Int. J. Architect. Eng. Urban Plan, 29(1): 69-78, June 2019

RESEARCH PAPER

Environmental Design

Developing a Tool for Analyzing and Generating the Fittest Urban Morphology Based on the Sky View Factor and Insolation (A Case Study on Yazd)

Sh. Roshanzamir[1,*], M. Farhadian Dehkordi[2]

[1]*PhD, Department of Architecture & Urban Design, Art University of Isfahan, Isfahan, Iran*
[2]*PhD. Candidate, University of Applied Arts Vienna, Vienna, Austria*

Received: November 2018, Revised: April 2019, Accepted: April 2019, Available online: June 2019

Abstract

Urban morphology, including buildings' typology and configuration, affects sky view factor and insolation as two of the most prominent parameters in urban microclimate, particularly in extreme environmental conditions. This research aims to generate various rule-based urban block typologies in a parametric environment and then evaluate them based on the parameters mentioned above to find the fittest climate responsive morphology. Grasshopper, Ecotect, and Genetic algorithms are used for evaluation in relatively short computing time. Introducing a high-speed and user-friendly environment for designers to generate forms and evaluate them in several iterations was the main consideration. The proposed tool consists of two parts, namely generative algorithms to create various rule-based morphologies and analytics algorithms to find the fittest climate responsive urban morphology based on insolation and sky view factor. As a case study, the focus is on different urban morphologies in Yazd to find the fittest option. The maximum sky view factor and minimum insolation on building surfaces are ideal in hot and arid climates; however, these two parameters suggest contradicting solutions for urban morphology. Considering the existing urban fabric in Yazd, various block typologies and arrangements are parametrically generated. In each scenario, the evaluation iterations identify the most suitable typologies and arrangements. After comparing the fittest versions of different types, the most proper building typology, collective arrangement, and the best orientation are provided.

Keywords: *Sky view factor, Insolation, Urban morphology, Building typology, Parametric design, Yazd.*

1. INTRODUCTION

Due to the limitation in energy sources and problems like Urban Heat Island (UHI), designers should consider the enhancement of urban microclimates for inhabitants' comfort and reduction of energy consumption in active and passive ways. Sky View Factor (SVF) and insolation are two of the utmost factors that are directly linked to urban density and configuration and influence urban microclimate, energy production, and energy consumption by affecting received daylight and solar access, daytime heat gain, and night-time heat loss through radiation or exposure to the outside environment. This article tries to introduce a low-cost, fast, and accessible tool to generate, evaluate, and optimize different design scenarios based on these factors. As a case study, the proposed tool is examined on different block configurations in Yazd, a city located in the central part of Iran.

* *Corresponding author: Sh.Roshanzamir@aui.ac.ir*
Tell: +983132200003

The SVF is a dimensionless parameter ranges from zero to one. As defined by Oke "It represents the fraction of visible sky on a hemisphere centered over the analyzed location" [1]. The relation between urban geometry, SVF, and UHI is well studied [1-5]. Many types of research consider SVF the main index of UHI [6-7], in the sense that the higher the mean SVF, the lower the UHI formation. However, this can lead to more exposure to solar radiation. In this case, insolation comes to play. Insolation is the solar radiation at the surface of the earth, represented in units of energy/square meter [8]. This can be a factor to evaluate daytime heat gain through radiation.

As discussed, insolation and SVF can have contradictory effects on the optimization process of the block's form, layout, and orientation. For instance, to achieve the maximum radiative heat transfer to the sky, maximum openness and SVF are needed, which means an increase in daytime insolation and heat gain. Most of the related studies on SVF have failed to consider this contradiction [9-11], and few studies have merely pointed to this issue without directly including it in their analyses [6, 12-13].

The present study is divided into two parts. The First part is devoted to the introduction of the proposed tool that provides the designer with the possibility to parametrically generate different block configurations and analyze their suitability based on average SVF and insolation values. Then, using an evolutionary process based on the designer setup, the program would suggest the optimum block typology, proportion, openness, and arrangement in an urban grid. In the second part, the program is used to analyze common configurations in the existing urban texture of Yazd and consequently suggest an optimized version of each configuration. As the focus of the proposed tool is on insolation and SVF calculation, it was decided to study Yazd as a city with a high level of solar radiation and clear sky (i.e., better effect of SVF on night radiative cooling) with overall demand for cooling. It is worth mentioning that although factors such as ventilation and surface area to volume ratio are also important factors in urban microclimate, for the sake of simplicity, they were excluded from the optimization process.

2. AN EVOLUTIONARY MODEL FOR URBAN MORPHOLOGY OPTIMIZATION BASED ON SVF AND INSOLATION

The main goal of this research was developing a tool to achieve the optimized urban blocks configuration and layout based on SVF and insolation through an evolutionary process in Yazd. Evolutionary algorithms, as a class of heuristic techniques, were developed in the 60s for the optimization problems [14]. In this study, Grasshopper Galapagos, which is a plug-in for Rhino, was chosen as the evolutionary algorithm.

To set the process, the first step is to parametrically define the shape grammar for desired blocks and their arrangements. Therefore, the program would generate a vast range of geometrical configurations based on different combinations of parameters. A certain number of generated 3D models would be randomly selected as the first step. Then, after the analysis process, the models with higher SVF and lower insolation would be selected for the next step. Then, the selected models again compete with the newly generated ones to achieve the fittest model.

Many types of research have recently used generative and evolutionary models to find energy optimization-driven design. The studies with greater similarity with this project have mostly focused on either solar access [14-21], or SVF [6-7], [22-23] or failed to consider them as contradictory factors [10] in search of more solar access. Some studies have investigated the effect of block shapes on both indoor condition and energy demand [10, 24-26]. Also, most of the works have presented very simple and reductionist building typologies and forms limited to simple extrusions or just street canyons and in-between spaces, [7, 14, 20, 24, 27-29].

The most challenging part is to come up with an analysis method that would be fast and potent enough to work with parametric 3D models. To this end, Ecotect and Geco plug-in for Grasshopper were used to calculate insolation. For SVF, a Grasshopper definition was set in line with the project purpose. In general, Grasshopper and its plug-ins are widely-used and proper tools for both generative- and evolutionary-based designs [7, 10, 15, 19, 21, 23, 27, 29].

The most common methods to calculate SVF include mathematical models, fisheye-lens photographs analysis, image processing, diagrams, and graphical determination [30]. The focus of these models is on the existing urban masses; therefore, they fail to be appropriate for the analysis of design scenarios. Also, the calculations conducted using these methods are not straightforward and are usually costly and time-consuming [31]. In this research, the focus is mainly on computer programs. Generally, there are two main software approaches, viz. vector and raster. In the raster-based method, a digital elevation model (DEM) database is often employed. In these models, each pixel representing building height can be displayed in the shade of grey as a digital image like the model developed by Ratti and Richens [32]. In this model, a 'shadow casting' algorithm calculates building shadow patterns based on high-resolution DEM. This algorithm that has been validated by Lindberg [33] to generate satisfactory results is further modified to calculate SVF. The accuracy of the method depends on the resolution of the raster database [34]. The problem with using DEM is that only the visible parts from above are considered in the analysis, and the shapes and voids in the section are ignored Fig. 1. Although this model is useful for the evaluation of very large-scale urban textures, it fails to be efficient for studying urban configurations, block typology, and their arrangement in smaller scales [30]. In the vector method, buildings are typically simplified to flat-roofed blocks. To calculate SVF, a hemispheric radiating environment is defined and divided into equal slices by a rotation angle. Then, the tool searches for a single building with the largest elevation angle along a particular rotation angle. The sky segment obstructed by this building is considered a slice of the basin. Then, SVF can be calculated by summing up the view factors of all the basin slices for all directions [35]. The accuracy of this method depends on the rotation angle and the searching radius, in the sense that a smaller rotation angle and larger radius result in a more accurate SVF estimation [34].

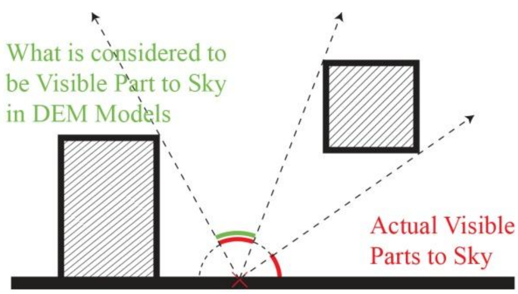

Fig. 1 A view of the section configuration ignored in the DEM (in this example, the red part would not be considered in SVF, resulting in lower values for SVF and insolation)

Most models are based on representations of buildings [31] or digital elevation models (DEM) [36], allowing only for simple-shaped building and flat roofs except a few models which are allowing for modeling non-flat roofs [37].

To date, different tools have been developed for SVF calculation in Grasshopper environment [38-40]. However, to evaluate different geometries from simple cubic to more curved and complex ones in a relatively short time, as explained further in the essay, the idea of obstacles and the hemispheric radiating environment was applied in this study.

There were also other challenges required to be overcome to this end. Firstly, it was needed to develop an algorithm to enable the generation of different 3D model configurations, and secondly, a proper analysis grid matching with the ever-changing models had to be prepared.

2.1. Parametric 3D model setup

In this study, two different setups were employed to generate block typology and create different arrangements. Value assignment to each parameter was conducted using three methods. For (n) instances of the same parameter, the assigned value can be: a) Constant for all components (fixed or variable), b) Different for each instance (one-to-one correspondence), or c) Different based on the zone where the instance is located. The values will be assigned to the fixed zones with the definable resolution, and the instances will get the value from the related zone Fig. 2.

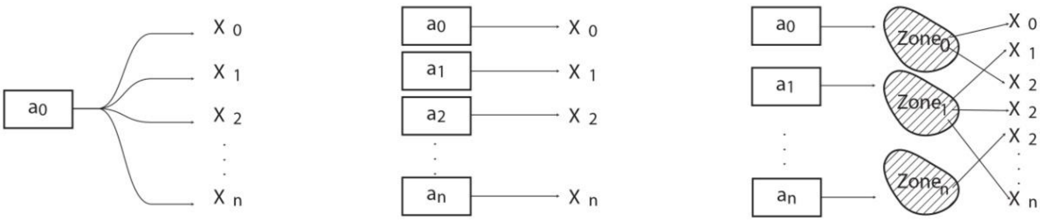

Fig. 2 Different ways of assigning values to parameters

The first diagram in Fig. 3 shows how different block typologies can be generated. Values for overall Floor Area Ratio (FAR), land area, and the number of lots in the Y direction are fixed while the other values can be either fixed or variable. As the number of lots in the X direction is variable, values for voids type, proportion, or the number of levels fail to be directly assigned hence the values were firstly assigned to zones, and then, the lots will be subsequently assigned accordingly. Based on the designer scenario and genotype setup, different phenotypes can emerge. In the next step, different arrangements of a certain block are generated in a parametric process Fig. 3.

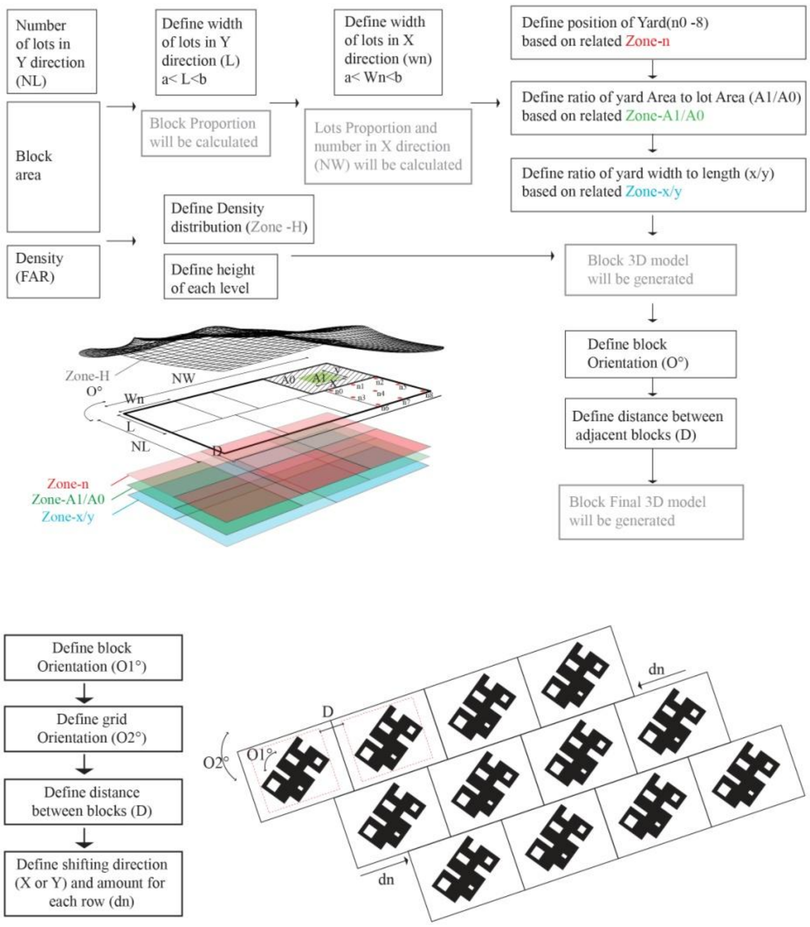

Fig. 3 Parametric setup to generate different blocks and their arrangement in the grid

2.2. Analysis grid preparation

The analysis grid should be sufficiently precise and time-saving. To this end, a uniform grid was used whenever possible, but the problem is that the model has to be rasterized. In addition to the low quality of edge presentation, it may affect the analyses in two ways. First, the distance between the adjacent points and objects under analysis is not equal, which leads to misestimation of values. Second, in the case of small openings, the cells might be represented as part of the interior space. To achieve precision, the resolution should be increased, which will affect the calculation time.

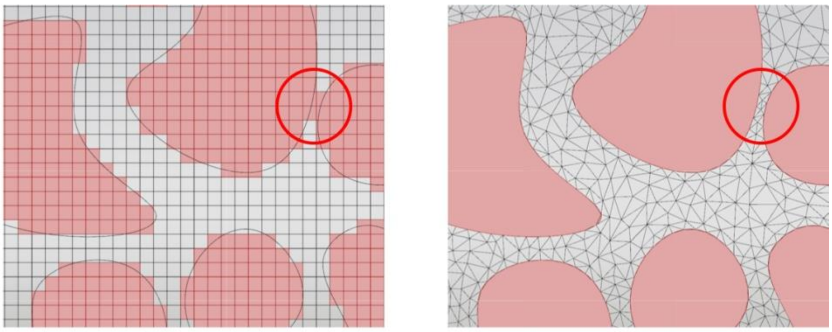

Fig. 4 A schematic of uniform analysis grids that fail to be adequately precise to show boundary edges or connect forms in case of short distances. The right image shows the proposed analysis grid

To solve the problem associated with uniform analysis grid, albeit in some cases, a non-uniform triangulated mesh was used, in which there are rows of sample points with equal distance to objects in addition to ones located at the same distance from the object boundaries Fig. 4.

2.3. SVF and insolation analysis tools

To calculate SVF, a vector from each sample point on the analysis grid is connected to equally distributed points on the radiating hemisphere. The sky-dome is big enough to enable relatively similar ray angles for all sample points. For each one, the obstacles at a certain distance was considered. Then, the SVF value calculated as the ratio of the number of occluded rays to the total number of rays. Like the vector method, the accuracy of this model also depends on the number of points on sky-dome, resolution of the analysis grid, and the obstacles' radius (Fig. 5). The tool is set inside Grasshopper; hence, it can directly collaborate with parametric design model and other analysis tools. Besides, short computing time makes it work properly with Galapagos plug-in. Another advantage of the proposed tool over its existing counterparts is that the sample points under analysis can be in any location, the SVF value, for instance, can be calculated for façade of the buildings. As mentioned earlier, insolation was calculated using Ecotect.

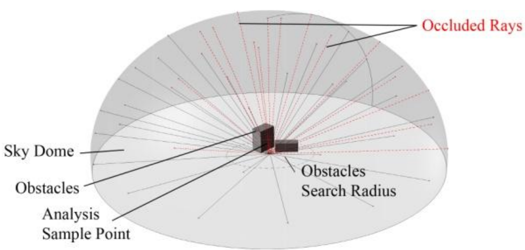

Fig. 5 The SVF calculated as the number of rays-from sky-dome to sample points—occluded by obstacles in a certain distance to the total number of rays

3. THE PROPOSED OPTIMIZED BLOCK TYPOLOGY AND ARRANGEMENT FOR YAZD AS THE CASE STUDY

There are a couple of researches on the effect of SVF on urban textures in hot and arid climates. Extensive scientistfic literature proves the desirability of low sky view factor for these climates. In hot and arid climates, night-time temperatures are usually significantly lower than day-time temperatures, and an increase in temperature at night would be probably welcomed if the extreme temperature stress during the day is concomitantly alleviated [41]. However, some other studies suggest that high SVF value for these climates might be desirable [42]. An increase in the greenhouse effect and urban density in big cities has changed urban climates and caused many of these cities to experience warm nights. This trend has evoked new researches on urban pattern with the aim of maximizing cooling, i.e., minimum insolation and maximum sky cooling and SVF in turn, reflecting more daylight access and less heat gain from direct solar radiation. Therefore, the present study seeks to maximize SVF and minimize insolation through optimized urban morphology in Yazd as the selected case study.

The analysis time was set up in months in which radiation and temperature are high and out of comfort zone, i.e., May to October [43]. The sky is considered to be clear for calculations. In the first step, some common urban configurations are analyzed, and then several optimized versions are suggested. To find the fittest layout, different arrangements of the most common and suitable typologies are evaluated.

3.1. The common morphologies and typologies in Yazd

There are two recognizable configurations in Yazd urban fabric. One pattern is related to the old part of the city with dense massing and irregular narrow streets covered with vaults. In this section of the city, the buildings are mainly one-story courtyard types with high ceilings. Another pattern is the newly developed areas with a uniform grid, relatively wide streets, and rows of attached two- to seven-story buildings. In both patterns, the overall orientation is 45° to -45° to the south. Fig. 6 shows the analyses of these configurations.

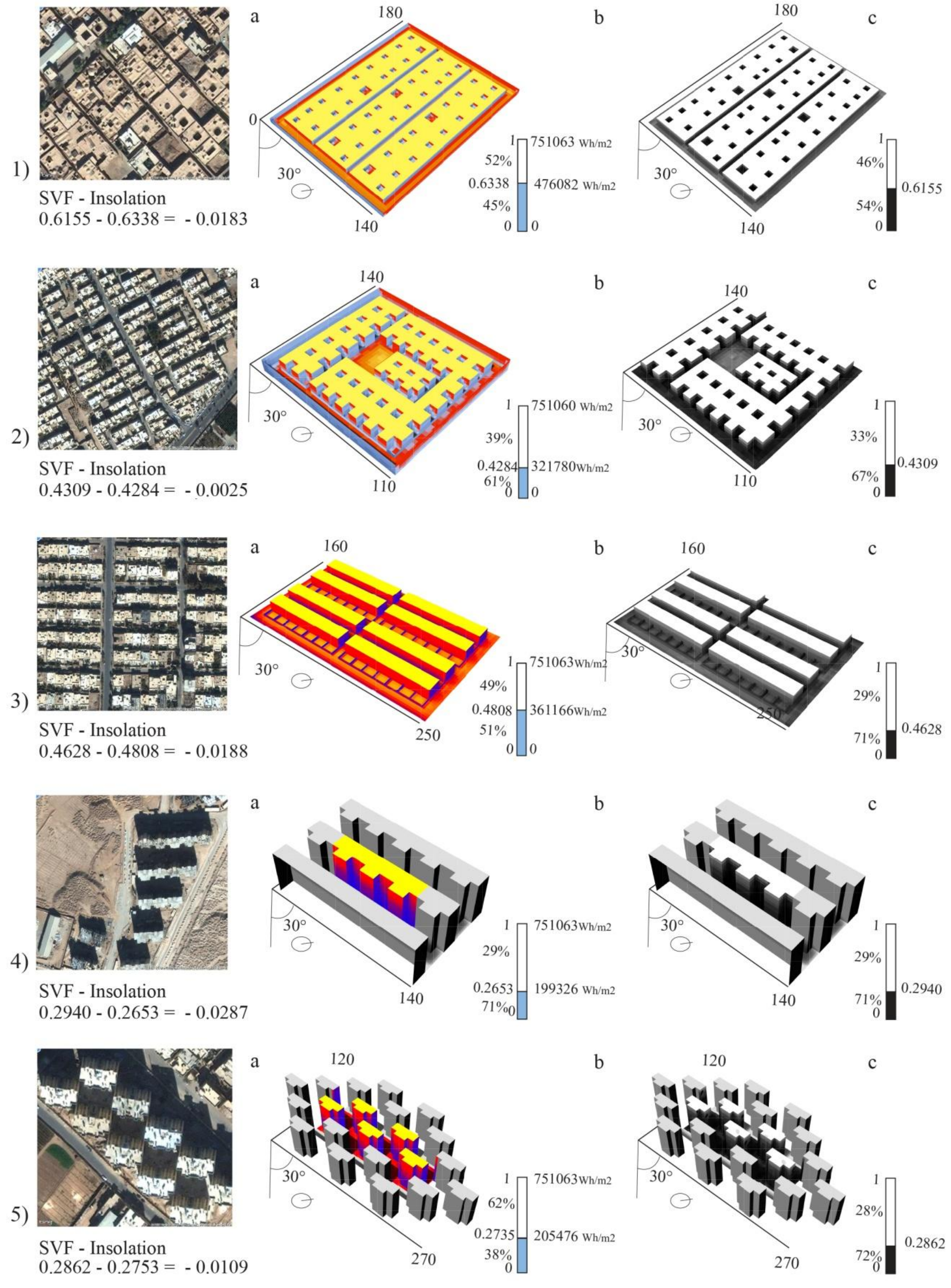

Fig. 6 The most common urban patterns in Yazd from older to more recent. (a) Google earth view, (b) Insolation analysis, (c) SVF analysis

The bars in Fig. 6 represent the average insolation and SVF values for each sample point and their percent values. Average insolation values for the selected points are remapped to a domain from zero to one and then subtracted from the average SVF values to recognize which configuration, on average, has the maximum SVF and minimum insolation values. In this regard, the higher values mean better function. As illustrated, the estimated values have a less correlation with the density or height and mostly depend on the configuration of elements. Orientation in all models is 30° to the south. As shown, courtyard typologies and proposed layout of blocks (models 2, 5, and 1, respectively) have better performance than the row layouts (models 3 and 4, respectively) which are more common in new developments.

The next part presents the parametric model of the most common block types and their evaluations. The most widely used blocks are those with double rows of housing repeated in urban grid, which are common in both traditional and recent developments of the city.

3.2. Generation, evaluation, and comparison of the optimized block typologies

The first model is a block with modular units. In all analyses, the neighbors' condition is set to be the same as the block; it should be notified that the respective condition was considered in evaluations but fails to be represented in figures. As mentioned earlier, the FAR and area values are fixed in all models. In this model, all the other parameters are variable; however, they are the same for the lots. The evaluation suggests that a block with 30° orientation to south and rows of buildings with yards in north direction is the best pattern to achieve the maximum SVF and minimum insolation. In all figures, the table shows the parametric set up of blocks, the upper images illustrate SVF and insolation analysis, and the lower images indicate which parts of the model are flexible.

Parameter	Value Assignment Type - N*- Variable Domain	Result
FAR	Constant-1	3
Block Area	Constant-1	3000
Block proportion (width-Length)	Variable -1-(20 to 150)	37.5 * 80
Number of Lots	Variable-1- (5 to 15) * 2	5 to 8
proportion of lots	Variable-1-(5 to 30)	11.25 * 10 to16
number of Levels per unit	Variable-1-(2 to 7)	5
Height of levels	Variable-1-(3 to 6)	6
Yard Position	Variable-1-(0 to 8)	6-7-8 (north)
Ratio of Yard Area to unit area	Variable-1-(30 to 60 %)	40%
Proportion Of Yard (n % of Unit Edge)	Variable-1-(30 to 100 %)	100 %
Block Orientation to south	Variable-1-(-80° to 80°)	30°
Distance between blocks	Constant-1-(4 to 10m)	–

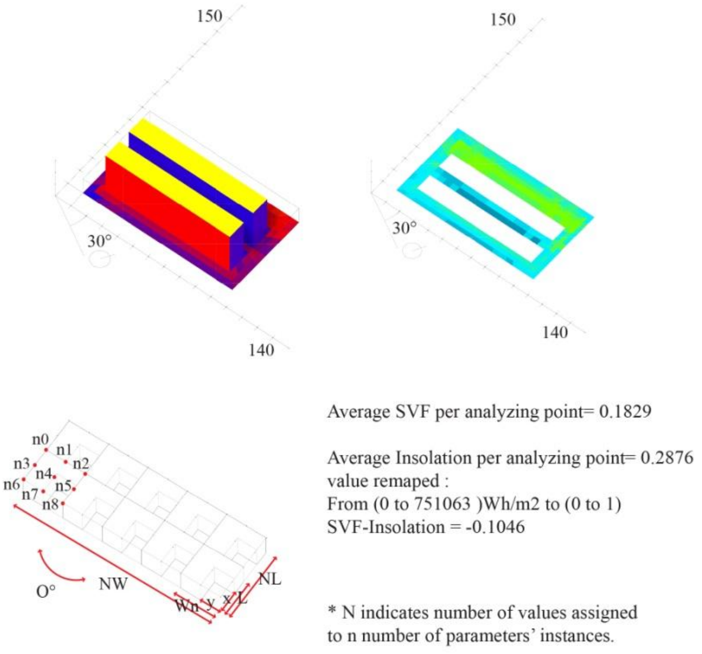

Fig. 7 The layout of the best configuration related to row buildings with yards positioned in northern side in a modular setup with variable parameters

As courtyard types are associated with hot and arid climates [41], the next part of the study merely focuses on the position and proportion of the yard in modular lots and the overall orientation of the block. Each lot is divided into nine points, in such a way that the yard is located either in the center of the area or in the middle or corner of the edges. The yard area is 30% of the lot area, but its proportion is variable. As illustrated in Fig. 8, the optimized configuration is related to the block oriented 30° to the south with detached parallel buildings and yards on the western site. In the next step, a block configuration with maximum possible flexibility is studied.

Parameter	Value Assignment Type - N*- Variable Domain	Result
FAR	Constant - 1	3
Block Area	Constant - 1	3200
Block proportion (width-Length)	Constant - 1	40 * 80
Number of Lots	Constant - 1	4*2
proportion of lots	Constant - 1	20 * 20
number of Levels per unit	Constant - 1	4
Height of levels	Constant - 1	3.5
Yard Position	Variable - 1-(0 to 8)	2 (west)
Ratio of Yard Area to unit area	Constant -1	30%
Proportion Of Yard (n % of Unit Edge)	Variable-1-(30 to 100 %)	100 %
Block Orientation to south	Variable-1-(-80° to 80°)	40°
Distance between blocks	Constant - 1	6

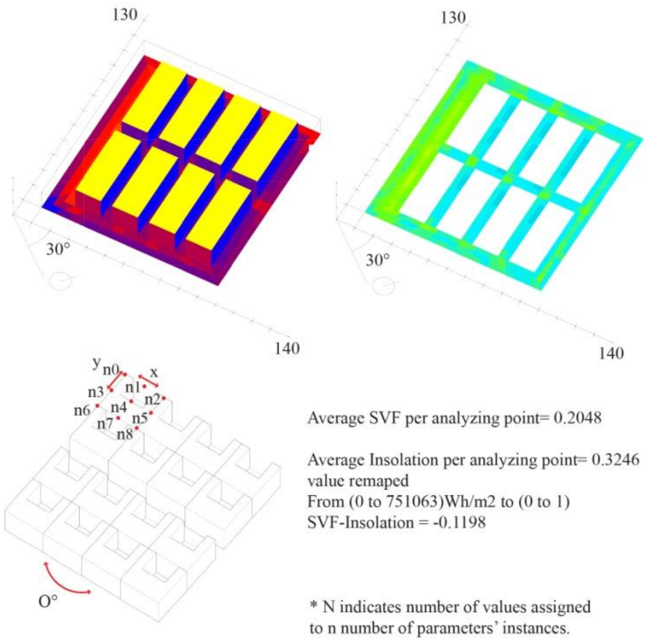

Fig. 8 A layout of the best configuration related to the blocks with detached parallel buildings with yards on the western site in a modular setup with yard position, yard proportion, and block orientation set as variable parameters

Parameter	Value Assignment Type - N*- Variable Domain
FAR	Constant - 1
Block Area	Constant - 1
Block proportion (width-Length)	Variable - 1 - (20 to 150)
Number of Lots	Variable - 4 - (5 to 15) * 2
proportion of lots	Variable - n - (5 to 30)
number of Levels per unit	Variable - 16 zones
Height of levels	Variable - 1 - (3 to 6)
Yard Position	Variable -16 zones- (0 to 8)
Ratio of Yard Area to unit area	Variable - 16 zones
Proportion Of Yard (n % of Unit Edge)	Variable - 16 zones
Block Orientation to south	Variable - 1 - (-80° to 80°)
Distance between blocks	Variable - 1 - (4 to 10m)

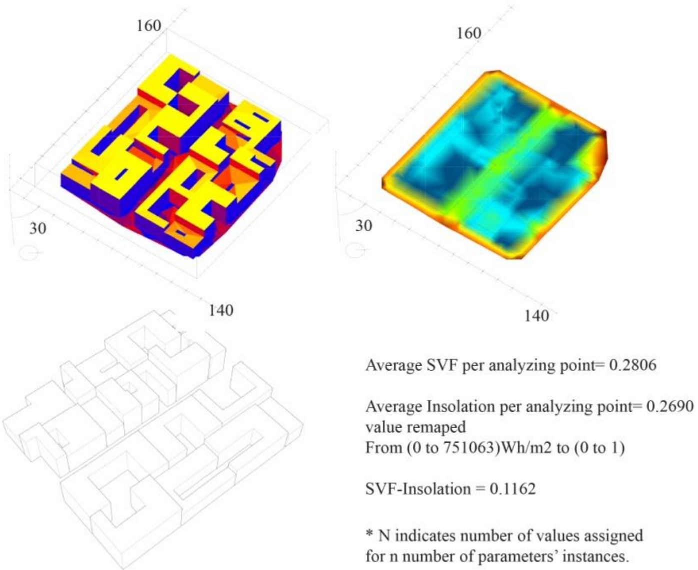

Fig. 9 The model with maximum flexibility that shows the best performance

The optimum configuration in a model with high flexibility resembles the old texture of the city (Fig. 9). The variations in yards and heights helped the model to achieve better results. However, some of the proportions, such as courtyard dimensions, may fail to be suitable for new developments.

In summary, for all the studied models, the best orientation is 30° to the south. In general, different results can be obtained depending on the flexibility of models and the values of the fixed parameters. Even though in this research, the model with a high level of flexibility shows the best performance, more investigations are needed to identify the fittest configuration in Yazd. In this case study, the average value of SVF is higher than that of insolation. Also, each factor has a better value in comparison with other models. For arrangement studies, the first model with modular buildings was used due to its better results compared with the second model; also, its proportions and modularity are suitable for new developments.

3.3. Analysis of the most optimum arrangement of blocks in urban grid

In this part, the same modular blocks are set inside a grid, with the possibility to change their both orientation and layout. The grid cell size is the result of the desired distance between blocks and their orientation in relation to the grid plane. The shifting parameter works in either the X or Y direction to make the staggered patterns possible Fig. 10.

Parameter	Value Assignment Type - N*- Variable Domain	Result
Block Module Type	Constant - 1	_
Block Orientation	Variable - 1 - (-80° to 80°)	40°
Grid Orientation	Variable - 1 - (-80° to 80°)	0°
Distance Between Blocks in X and Y Directions	Variable - 1 - (4 to 10m)	4-10 m
Number of Grid Cells In YDirection = a	Constant - 1	5
Number of Grid Cells In XDirection = b	Constant - 1	3
Shifting in Y Direction % of cell edge size	Variable - b - (-80 to 80 %)	20%, 60%, -40%
Shifting in X Direction % of cell edge size	Constant - 1 - (-80 to 80 %)	0

Parameter	Value Assignment Type - N*- Variable Domain	Result
Block Module Type	Constant - 1	_
Block Orientation	Variable - 1 - (-80° to 80°)	40°
Grid Orientation	Variable - 1 - (-80° to 80°)	0°
Distance Between Blocks in X and Y Directions	Variable - 1 - (4 to 10m)	4-10 m
Number of Grid Cells In YDirection = a	Constant - 1	3
Number of Grid Cells In XDirection = b	Constant - 1	5
Shifting in Y Direction % of cell edge size	Constant - 1 - (-80 to 80 %)	0
Shifting in X Direction % of cell edge size	Variable - a - (-80 to 80 %)	20%, -60%, -20%

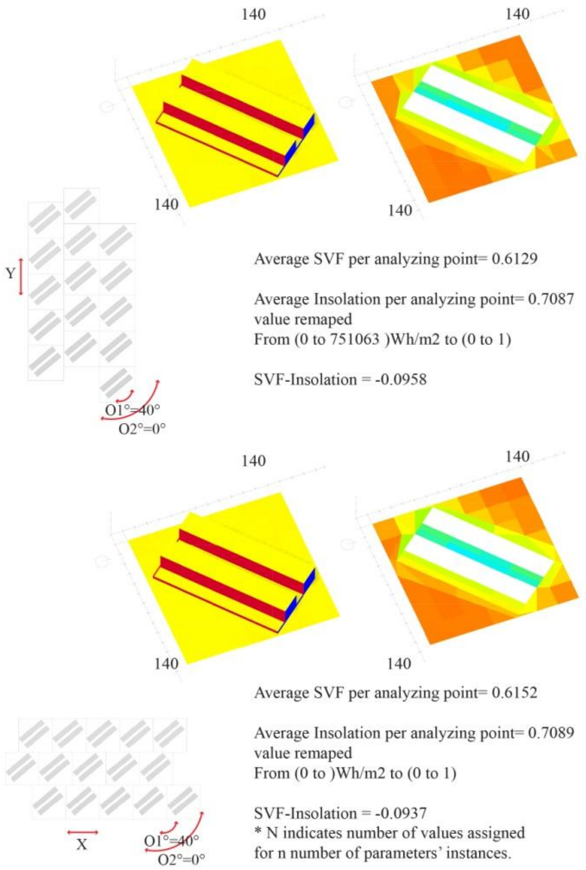

Fig. 10 The tables on the left show the parameters and their values, the upper images illustrate insolation and SVF values for the middle block in the optimum arrangement, and the lower images show the parametric flexibility and the optimized arrangement

In both studies, blocks and the grid oriented 40° and 0° to the south, respectively, with a staggered layout to maximize shading. Shifting in the X direction has a better cooling effect because of a higher SVF value. However, with respect to the daytime heat gain reduction, the first model shows lower values for insolation, and it can be considered a better layout according to the final results

4. CONCLUSION

The tool presented in this study using generative and evolutionary models based on SVF and insolation analyses can be a helpful program for designers to evaluate different urban configuration scenarios and find the most suitable solutions. The optimum block configuration can improve outdoor climate condition by providing shadow and effective night-time radiative cooling. This, in turn, affects the indoor environment and energy use of buildings. However, other parameters, including ventilation and ratio of surface to volume, should also be considered to come up with a desirable solution. The proposed tool has the potential to be further developed to work with other analysis tools. It is noteworthy to mention that the aim of this study was not to simulate the real situation, but rather to find a decision-making support tool for a climate-responsive design.

The present study sought to find the optimum block typologies and arrangements in Yazd. These can vary based on different constant and variable setups. However, analyses suggest that 30° to 40° orientation to the south seem to be desirable in all cases. The block model with maximum flexibility in height and courtyard configurations showed the best results in comparison with the modular ones. In arrangement studies, the grids tend to orient toward the south. Shifting grid rows in the X or Y direction had a similar effect on the final values. In both models, the staggered layout was proved as the fittest solution. Shifting in the X direction provided higher values of SVF, which makes it suitable for better night cooling effect. However, shifting in the Y direction was more effective on insolation and more helpful for controlling heat gain through the daytime. Notably, the claim to find the most efficient urban patterns needs further studies on configurations and arrangements with different variable setups. In this regard, the use of the generative evolutionary model in Grasshopper environment proved to be very useful and fast in calculating the results.

This study reveals the importance of coupling SVF with insolation in the evaluation of climatic behavior of various urban morphologies. Accordingly, the results of the researches with a specific focus on each of the factors should be carefully employed in real design cases, having in mind other influential parameters that can affect the overall fitness. In addition, the possibility of having different building typologies and multi-scale nature of the proposed tool makes it more applicable for real design tasks.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

REFERENCES

[1] Oke TR. Canyon geometry and the nocturnal urban heat island: Comparison of scale model and field observation, International Journal of Climatology, 1981, Vol. 1, pp. 237-54.

[2] Johnson GT, Watson ID. The determination of view -factors in urban canyons, Journal of Climate and Applied Meteorology, 1984, Vol. 23, pp. 329-35.

[3] Bärring l, Mattsson JO, Lindqvist S. Canyon geometry, street temperatures and urban heat is land in Malmö, Journal of Climatology, 1985, Vol. 5, pp. 433-44.

[4] Ratti C, Richens P. Urban texture analysis with image processing techniques. In: G. Augenbroe, Ch. Eastman (ed.), Proceedings of the CAAD Futures 99 Conference, Kluwer Academic Publishers, Atlanta, GE, 1999, pp. 49-64.

[5] Chapman L, Thornes JE, Bradley AV. Rapid determination of canyon geometry parameters for use in surface radiation budgets, Theoretical and Applied Climatology, 2001, Vol. 69, pp. 81-90.

[6] Hua Y, Whiteb M, Dinga W. An urban form experiment on urban heat island effect in high density area, Procedia Engineering, 2016, Vol. 169, pp. 166-174.

[7] Sakar B. Parametric modelling for the mitigation of urban heat island effect: A model proposal, Middle East Techical University, Ankara, 2018.

[8] Nelson V. Introduction to renewable energy, Taylor & Francis, New York, USA, 2011.

[9] Masoud B, Coch RH, Crespo CI, Beckers B. Effects of urban morphology on shading for Pedestrians Sky view factor (SVF) as an indicator of solar access. In: E. Ng, S. Fong, C. Ren (ed.), Proceedings of the 34th International Conference on Passive and Low Energy Architecture, PLEA, Hong Kong, China, 2019, pp. 1029-1031.

[10] Chang S, Saha N, Castro-Lacouture D, Yang P. Generative design and performance modeling for relationships between urban built forms, sky opening, solar radiation and energy, Energy Procedia, 2018, Vol. 158, pp. 22-25.

[11] Lópeza CS, Salab M, Tagliabuec LCh, Frontinia F, Bouziria S. Solar radiation and daylighting assessment using the sky-view factor (SVF) analysis as method to evaluate urban planning densification policies impacts, Energy Procedia, 2016, Vol. 91, pp. 989-996.

[12] Ratti C, Raydan D, Steemers K. Building form and environmental performance: Archetypes, analysis and an arid climate, Energy and Buildings, 2003, Vol. 35, pp. 49–59.

[13] Choi Y, Lee S, Moon H. Urban physical environments and the duration of high air temperature: focusing on solar radiation trapping effects, Sustainability, 2018, Vol. 10, No. 12, pp. 4837. https://doi.org/10.3390/su10124837.

[14] Vermeulen T, Knopf-Lenoir C, Villon P, Beckers B. Urban layout optimization framework to maximize direct solar Irradiation, Computers, Environment and Urban Systems, 2015, Vol. 51, pp. 1-12.

[15] Peronato G, Nault E, Cappelletti F, Peron F, Andersen M. A parametric design-based methodology to visualize building performance at the neighborhood scale. In: M. Baratieri, V. Corrado, A. Gasparella and F. Patuzzi (ed.), Proceedings of Building Simulation Applications, University Press, Bolzano, Italy, 2015, pp. 351-358.

[16] Grifoni RC, D'Onofrio R, Sargolini M, Pierantozzi M. A Parametric Optimization approach to mitigating the urban heat Island effect: A case study in ancona, sustainability, 2016, Vol. 8, No. 9, pp. 896.

[17] Taleb H, Musleh MA. Applying urban parametric design optimisation processes to a hot climate: Case study of the UAE, Sustainable Cities and Society, 2015, Vol. 14, pp. 236-253.

[18] Chen KW, Janssen P, Norford L. Automatic parameterization of semantic 3D city models for urban design optimization, In: G. Çagdas, M. Özkar, L.F. Gül, E. Gürer (eds.), Computer-Aided Architectural Design Futures: Future Trajectories, Springer, Istanbul, Turkey, 2017, pp. 51-65.

[19] Eltaweel A, SU Y. Parametric design and daylighting: A literature review, Renewable and Sustainable Energy Reviews, 2017, Vol. 73, pp. 1086-1103.

[20] Lobaccaroa G, Frontinib F. Solar energy in urban environment: how urban densification affects existing buildings, Energy Procedia, 2014, Vol. 48, pp. 1559-1569.

[21] Amadoa M, Poggib F. Solar urban planning: a parametric approach, Energy Procedia, 2014, Vol. 48, pp. 1539-1548.

[22] Wei R, Song D, Wong NH, Martin M. Impact of urban morphology parameters on microclimate, Procedia Engineering, 2016, Vol. 169, pp. 142-149.

[23] Chokhachian A, Perini K, Giulini S, Auer T. Mathematical generative approach on performance based urban form design. in: m. burlando, M. Canepa, A. Magliocco, K. Perini and M.P. Repetto (ed.), Proceeding of International Conference on Urban Comfort and Environmental Quality, Genova University Press, Genoa, Italy, 2017, pp. 30-35.

[24] Nagy D, Villaggi L, Benjamin D. Generative urban design: integrating financial and energy goals for automated neighborhood layout, In: T. Rakha, M. Turrin, D. Macumber, F. Meggers and S. Rockcastle (eds.), Proceedings of the Symposium for Architecture and Urban Design Design, Delft, the Netherlands, 2018, pp. 265-274.

[25] Rodriguesa E, Amarala AR, Gaspara AR, Gomesb Á. An approach to urban quarter design using building generative design and thermal performance optimization, Energy Procedia, 2015, Vol. 78, pp. 2899-2904.

[26] Rodriguesa E, Soaresa N, Fernandesa MS, Gaspar AR, Gomes A, Costa JJ. An integrated energy performance-driven generative design methodology to foster modular lightweight steel framed dwellings in hot climates, Energy for Sustainable Development, Vol. 44, pp. 21-36.

[27] Vasanthakumar S. A Computational design system for environmentally responsive urban design, University of Waterloo thesis, Waterloo, Ontario, Canada, 2015.

[28] Shi Z, Fonseca JA, Schlueter A. A review of simulation-based urban form generation and optimization for energy-driven urban design, Building and Environment, 2017, Vol. 121, pp. 119-129.

[29] Bassolino E, Ambrosini L. Parametric environmental climate

adaptive design: the role of data design to control urban regeneration project of borgo antignano, Naples, Procedia – Social and Behavioral Sciences, 2015, Vol. 216, pp. 948-959.

[30] White M, Hu Y, Langenheim N, Ding W, Burry M. Cool city design: Integrating real-time urban canyon assessment into the design process for chinese and australian cities, Urban Planning, 2016, Vol. 1, No. 3, pp. 25-37.

[31] Souza LCL, Rodrigues DS, Mendes JFG. A 3D GIS extension for sky view factors assessment in urban environment, In: Proceedings of the 8th International Conference on Computers in Urban Planning and Urban Management, Centre for northeast Asian studies, Tohoku, Japan, pp. 27-9, 2003.

[32] Ratti C, Richens P. Raster analysis of urban form, Environment and Planning B: Planning and Design, 2004, Vol. 31, pp. 297-309.

[33] Lindberg F. Towards the use of local governmental 3-D data within urban climatology studies, Mapping Image Science, 2005, Vol. 2, pp. 32-7.

[34] Chen L, Ng E, An X, Ren C, Lee M, Wang U, He Z. 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, 2012, Vol. 32, pp. 121-36.

[35] Gal T., Lindberg F, Unger J. Computing continuous sky view factors using 3D urban raster and vector databases: comparison and application to urban climate, Theoretical and Applied Climatology, 2009, Vol. 95, pp. 111-23.

[36] Gal T, Rzepa M, Gromek B, Unger J. Comparison between sky view factor values computed by two different methods in an urban environment, ACTA Climatologica Et Chorologica, 2007, Vol. 40, pp. 17-26.

[37] Matzarakis A, Rutz F, Mayer H. Modeling radiation fluxes in simple and complex environments-application of the Rayman model, International Journal of Biometeorology, 2007, Vol. 1, pp. 323-34.

[38] Jie W, Zhang Y, Meng Q. Calculation method of sky view factor based on rhino grasshopper platform, In: E. Wurtz (ed.), Proceedings of the 13th Conference of the International Building Performance Simulation Association, Miller-Thompson, Chambéry, France, 2013, pp. 2658-2666.

[39] Jiang Z, You W, Ding W. Calculation of ground view factor as an index for urban thermal environment optimization, Energy Procedia, 2017, Vol. 142, pp. 2996-3001.

[40] Al-Sudani A, Hussein H, Sharples S. Sky view factor calculation a computational-geometrical approach. In: A. Fioravanti, S. Cursi, S. Elahmar, S. Gargaro, G. Loffreda, G. Novembri and A. Trento (eds.), Proceedings of the 35th eCAADe Conference, Sapienza University of Rome, Rome, Italy, 2017, Vol. 1, pp.673-682.

[41] Ratti C, Raydan D, Steemers K. Building form and environmental performance: archetypes, analysis and an arid climate, Energy and Buildings, 2003, Vol. 35, pp. 49–59.

[42] Di Sabatino S, Hedquist BC, Carter W, Leo LS, Fernando HJS. Phoenix urban heat island experiment: effects of built elements, In: Proceedings of the Eighth Symposium on the Urban Enviroment, Phoenix, Arizona, 2009.

[43] Yazd weather data, Available at: <http://apps1.eere.energy.gov/buildings/energyplus/weatherdata.cfm> [Accessed 12 May 2013].

AUTHOR (S) BIOSKETCHES

Roshanzamir, Sh., *PhD, Department of Architecture & Urban Design, Art University of Isfahan, Isfahan, Iran*
Email*: Sh.Roshanzamir@aui.ac.ir*

Farhadian Dehkordi, M., *PhD. Candidate, University of Applied Arts Vienna, Vienna, Austria*
Email: *M.Farhadian.d@gmail.com*

HOW TO CITE THIS ARTICLE

Roshanzamir, Sh., Farhadian Dehkordi, M., (2018). Developing a tool for analyzing and generating the fittest urban morphology based on the sky view factor and insolation (A case study on Yazd). Int. J. Architect. Eng. Urban Plan, 29(1): 69-78, June 2019.

URL: http://ijaup.iust.ac.ir/article-1-207-en.html