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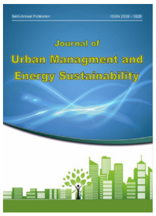

ORIGINAL RESEARCH PAPER

Optimizing Building Volume and Solar Access in Isfahan's Urban Context: A Solar Envelope Approach Using Parametric Design Tools

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ABSTRACT

This study investigates the application of Solar Envelope methodology integrated with Parametric Design tools to optimize building volume and Direct Solar Access in Isfahan's urban context. Through comprehensive Environmental Simulation using Rhino/Grasshopper and Ladybug plugins, this research develops an innovative approach to Urban Planning that balances construction density with solar rights. The Energy Optimization analysis demonstrates that the Solar Envelope method achieves a 26.13% increase in buildable volume and 41.11% increase in area compared to current regulations, while enhancing solar energy on adjacent building facades by 2.60%. The study employs Parametric Design workflows to generate and evaluate multiple solar-driven alternatives, ensuring Direct Solar Access during critical periods (December 21st, 8 am-4 pm). Comparative analysis Isfahan, Mashhad, and Tabriz validates the climate-responsive nature of the Solar Envelope approach. Results indicate that current Urban Planning regulations inadequately address solar access rights, often leading to violations. The proposed Environmental Simulation methodology offers a robust framework for Energy Optimization in dense urban developments, demonstrating that 100% land occupancy can be achieved while maintaining solar access standards. This research provides critical evidence for updating architectural and Urban Planning laws in Iran to incorporate Solar Envelope principles for sustainable urban development.

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INTRODUCTION

The sun is the most important light source for the urban environment and the interior of buildings during the day. The visible light spectrum guarantees the comfort of vision. (Lockley, 2009). As a matter of fact, by following nature's example, the buildings and the city we live in are dependent on the daily energy of sunlight. Daylight penetrates into the building in various forms, including direct sunlight, exposure to airborne particles, or reflections from objects in the surrounding environment. Direct sunlight has the highest penetration inside the building (Reinhart, 2014), and is the best replacement for artificial light and heat. The amount of daylight available in a building depends on the type of sky cover, and the clear sky depends on the position of the sun, varying in latitude, as well as the date and time of use. Sunlight is always needed to create natural light indoors. But since this light eventually turns into heat, the amount of radiation required for each building must be determined by its type and the climatic conditions of the site (Kasmaee, 1993). In ancient times, areas such as China and Greece used to plan buildings and urban planning to access the sun according to height, shape, orientation, and building environment (Butti et al., 1980). As it was mentioned, the importance of street orientation is clear in solar planning and in access to light. William Atkinson devotes a chapter in his book 'The Orientation of Buildings, or Planning for Sunlight' (1912) to the building shape: The method of limiting the height of buildings by a horizontal plane, either at a fixed height or at a height proportional to the width of the street, is simple in application but is not scientific, since it assumes that what is the proper height for the front wall or facade is also the proper height for the rear portions of the building. (Atkinson, 1912, p. 121). With proper design, natural light can be used for indoor lighting, and this is the first step in designing space geometry. Taking into account the general shape, orientation, attention to the depth of light penetration to the interior, and the length of the sunny fronts, are the most important factors in proper design (Tahbaz, 2017). As J. Steele in his book 'Sustainable Architecture' (1997), asserted: Our predilection in favor of growth over maintenance has raised doubts about a sustainable future. So far, there has been little incentive for developers to worry about the long-term energy costs of keeping our buildings comfortable and repaired. Because of the enormous pressures to build quickly and move on to the next project, construction techniques prioritize rapid assembly over the effects of long-term wear and tear. Developers do not pay the bills for heating, cooling, and lighting over time and seasons. Consequently, they have demanded that architecture specify energy-intensive systems rather than make the effort to design with nature. We grow cheap and maintain expensively, in the most basic ungrammatical terms (Steele, 1997). There are various views and opinions on the question of creating favorable conditions for the comfort of human life, ranging from 58 degrees Fahrenheit in the United Kingdom to 80 degrees Fahrenheit, the highest temperature of human comfort by American experts. A person's ability to feel comfortable without the use of heating and cooling (neutral thermal environment) (without feeling cold or heat) is called a comfort zone. In other words, the range of temperatures where the heat distribution is satisfiedtorily would have existed in the human comfort zone is called (Parsons, 2014).

In contemporary times, with the ever-increasing growth of cities and building congestion, especially in metropolises, the considerations and rules of access to sunlight at design time are largely ignored. This can be attributed to the weakness of architectural and urban regulations, the ease of access to artificial light and air conditioning in the building, the lack of building design standards, the planning requirements for sunlight, and the lack of adequate natural light in the building (De Luca, 2016). Using and utilizing energy and sunlight throughout the day can greatly help in designing and planning cities. Hours of sunlight utilization in a building can be calculated with environmental simulation software that allows the designer to accurately analyze the volume of the building.

The Solar Envelope (SE), introduced by Ralph Knowles, is a geometric evaluation approach aimed at ensuring solar access to surrounding buildings by defining the maximum buildable volume based on building height and overshadowing. This method minimizes the impact of building shading on the environment and guides designers in optimizing building volume to reduce shading during critical times of the year. Optimizing building volume and solar access within urban contexts increasingly involves utilizing solar envelope methodologies in conjunction with parametric design tools to enhance energy efficiency (Luca et al., 2021). Parametric design approaches enable the generation and evaluation of various urban designs in the early stages, effectively simulating different aspects of solar integration with buildings (Bushra, 2022). For instance, Rhino and Grasshopper, coupled with Ladybug Tools (LBT) and Honeybee, are widely used for parametric modeling and thermal simulation to forecast energy consumption and perform detailed environmental analyses (Chen et al., 2024). (Tab. 1)

Initial attempts at defining solar access solutions, such as Arumi's (1979) computer model for maximum building height, laid the groundwork for further developments. Knowles (1981) later refined this by proposing a solar envelope method for urban blocks, inspiring subsequent models like Solvelope by Schiler and Uen-Fang (1993). While early methods often relied on basic CAD tools, the advent of advanced computational systems has significantly expanded the possibilities for simulating solar envelopes. Despite decades of research and the development of theoretical solutions, the practical application of the Solar Envelope method as a widespread design regulator and extender in urban planning has remained limited (Niemasz et al., 2013). Modern environmental simulation software, such as the Ladybug plugin for Rhino/Grasshopper, has democratized the analysis of direct sunlight access and solar envelope generation. This powerful tool, building upon the work of Knowles, Capeluto, Niemasz, Sargent, and Reinhart, requires specific inputs including time, location, topography, neighboring building data, and solar position to generate an optimal design volume. Urban design parameters such as street width and orientation, as well as building design parameters like roof shape and building envelope design, significantly affect so-

Table 1. The height and occupation level rules and regulations

Maximum Occupancy Level (%)	Maximum permissible height of building from passage level to parapet roof of building (m)	Number of floors
60	8	2floors on the ground (with seats)
60	10.5	2floors on the ground ground level
60	14	3floors on the ground level
60	17	4floors on the ground level
60	20	5floors on the ground level
55	23.5	6floors on the ground level
50	26.5	7floors on the ground level
50	30	8floors on the ground level
45	33	9floors on the ground level
35	Add 3.20 m for each floor (up to approved elevation code)	10floors above ground leveland higher (high)

lar access (Esch et al., 2012). Advanced computer design tools can automatically create solar envelopes (Luca et al., 2021). For instance, the Solar Block Generator (SBG) is a parametric workflow that uses an additive voxelization method to generate and evaluate multiple solar-driven massing alternatives for a given site (Natanian et al., 2021). Furthermore, AutoBPS is an urban building energy modeling tool used to calculate urban building energy demands and to analyze energy retrofit and rooftop photovoltaic (PV) potential (Deng et al., 2023). The significance of solar access extends to urban planning regulations, as it profoundly impacts both building performance and the overall urban image (Luca and Dogan, 2019). Solar Envelope Zoning (SEZ) is increasingly recognized as a vital zoning tool to promote health, comfort, and resiliency in urban areas (Saunders, 2021). This method precisely regulates building density based on factors such as plot size, orientation, ground slope, latitude, and duration of insolation (Stasinopoulos, 2018). This growing recognition underscores the importance of integrating such advanced methodologies into contemporary urban legislation, particularly in rapidly developing cities.

The street patterns greatly influence the size and shape of the solar envelope, and hence the size of the solar envelope and development varies with the street orientation. In general, the higher the solar envelope height in each of the two directions of the metropolitan block within the accessible grid. There is more and it increases urban legibility. Areas and paths will have a perceptual meaning when they are understood when the solar envelope becomes a model for urban design. Lynch asserted in his book ‘The Image of the City’ (1960): To become completely lost is perhaps a rather rare experience... but let the mishap of disorientation once occur, and the sense of anxiety and even terror that accompanies it reveals to us how closely it is linked to our sense of balance and well-being. (Asserted, 1960). The SustArc model, expansive Solar Envelope, offers two types of solar envelope: the SRE, which has a three-dimensional range of maximum height that can be prevented from blocking access to the sun at specific times and dates; and the SCE, which specifies the range at which the volume of the building can be built with the lowest height, so that it has the most access to the sun, given the texture shadows of the surrounding buildings. Finally, the combination of these two types of shells provides a final volume that provides sustainable development and maximum use of the sun for the building and its surrounding site. So, if the building is designed and built within this volume, it will provide the best access to the sun at critical times of the year (Capeluto, 2003).

Against this background, this study is designed to achieve two primary goals. Firstly, it analyzes the solar envelope at the specified site to determine the maximum building volume that ensures optimal sunlight access for surrounding buildings. Secondly, it thoroughly examines and compares this proposed building volume with both the existing construction regulations in Isfahan and the current building status, evaluating them against the Solar Envelope approach using the same occupancy levels. (Fig. 1)

The aims of the current study is to analyze the solar envelope at the specified site to determine the maximum building volume that ensures optimal sunlight access for surrounding buildings. Secondly, it thoroughly examines and compares this proposed building volume with both the existing construction regulations in Isfahan and the current building status, evaluating them against the Solar Envelope approach using the same occupancy levels. This study has been carried out in Isfahan, Iran in recent years. To validate the robustness and climate-adaptability of the proposed Solar Envelope methodology, this study extends its analysis beyond Isfahan to include two other major Iranian cities with distinct climatic conditions: Tabriz (cold semi-arid climate) and Mashhad (cold steppe climate). This comparative approach ensures the methodology’s applicability across diverse geographical contexts.

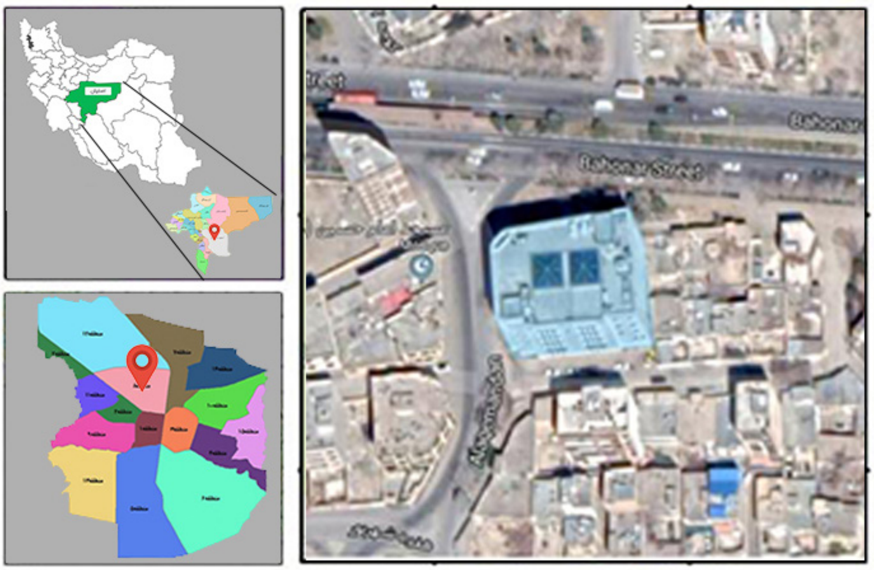

Figure 1: Geographical location of the study area in District 8, Isfahan city, Isfahan province, Iran.

MATERIALS AND METHODS

This article is designed to achieve two goals. At the first level, the solar envelope is analyzed at the mentioned site and the maximum volume is reached for the building, so that maximum sunlight is provided to the surrounding buildings, which will be elaborated in Section 5. The second level examines the building with the existing rules of construction in Isfahan and the existing state of the building. Then we will compare them with those of the Solar Envelope, which uses the same occupancy level. Although much of the past research focused on energy saving, they show that the access to sunlight and shading play is an important role in inducing thermal comfort both for indoors and out of the building (Arens, et al, 2015). To illustrate this point, the 'Isfahan Climate Needs Diagram' has been provided throughout the year. (Fig. 2) shows that 7.5% (661 h) of comfort conditions and 25.9% (2265 h) of Evaporative Cooling, 16.4% (1440 h) of Thermal mass + Night Vent, 4.8% (417 h) of Natural Ventilation, 46.1% (4036 hrs) With Passive Solar Heating, 79.4% (6958 hrs) can achieve thermal comfort conditions in Isfahan city throughout the year.

Calculating Parametric Solar Envelopes (PSE)

The calculation of a solar parametric shell begins with the conditions for which direct sunlight is needed. While there are no fixed time rules, site conditions are the main option for calculation. To calculate, we first need to create a 2D boundary of the site and then model it in Rhino software. Next, in the next phase, by inserting a weather file (EPW) into the Ladybug plug, we should determine the conditions for sunshine and minimum temperature for modeling. In this study, the air temperature was kept below 20 °C, which is the minimum temperature required to create thermal comfort conditions at the time considered, as well as the amount of energy received from the sun was kept below 475 w/m2 on the 21st of December (the shortest day of the year). The site is then introduced to the Ladybug plug-in along with the buildings and surroundings to determine the height of the shadow boundary on the surrounding buildings, which require daylight for residential use, and the ground floor in these buildings are parking. As a result, the shading boundary is considered above ground level if it is at least 4 meters high (the minimum starting floor of adjacent buildings). In this pa-

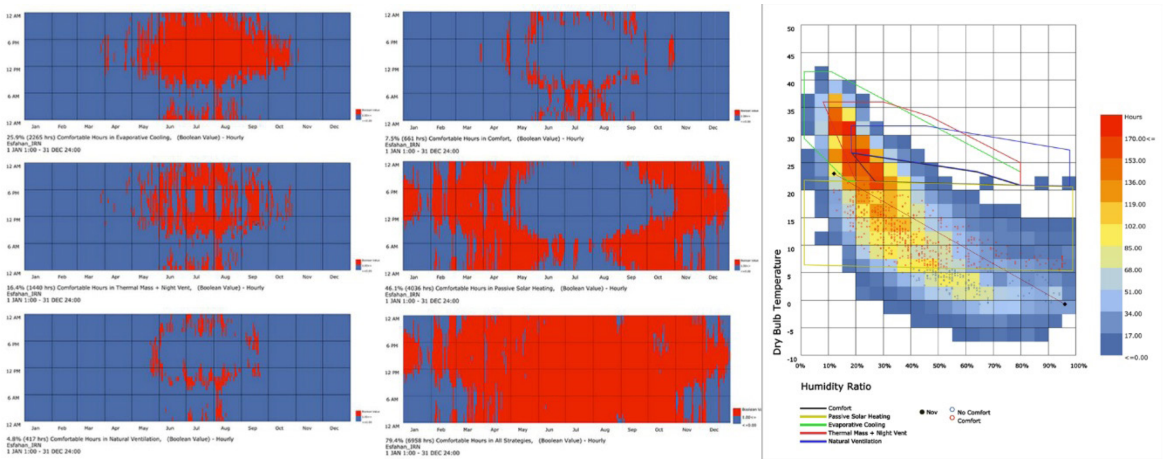

Figure 2. Right: Isfahan City Climate Demand Chart (December), Left: Effective strategies for creating a comfortable situation in Isfahan city through a year

per, the modeling time due to critical comfort conditions on the 21st of December from 8 am to 4 pm with a 60-time step is calculated as 60 analyses per 1 hour—one analysis per minute. Finally, a geometric polygon modeling process is created that has a maximum height of 20 meters. In the fifth section, the number of hours of adjacent buildings and levels of sunlight, the amount of energy received by the buildings, and the levels of land available in the building, and Isfahan city rules, the Solar Envelope modeling is based on 60% arena and 100% ground arena, as explained below: Figure 3. Solar Envelope production process diagram in Rhino / Grasshopper software and ladybug plugin

Parameters and Filters

In this way, the best possible results can be achieved by applying the software features and filters and constraints that are part of the software‘s various parameters, as follows:

1- The definition of the relevant geographic location based on the Climate Data File, Energy Plus Weather : (EPW)

This file, provided to at Meteonorm Meteorological Station and Software, include information on geographic climate characteristics, minimum and maximum temperature, dry and wet temperature, dew point, relative humidity, wind speed and wind direction.

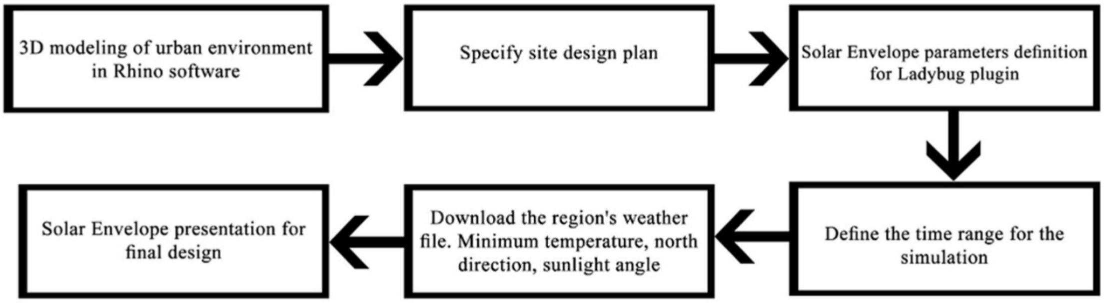

Figure 3: Solar Envelope production process diagram in Rhino/Grasshopper software and ladybug plugin

2- The use of other parameters such as the use of adjacent buildings, streets and access, landscapes, temperature, shadow boundary on adjacent buildings, height of the building, time and minimum amount of solar energy received by Solar Envelope and etc, is a part of the software‘s features.

Case Study

The study site is located in Isfahan, Iran (51E.32N). The area has a warm and dry climate, with hot and dry summers and cold winters. The site is located in an urban setting and is located on the South, east and west of the study site are 2 to 5 storey residential buildings and north of a 32 m wide street. The case study is made with 100% density. And has violated Isfahan's urban planning, (according to Isfahan's architectural and urban planning rules, the occupancy level should be 60%) and has violated access to sunlight in surrounding buildings. It is noteworthy that in Isfahan the laws of architecture and urban planning in buildings can not be respected and in the final stages by paying fines, the final approval will receive which indicates the aging, weakness and inefficiency of existing laws and the need to use more occupancy and the rights of others to enjoy the light.

This article describes the different stages of modeling to analyze the amount of sunlight available in, A: Building with 60% of the land area, according to the laws of Isfahan B: Existing building status C: Solar Envelope Model for 60% Occupancy Level and D: Solar Envelope Model. Modeling according to existing municipal laws is intended as a basis for information analysis to investigate the existing municipal laws in order to review the existing municipal laws and the Solar Envelope method to get the most out of the building so that the rights to sunlight on other adjacent buildings are not eliminated.

A meteorological organization has been used to simulate an EPW weather file from Isfahan. The shading boundary is intended for use on the ground floor of most surrounding buildings at a height of 4 meters above the ground. The analysis period is due to be the coldest day of the year and the most critical day for sunlight on December 21st, from 8 a.m. to 4 p.m. To validate the model's applicability across different climatic zones, the same Solar Envelope analysis was replicated for Tabriz and Mashhad using their respective EPW weather files. All site conditions, modeling parameters, and analysis periods remained consistent with the Isfahan case study to ensure comparability of results.

DISCUSSION AND FINDINGS

Simulation of volume and area changes

In the above simulation, it can be seen that by applying filters based on the Solar Envelope method, the capability to develop requires more volume in the building than what is available in the existing architectural and urban laws. Fig. 5, shows that the Solar Envelope method achieved a 26.13% volume increase. (Tab. 1) represents the number of permitted floors according to municipal law, and shows The total area of each model in Figure 5 shows a 41.11% increase in metrics over 100% of land in the Solar Envelope method.

Simulation the amount of energy received from the sun on the earth's surface around the site

In the discussion of receiving energy for the land, the surface around the site was examined. Figure 6 shows the amount of energy received in different modes for a range of 31,464 m2 and the number of 1923 point tests obtained with a grade of 4 for the range. It is observed that the amount of received energy of the earth from the sun is -1.64% at 903 kWh/m2 compared to urban laws, while the solar envelope has a 0.21% increase in energy consumption for 60% of the earth. This shows the weakness of the rules, and there is an increase of 346 kWh/m2 by the Solar Envelope method with an occupancy level of 100%. There is an increase of 0.63% to 346 kWh/m2 compared to city law.

Simulation The amount of sunlight on the earth around the site

Figure 7, shows the survey of the Earth's surface hours of sunlight in an area of 31,464 square meters and the number of 1923 Point and Grade 4 tests:

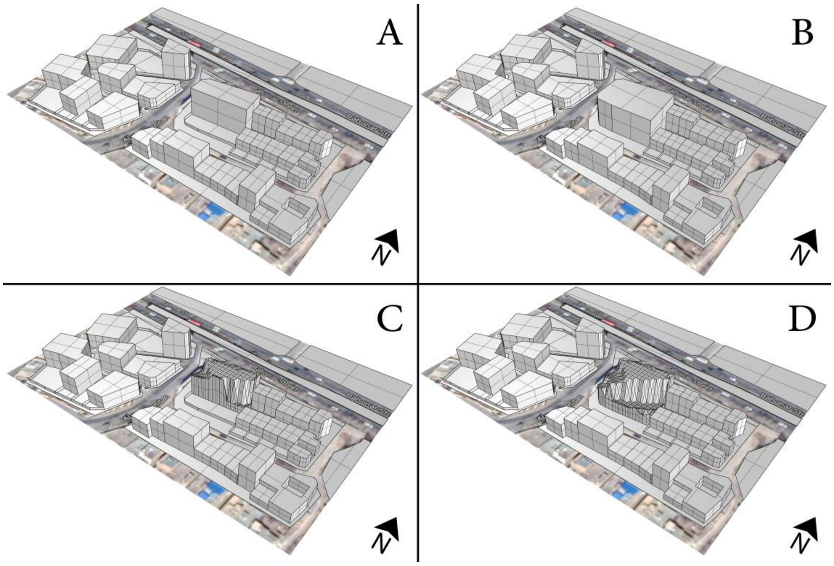

Figure 4: Solar Envelope created in Grasshopper software
A: A building according to Isfahan Urban Architecture Laws occupy 60% of the land
B: Existing building status
C: Solar Envelope method with 60% occupancy level
D: Solar Envelope method with 100% occupancy level

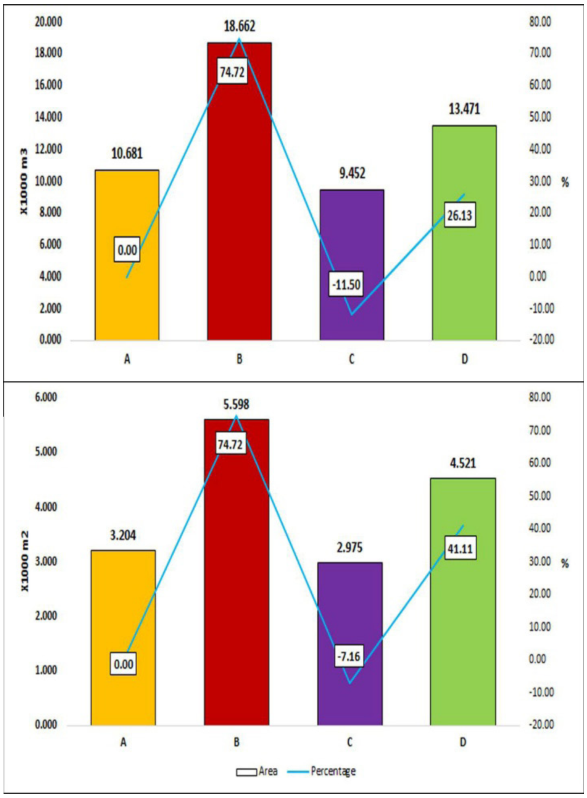

Figure 5: Comparison diagram of building volume and building area in Figure 4

In the above modeling, it is observed that the building in its present situation, -1.58% equals about 2052 hours and in total 1923 test points, has less sunlight at ground level. In C mode, there will be an increase of 0.25% to 325 hours of the use of the sunlight on the surface of the earth, and in D mode there will be a decrease of -1.22%, equal to 1582 hours.

Simulation The amount of energy received from the sun in the facade of buildings around the site

In terms of sunlight and energy for adjacent buildings, the modeling shown in Figure 8, shows the results for 21st of December in the facade of the surrounding buildings with an area of 1478.96 square meters and 1343 test points and with the grade of size 1. Indeed, it can be observed very simply that Model B has 2948.25 kWh/m2 of solar energy, which is 3.49% less than A's 106.67 kWh/m2 of energy from the surrounding buildings. In C mode, 3.16% of the 96.48 kWh/m2 Solar Envelope method can be obtained in the view of the surrounding buildings compared to Model A with the same energy density. This is in the case where D modeling can see 2.60% more energy at 79.44 kWh/m2 in the view of surrounding buildings.

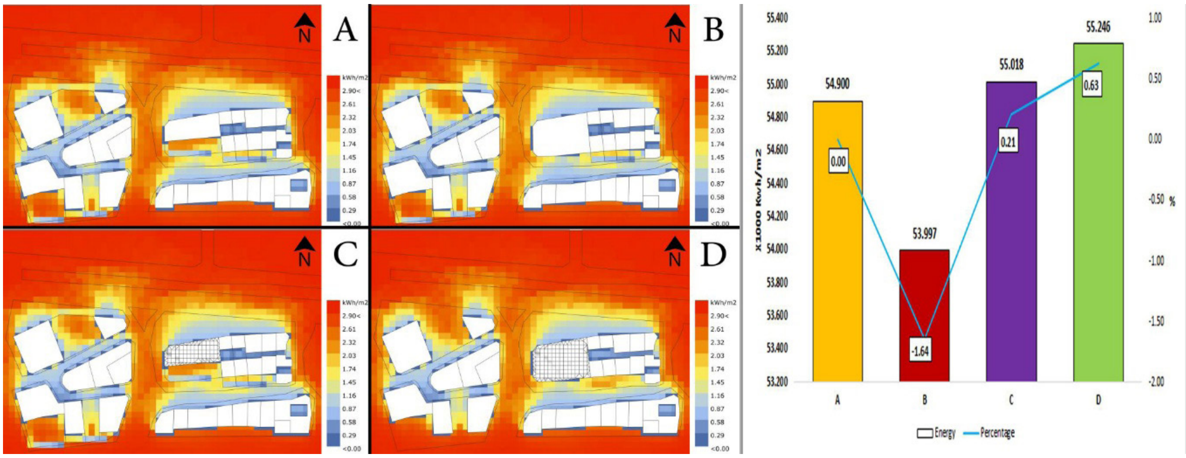

Figure 6: Received energy from the sun light on the earth's surface around the site (kWh/m2) and Comparison chart of received energy from the sun on the surface of the earth around

A: The amount of received energy by the land surface according to Isfahan city laws with 60% occupancy level.

B: The amount of received energy by the land surface according In the current state of the building.

C: The amount of received energy on the surface is based on the Solar Envelope method with a 60% occupancy level

D: The amount of received energy by the earth is based on the Solar Envelope method with a 100% occupancy level

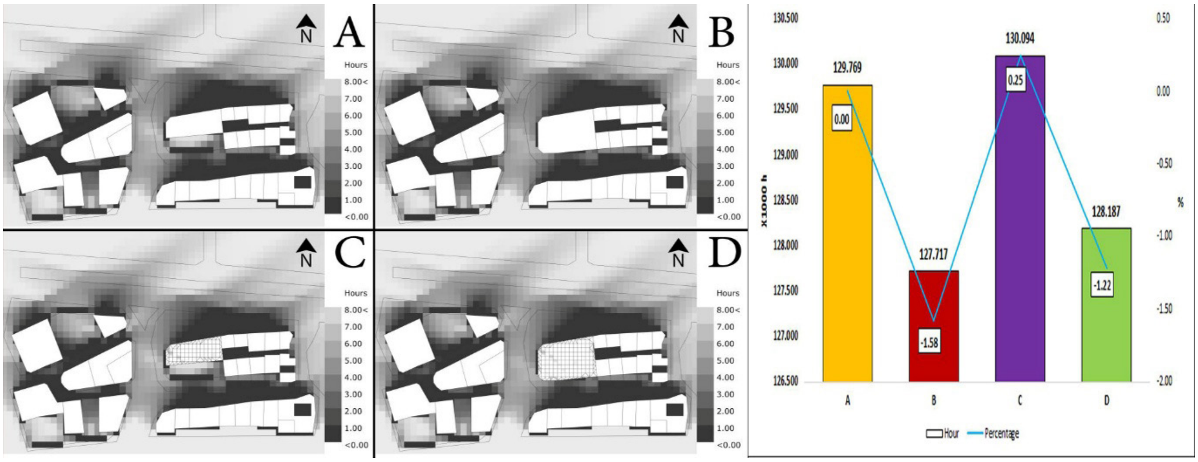

Figure 7: Hours of sunlight on the ground around the site and Comparison diagram of hours of sunlight on the ground around

A: Hours of sunshine according to Isfahan city laws with 60% occupancy level of the ground arena

B: Hours of available sunlight in building

C: Hours of available sunlight based on Solar Envelope method with 60% of the ground arena

D: Hours of available sunlight based on Solar Envelope method with 100% occupancy of the ground arena

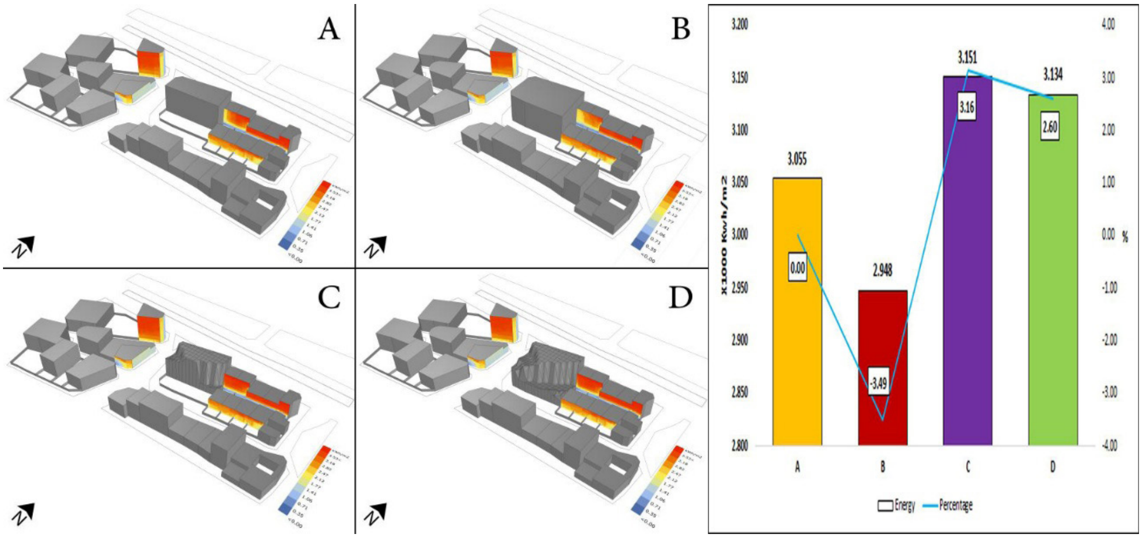

Figure 8: Receives energy from the sun on the facade of surrounding buildings and Comparison chart of the receives energy from the sun on the facade of the surrounding buildings

A: The amount of received energy from the sun on the facade of surrounding buildings based on Isfahan urban laws with 60% occupancy level of the ground arena.

B: The amount of received energy from the sun on the facade of surrounding buildings with In the current state of the building.

C: The amount of received energy from the sun on the facade of the surrounding buildings based on Solar Envelope method with 60% of the ground arena.

D: The amount of received energy from the sun on the facade of the surrounding buildings based on Solar Envelope method with 100% of the ground arena.

Simulation The amount of sunlight on the facade of buildings around the site

Figure 9, shows the modeling results for the amount of sunlight in the facade of surrounding buildings:

From the above analysis, it can be seen that the construction process, according to Isfahan urban law, 6961.91 hours and a total of 1343 point test, will use sunlight. In this case, in B mode, -3.97% equals about 287.45 hours. The building will receive less sunlight, but in C, it was observed that 3.85% equals about more than 279.15 hours, and even more than A mode. The facade of surrounding buildings will receive more sunlight. In D mode, the building will receive 3.6 percent, which is about 260.93 hours of sunlight, even more than in A mode, and the view of surrounding buildings will receive more sunlight.

Comparative Analysis Across Different Climatic Zones

To demonstrate the climate-responsive nature of the Solar Envelope methodology as outlined in the Methods section, Table 3 presents the comparative results for Isfahan, Mashhad, and Tabriz. These cities were selected based on their distinct climatic characteristics (Tab. 2) to validate the model's adaptability. To clearly show the climatic differences between the studied cities as the main factor in the simulation results, a general overview of their climatic parameters is essential. The following table provides a summary of key climatic data for each of the cities of Isfahan, Mashhad, and Tabriz. This comparison not only helps in a better understanding of the reasons for the observed differences in optimal building volume, but also emphasizes the importance of local climatic analysis in climatic design and building energy optimization. (Tab. 2)

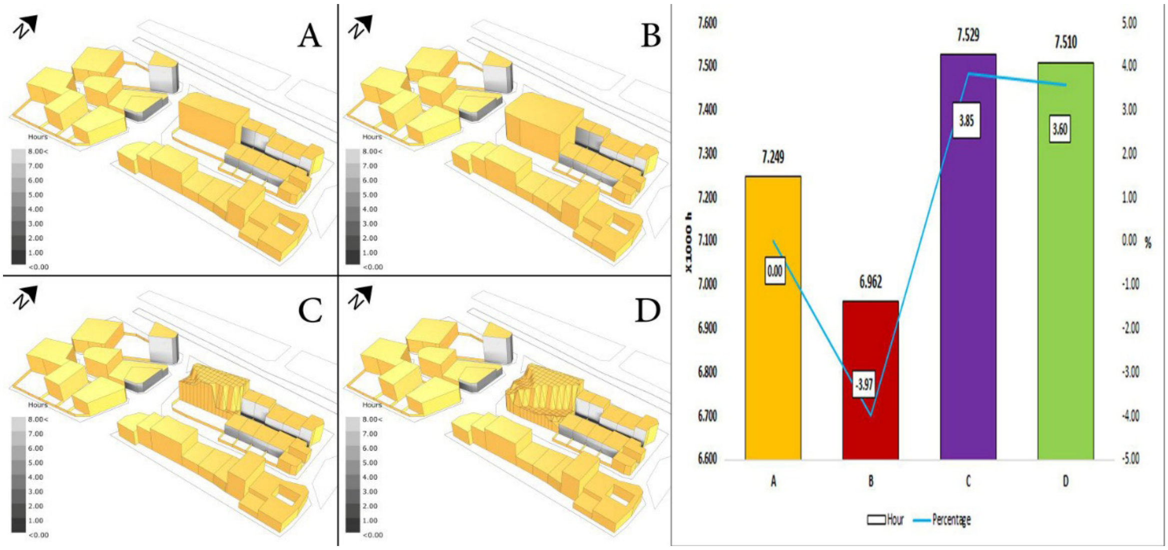

Figure 9: Hours of available sunlight on the facade of the surrounding buildings and Comparison diagram of hours of available sunlight on the facade of the surrounding buildings

A: Hours of available sunshine on the facade of the surrounding buildings based on Isfahan urban law with 60% occupancy level.
B: Hours of available sunshine on the facade of the surrounding buildings when In the current state of the building.
C: Hours of available sunshine on the facade of the surrounding buildings based on Solar Envelope method with 60% of ground arena
D: Hours of available sunshine on the facade of the sorrowing buildings based on Solar Envelope method with 100% of ground arena

Table 2. Climatic characteristics of three Iranian cities for studying simulation results

Climatic Parameter	Isfahan	Mashhad	Tabriz
Latitude (degrees)	32.4	36.3	38.1
Temperature (Celsius)			
Average Minimum	6.18	4.25	3.86
Average Maximum	26.64	26.71	22.93
Insolation (Wh/M2)			
Annual Average	6100.25	6527.67	7745.34
Relative Humidity (%)			
Annual Average 9:00 a.m	37.75%	39%	49.17%
Annual Average 3:00 p.m	22.1%	31.16%	30.09%

To further validate the model's robustness and demonstrate its applicability across diverse climatic conditions, the Solar Envelope analysis was replicated for two other major cities in Iran: Tabriz and Mashhad. Tabriz, located in a cold semi-arid climate, typically experiences harsher winters and a shorter solar gain season compared to Isfahan. Mashhad, situated in a cold steppe climate, also presents distinct climatic challenges, particularly in winter, influencing solar design considerations. The analysis maintained all the previous site conditions and modeling parameters, utilizing the respective meteorological files for each city. As illustrated in Table 3, the optimal solar envelope volume varies considerably across these different climates. For instance, the Solar Envelope volume (A) for Isfahan is approximately 13,47 m³, for Tabriz about 6,67 m³, and for Mashhad about 11,66 m³. This significant variation confirms that optimal building volume is highly climate-dependent, with colder regions generally exhibiting smaller solar envelope volumes. This is primarily because in colder climates, maintaining sufficient solar access for heating purposes during winter often necessitates stricter limits on building heights and densities to prevent excessive overshadowing. (Tab. 3)

Table 3. Solar Envelope simulation for different cities

Parameter	Isfahan	Mashhad	Tabriz
Solar Envelope volumen (M3)	13.47	6.67	11.66
Receives energy from the sun on the facade of surrounding buildings (KWh/M2)	3.13	4.24	6.70
Hours of available sunlight on the facade of the surrounding buildings (Hour)	7.51	7.23	7.33

Regarding the solar energy received on the facade of surrounding buildings (B), the values show relatively closer ranges: Isfahan at approximately 3.13 kWh/m², Tabriz at 4.24 kWh/m², and Mashhad at 6.70 kWh/m². Similarly, the hours of available sunlight on the facade of surrounding buildings (C) are comparable: Isfahan at about 7.51 hours, Tabriz at 7.23 hours, and Mashhad at 7.33 hours. While there are some differences, particularly in received energy, the overall consistency in solar access hours on facades suggests that the Solar Envelope method effectively ensures a minimum threshold of direct solar access for surrounding buildings, regardless of the specific climatic zone, validating its core premise. This comparative analysis demonstrates the model's adaptability and reinforces its potential as a versatile tool for urban planning in diverse geographical and climatic contexts.

CONCLUSION AND RESULTS

This study demonstrates that implementing a Solar Envelope approach for 100% land occupancy, even during the most critical solar access period of the year, yields a significant increase in design volume and area. Specifically, our findings for Isfahan indicate a 26.13% increase in buildable volume (approx. 2790 m³) and a 41.11% increase in area (approx. 1317 m²) compared to current urban planning regulations. While a slight reduction in direct sunlight on the immediate ground surface (1.22% decrease or 1582 hours) was observed, the solar energy received and sunlight hours on the facades of surrounding buildings notably increased (2.60% and 3.60% respectively), indicating a net positive effect on the adjacent structures' solar performance. The findings resonate with broader scholarly work on solar envelopes and parametric design. Our results reinforce the foundational concepts established by Knowles (1981,1985) regarding the potential of Solar Envelopes for denser yet solar-optimized urban development. The ability of our parametric model to generate optimal building volumes that maintain solar access aligns with approaches highlighted by Luca et al. (2021) and the capabilities of computational tools like Ladybug and Grasshopper as noted by Chen et al. (2024). Furthermore, the identified inadequacy of current Isfahan urban planning regulations in effectively addressing solar access, which often leads to disregard for solar rights, mirrors concerns raised by Luca and Dogan (2019) and De Luca (2016) regarding the need for more nuanced, climate-responsive regulations. The potential for integrating Solar Envelope Zoning (SEZ) as a progressive zoning tool, as explored by Saunders (2021), is strongly supported by our empirical results in a real-world urban context. In conclusion, the proposed method, which leverages meteorological data and site-specific design conditions instead of relying solely on outdated city laws, demonstrates significant potential for advancing year-round solar access in buildings and maximizing land use for increased volume. These results critically underscore the urgent need for formulating new, solar-responsive architectural and urban planning laws and updating existing regulations in Iran to meet the growing demands for denser, yet sustainable, urban development.

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