊	❊		24
					❊		❊			❊				25
					❊				❊	❊		❊		26
					❊					❊				27
							❊			❊				28
					❊					❊				29
					❊		❊			❊				30
								❊	❊			❊		31
									❊			❊		32
					❊				❊	❊		❊		33
										❊				34
					❊					❊				35
									❊			❊		36
					❊				❊	❊		❊	❊	37
					❊				❊	❊	❊	❊		38
					❊					❊				39
		❊	❊				❊			❊				40
❊										❊				41
				❊								❊		42

A It has been mentioned in studies by (Chapman & Thornes, 2004; Chen et al., 2012; Unger, 2009; Watson & Johnson, 1987).

B It has been mentioned in studies by (Grimmond, Potter, Zutter, & Souch, 2001; Watson & Johnson, 1987).

C, E, F, # It has been mentioned in a study by (Unger, 2004).

D It has been mentioned in studies by (Grimmond et al., 2001; Unger, 2009).

G Australian, European and North American cities

H Korean & Japanese Cites

END NOTE

1. Other environmental indicators include air temperature, wind speed and humidity.
2. Eliasson (1992) refers to it as the graphical method.
3. It is one of the remote sensing technologies, which measures distances by illuminating the target with laser light and measuring the reflection with a sensor.
4. Google Street View (GSV) is a global network of panoramas excluding China and several other countries. However, Baidu Street View (BSV) and Tencent Street View (TSV) focus their efforts within China, and have covered hundreds of cities (Liang et al., 2017).
5. The advantages of real-time processing via a mobile platform include increased data collection speed and minimum data storage. This should be possible using an objective calculation algorithm and a high-speed computer processor (Chapman & Thornes, 2004).
6. ANN better models nonlinear and irregular datasets than simple regression techniques (Debbage, 2013).

REFERENCES

- Anderson, M.C. (1964). Studies of the Woodland Light Climate: I. The Photographic Computation of Light Conditions. *The Journal of Ecology*, 25(1), 27-41. https://www.jstor.org/stable/2257780?seq=1
- Asawa, T., Hoyano, A., & Nakaohkubo, K. (2008). Thermal Design Tool for Outdoor Spaces Based on Heat Balance Simulation Using a 3D-CAD System. *Building and Environment*, 43(12), 2112-2123. doi:10.1016/j.buildenv.2007.12.007
- Bärring, L., Mattsson, J.O., & Lindqvist, S. (1985). Canyon Geometry, Street Temperatures and Urban Heat Island in Malmö, Sweden. *International Journal of Climatology*, 5(4), 433-444. https://doi.org/10.1002/joc.3370050410
- Behzadfaz, M., & Monam, A. (2012). The Impact of Sky View Factor on Outdoor Thermal Comfort; Case Study: Tehran Urban Parks. *ARMANSHAHR*, 3(5), 23-34. https://www.sid.ir/en/journal/ViewPaper.aspx?id=247369
- Bottyán, Z., & Unger, J. (2003). A Multiple Linear Statistical Model for Estimating the Mean Maximum Urban Heat Island. *Theoretical and Applied Climatology*, 75(3), 233-243. https://link.springer.com/article/10.1007/s00704-003-0735-7
- Bourbia, F., & Boucheriba, F. (2010). Impact of Street Design on Urban Microclimate for Semi Arid Climate (Constantine). *Renewable Energy*, 35(2), 343-347. doi:10.1016/j.renene.2009.07.017
- Bradley, A., Thornes, J., & Chapman, L. (2001). A Method to Assess the Variation of Urban Canyon Geometry From Sky View Factor Transects. *Atmospheric Science Letters*, 2(1-4), 155-165. https://doi.org/10.1006/asle.2001.0031
- Chapman, L., & Thornes, J. (2004). Real-Time Sky-View Factor Calculation and Approximation. *Journal of Atmospheric and Oceanic Technology*, 21(5), 730-741. https://doi.org/10.1175/1520-0426(2004)021<0730:RSFCAA>2.0.CO;2
- Chapman, L., Thornes, J., & Bradley, A. (2001). Rapid Determination of Canyon Geometry Parameters for Use in Surface Radiation Budgets. *Theoretical and Applied Climatology*, 69(1), 81-89. https://link.springer.com/article/10.1007/s007040170036
- Chapman, L., Thornes, J. E., & Bradley, A. V. (2002). Sky-View Factor Approximation Using GPS Receivers. *International Journal of Climatology*, 22(5), 615-621. doi:10.1002/joc.649
- Chapman, L., Thornes, J.E., Muller, J.P., & McMuldroch, S. (2007). Potential Applications of Thermal Fisheye Imagery in Urban Environments. *IEEE Geoscience and Remote Sensing Letters*, 4(1), 56-59. https://www.researchgate.net/publication/3449816_Potential_Applications_of_Thermal_Fisheye_Imagery_in_Urban_Environments
- Chen, L., & Ng, E. (2011). Quantitative Urban Climate Mapping Based on a Geographical Database: a Simulation Approach Using Hong Kong as a Case Study. *International Journal of Applied Earth Observation and Geoinformation*, 13(4), 586-594. doi:10.1016/j.jag.2011.03.003
- Chen, L., Ng, E., An, X., Ren, C., Lee, M., Wang, U., & He, Z. (2012). Sky View Factor Analysis of Street Canyons and Its Implications for Daytime Intra-Urban Air Temperature Differentials in High-Rise, High-Density Urban Areas of Hong Kong: a GIS-Based Simulation Approach. *International Journal of Climatology*, 32(1), 121-136. doi:10.1002/joc.2243
- Chun, B., & Guldmann, J.M. (2014). Spatial Statistical Analysis and Simulation of the Urban Heat Island in High-Density Central Cities. *Landscape and Urban Planning*, 125, 76-88. doi:10.1016/j.landurbplan.2014.01.016
- De Souza, L.C.L., & Da Silva, A.N.R. (2006). Applying GIS Tools for Analysing Urban Thermal Environment. Paper Presented at the PLEA 2006-23rd International Conference on Passive and Low Energy Architecture, Conference Proceedings.
- Debbage, N. (2013). Sky-View Factor Estimation: A Case Study of Athens, Georgia. *The Geographical Bulletin*, 54(1), 49. https://www.researchgate.net/publication/277891280_Sky-View_Factor_Estimation_A_Case_Study_of_Athens_Georgia
- Dos Santos, I.G., De Lima, H.G., & De Assis, E.S. (2003). A Comprehensive Approach of the Sky View Factor and Building Mass in an Urban Area of the City of Belo Horizonte, Brazil. The Federal University of Minas Gerais, Belo Horizonte, MG, Brazil.
- Drezner, T.D., & Shaker, R.R. (2010). A New Technique for Predicting the Sky-View Factor for Urban Heat Island Assessment. *The Geographical Bulletin*, 51(2), 85. https://www.researchgate.net/publication/278677643_A_New_Technique_for_Predicting_the_Sky-View_Factor_for_Urban_Heat_Island_Assessment
- Eliasson, I. (1992). Infrared Thermography and Urban Temperature Patterns. *International Journal of Remote Sensing*, 13(5), 869-879. https://doi.org/10.1080/01431169208904160
- Eliasson, I. (1996). Urban Nocturnal Temperatures, Street Geometry and Land Use. *Atmospheric Environment*, 30(3), 379-392. doi:10.1016/1352-2310(95)00033-x

- Gál, T., Lindberg, F., & Unger, J. (2008). Computing Continuous Sky View Factors Using 3D Urban Raster and Vector Databases: Comparison and Application to Urban Climate. *Theoretical and Applied Climatology*, 95(1-2), 111-123. doi:10.1007/s00704-007-0362-9
- Gál, T.M., Rzepa, M., Gromek, B., & Unger, J. (2007). Comparison between Sky View Factor Values Computed by Two Different Methods in an Urban Environment. *Acta Climatologica et Chorologica*, 40, 17-26. https://www.researchgate.net/publication/255579829_Comparison_between_sky_view_factor_values_computed_by_two_different_methods_in_an_urban_environment
- Grimmond, C., Potter, S., Zutter, H., & Souch, C. (2001). Rapid Methods to Estimate Sky View Factors Applied to Urban Areas. *International Journal of Climatology*, 21(7), 903-913. https://doi.org/10.1002/joc.659
- Gustavsson, T. (1995). A Study of Air and Road Surface Temperature Variations During Clear Windy Nights. *International Journal of Climatology*, 15(8), 919-932. https://doi.org/10.1002/joc.3370150806
- Hämmerle, M., Gál, T., Unger, J., & Matzarakis, A. (2011). Comparison of Models Calculating the Sky View Factor Used for Urban Climate Investigations. *Theoretical And Applied Climatology*, 105(3-4), 521-527. doi:10.1007/s00704-011-0402-3
- Hodul, M., Knudby, A., & Ho, H. (2016). Estimation of Continuous Urban Sky View Factor from Landsat Data Using Shadow Detection. *Remote Sensing*, 8(7). doi:10.3390/rs8070568
- Holmer, B. (1992). A Simple Operative Method for Determination of Sky View Factors in Complex Urban Canyons From Fisheye Photographs. Meteorol. Z., NF, 1, 236-239. https://www.researchgate.net/publication/292755076_A_simple_operative_method_for_determination_of_sky_view_factors_in_complex_urban_canyons_from_fisheye_photographs
- Johnson, D. (1985). Urban Modification of Diurnal Temperature Cycles in Birmingham, UK. *International Journal of Climatology*, 5(2), 221-225. https://doi.org/10.1002/joc.3370050208
- Johnson, G.T., & Watson, I.D. (1984). The Determination of View-Factors in Urban Canyons. *Journal of Climate and Applied Meteorology*, 23(2), 329-335. https://www.jstor.org/stable/26181335?seq=1
- Jusuf, S.K., Ignatius, M., Wong, N.H., & Tan, E. (2017). Steve Tool Plug-in for SketchUp: A User-Friendly Microclimatic Mapping Tool for Estate Development. In Sustainable Building and Built Environments to Mitigate Climate Change in the Tropics (113-130): Springer.
- Li, W., Putra, S., & Yang, P. (2004). GIS Analysis for the Climatic Evaluation of 3D Urban Geometry. Paper Presented at the Proceeding of Seventh International Seminar on GIS in Developing Countries (GISDECO).
- Liang, J., Gong, J., Sun, J., Zhou, J., Li, W., Li, Y., Liu, J., & Shen, S. (2017). Automatic Sky View Factor Estimation from Street View Photographs—A Big Data Approach. *Remote Sensing*, 9(5). doi:10.3390/rs9050411
- Lindberg, F. (2005). Towards the Use of Local Governmental 3-D Data Within Urban Climatology Studies. *Mapping and Image Science*, 2, 32-37. https://www.researchgate.net/publication/229421427_Towards_the_use_of_local_governmental_3-D_data_within_urban_climatology_studies
- Lindberg, F., & Grimmond, C.S.B. (2010). Continuous Sky View Factor Maps From High Resolution Urban Digital Elevation Models. *Climate Research*, 42(3), 177-183. doi:10.3354/cr00882
- Matuschek, O., & Matzarakis, A. (2011). A Mapping Tool for Climatological Applications. *Meteorological Applications*, 18(2), 230-237. doi:10.1002/met.233
- Matzarakis, A., & Matuschek, O. (2011). Sky View Factor as a Parameter in Applied Climatology Rapid Estimation by the Skyhelios Model. *Meteorologische Zeitschrift*, 20(1), 39-45. doi:10.1127/0941-2948/2011/0499
- Matzarakis, A., Mayer, H., & Chmielewski, F.M. (2010). Berichte des Meteorologischen Instituts der Albert-Ludwigs-Universität Freiburg. Retrieved from
- Matzarakis, A., Rutz, F., & Mayer, H. (2000). Estimation and Calculation of the Mean Radiant Temperature within Urban Structures. Paper Presented at the Biometeorology and Urban Climatology at the Turn of the Millenium (ed. by RJ de Dear, JD Kalma, TR Oke and A. Auliciems): Selected Papers from the Conference ICB-ICUC.
- Oke, T.R. (1981). Canyon Geometry and the Nocturnal Urban Heat Island Comparison of Scale Model and Field Observations. *Journal of Climatology*, 1, 237-254.
- Oke, T.R. (1988). Street Design and Urban Canopy Layer Climate. *Energy and Buildings*, 11(1-3), 103-113. doi:10.1016/0378-7788(88)90026-6
- Park, H.S. (1987). City Size and Urban Heat Island Intensity for Japanese and Korean Cities. *Geographical Review of Japan*, 60, 238-250.
- Ratti, C. (2001). Urban Analysis for Environmental Prediction. University of Cambridge.
- Ratti, C., & Richens, P. (1999). Urban Texture Analysis with Image Processing Techniques. In Computers in Building (49-64): Springer.
- Ratti, C., & Richens, P. (2004). Raster Analysis of Urban Form. *Environment and Planning B: Planning and Design*, 31(2), 297-309. doi:10.1068/b2665

- Souza, L.C.L., Rodrigues, D.S., & Mendes, J.F. (2003a). A 3D-Gis Extensionf for Sky View Factors Assessment in Urban Environment.
- Souza, L.C.L., Rodrigues, D.S., & Mendes, J.F. (2003b). Sky View Factors Estimation Using a 3D-GIS Extension.
- Steyn, D.G. (1980). The Calculation of View Factors From Fisheye Lens Photographs: Research Note. *Atmosphere-Ocean*, 18(3), 254-258. doi:10.1080/07055900.1980.9649091
- Steyn, D.G., Hay, J., Watson, I.D., & Johnson, G.T. (1986). The Determination of Sky View-Factors in Urban Environments Using Video Imagery. *Journal of Atmospheric and Oceanic Technology*, 3(4), 759-764. https://doi.org/10.1175/1520-0426(1986)003<0759:TDOSVF>2.0.CO;2
- Svensson, M.K. (2004). Sky View Factor Analysis – Implications For Urban Air Temperature Differences. *Meteorological Applications*, 11(3), 201-211. doi:10.1017/s1350482704001288
- Unger, J. (2004). Intra-Urban Relationship between Surface Geometry and Urban Heat Island: Review and New Approach. *Climate Research*, 27(3), 253-264. https://www.researchgate.net/publication/269824081_Intra-urban_relationship_between_surface_geometry_and_urban_heat_island_Review_and_new_approach
- Unger, J. (2009). Connection between Urban Heat Island and Sky View Factor Approximated by a Software Tool on a 3D Urban Database. *International Journal of Environment and Pollution*, 36(1-3), 59-80. https://www.researchgate.net/publication/228717732_Connection_between_urban_heat_island_and_sky_view_factor_approximated_by_a_software_tool_on_a_3D_urban_database
- Upmanis, H., & Chen, D. (1999). Influence of Geographical Factors and Meteorological Variables on Nocturnal Urban-Park Temperature Differences—a Case Study of Summer 1995 in Göteborg, Sweden. *Climate Research*, 13(2), 125-139. https://www.researchgate.net/publication/250221501_Influence_of_geographical_factors_and_meteorological_variables_on_nocturnal_urban-park_temperature_differences-a_case_study_of_summer_1995_in_Goteborg_Sweden
- Upmanis, H., Eliasson, I., & Lindqvist, S. (1998). The Influence of Green Areas on Nocturnal Temperatures in a High Latitude City (Göteborg, Sweden). *International Journal of Climatology*, 18(6), 681-700. https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1002/%28SICI%291097-0088%28199805%2918%3A6%3C681%3A%3AAID-JOC289%3E3.0.CO%3B2-L
- Vieira, H., & Vasconcelos, J. (2003). Urban Morphology Characterisation to Include in a GIS for Climatic Purposes in Lisbon. Discussion of Two Different Methods. Paper Presented at the Proc 5th Int Conf on Urban Climate.
- Watson, I., & Johnson, G. (1987). Graphical Estimation of Sky View Factors in Urban Environments. *International Journal of Climatology*, 7(2), 193-197. https://doi.org/10.1002/joc.3370070210
- Wikipedia. (2018, 25 January 2018 18:43 UTC). Lidar. Retrieved from https://en.wikipedia.org/w/index.php?title=Lidar&oldid=822323709
- Yamashita, S., Sekine, K., Shoda, M., Yamashita, K., & Hara, Y. (1986). On Relationships between Heat Island and Sky View Factor in the Cities of Tama River Basin, Japan. *Atmospheric Environment* (1967), 20(4), 681-686. https://doi.org/10.1016/0004-6981(86)90182-4

HOW TO CITE THIS ARTICLE

ZarifianMehr, A., Jahanshahloo, L., Alijani, B., & Zabihi, H. (2020). A Review of the Definitions and Calculation Methods of Sky View Factor. *Armanshahr Architecture & Urban Development Journal*. 13(31), 189-203.

DOI: 10.22034/AAUD.2020.132007.1537

URL: http://www.armanshahrjournal.com/article_113271.html

Appendix 1: Registration (Abbreviations)

Latin Equivalent	Abbreviations
Artificial Neural Network	ANN
Clinometer or Theodolite	COT
Continuous SVF	CSVF
Digital Elevation Model	DEM
Digital Surface Model	DSM
Discontinued SVF	DSVF
Fish Eye	FE
Fish Eye Technique	FET
Geographic Information System	GIS
Global Positioning System	GPS
Ground Sky View Factor	GSVF
Height/Width	H/W
Inverse Distance Weighted	IDW
Land Surface Temperature	LST
Leaf Area Index	LAI
Height of SVF(Meter)	HSVF(m)
Mean Radiant Temperature	MRT
Mean SVF	MSVF
Mobile Survey Technique	MST
Remote Sensing	RS
Roof Sky View Factor	RSVF
Shadow Casting Algorithm	SCA
Shoulder Height	Sh
Sky View Factor	SVF
Street View Panorama	SVP
Surveying Techniques By Sites	STS
Total Sky View Factor	TSVF
Urban Heat Island	UHI
View Factor	VF
Visual Basic for Applications	VBA