MODELING THE DESIGN OF URBAN FABRI C WITH SOLAR RIGHTS CONSIDERATIONS

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ABSTRACT

A model for the design of urban grids and fabric with solar rights consideration taken into account is presented. The model allows the generation and evaluation of the building configurations, preserving the solar rights of each neighboring building, as well as the open spaces among them. The model presents a nomogram of the maximum available volume in which it is possible to build without violating the solar rights of any existing building, as well as the designed one. This volume is determined by two envelopes; the "Solar Rights Envelope" and the "Solar Collection Envelope" that are defined in this paper. We call this volume the "Solar Volume". The nomogram of the solar volume allows the determination of the preferred urban street orientation, proportion, and geometry to assure solar rights to each building and to the pedestrian sidewalks, in winter, as well as shading them in summer. The method is demonstrated by a case study. The results show that it is possible to achieve a high urban density quarter without violating solar rights.

INTRODUCTION

During the conceptual design phase of urban quarters, the designer deals with different geometrical characteristics related to the building's height in relation to the orientation and width of the open spaces and the pedestrian sidewalks. These include the determination of the proportion of the buildings, the open spaces and land subdivision. Each one of these topics is complex by itself, and the determination of the best design solution becomes specially complicated due to mutual influences. For example, the size of the open spaces influences the exposure of the buildings to winter sun, or can create the required summer shading. Clearly, this interrelation depends on the geometry of the buildings along the streets and the open spaces and the distance between them, as well as the geometry of the streets and the open spaces.

The aim at this stage is to achieve a design that will assure the exposure of the building's elevations and the pedestrian sidewalks to the sun during a desired period in winter. Moreover, the design should guarantee their protection from the undesirable summer sun. The design of urban quarters, without considering these factors from the very beginning may cause discomfort conditions inside the buildings, in the sidewalks and in the open spaces.

The importance of proper shading design was recognized by researchers more than forty years ago (Olgyay and Olgyay, 1957). The energy crisis of 1973 accelerated the attempts to find good CAD methods and tools for the design and evaluation of shading solutions on one hand and for proper insolation on the other. We can classify these CAD models according to the following categories:

a. CAD tools for the determination of proper shading devices.
b. CAD tools for the proper design of the open spaces between buildings regarding insolation, shadings, and the determination of solar rights.

Both tools categories can further be classified into generation tools and evaluation tools. The generative design tools aid to define the proper geometry. Some early examples are; Shaviv (1975, 1984a), McCluney and Sater (1984) for the design of sunshades, Arumi (1979), Shaviv (1984b) for solar rights and the design of the open spaces between the buildings. These tools generate nomograms that present all possible solutions to a given problem. These nomograms are called "Solar Envelopes". The evaluation tools, on the other hand, analyze the performance of a given design. Some examples are; Rogers et al. (1978), Reeves (1986), for evaluating the performance of shading devices, Smith (1978), Schiler and Greenberg (1980), Kroner and Abrey (1985), McPherson et al. (1985), Peckham (1988), Dupagne (1988), Kunic (1988), Goretzki (1989), Trijssenaar (1991), Yezioro and Shaviv (1994) for evaluating solar rights and the design of the open spaces between the buildings.

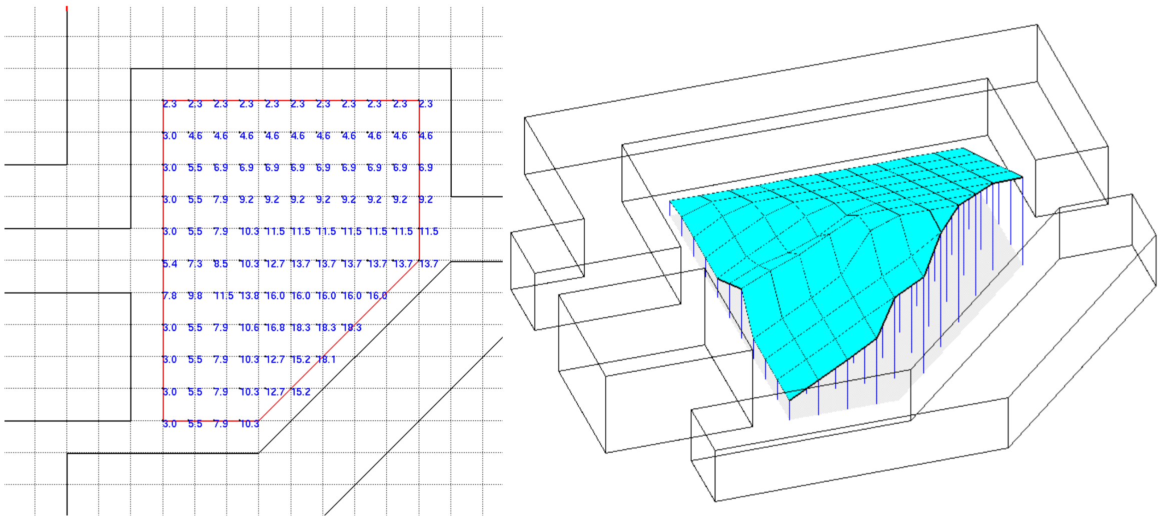

Figure 1. The Solar Rights Envelope (SRE)

The model SustArc (Sustainable Architecture), developed by Capeluto and Shaviv (1997) belongs to category "b", but was extends to deal with the urban grids and tissues. This model calculates the maximum allowed "Solar Volume" to be built without violating solar access from each building and open spaces during a required predefined period of the year. The model is able to generate solutions, as well as to evaluate their performance. The method for generating solutions will be presented in the following chapter. The algorithm for evaluating the performance is based on Yezioro and Shaviv (1994) and is described there. The model SustArc considers several environmental design issues, which include solar radiation, prevailing winds, and different visualization aspects. Our discussion in this paper will be limited to the solar radiation aspects only.

The questions that we would like to raise in this work are: I. "Is it possible to keep the solar rights of each building, sidewalks and open spaces and still achieve high density?" and II. "What urban fabrics, preserve the solar rights of each building, sidewalks and open spaces and yield the urban highest densities?"

THE "SOLAR ENVELOPES" AND THE "SOLAR VOLUME"

"Solar Envelopes" define the space of all possible solutions for the determination of a design that either considers solar insolation or solar shading. Different works have dealt with the determination of solar envelopes for different purposes. Shaviv (1975) proposed a computerized model for the design of fixed external sunshades. Arumi, (1979) developed a computerized model that allows to determine the maximum allowed height of a building that does not violate the solar rights of the existing neighboring buildings. Knowles (1981) suggested a method for assuring solar access to each residence unit in a community. DeKay (1992) made a comparative

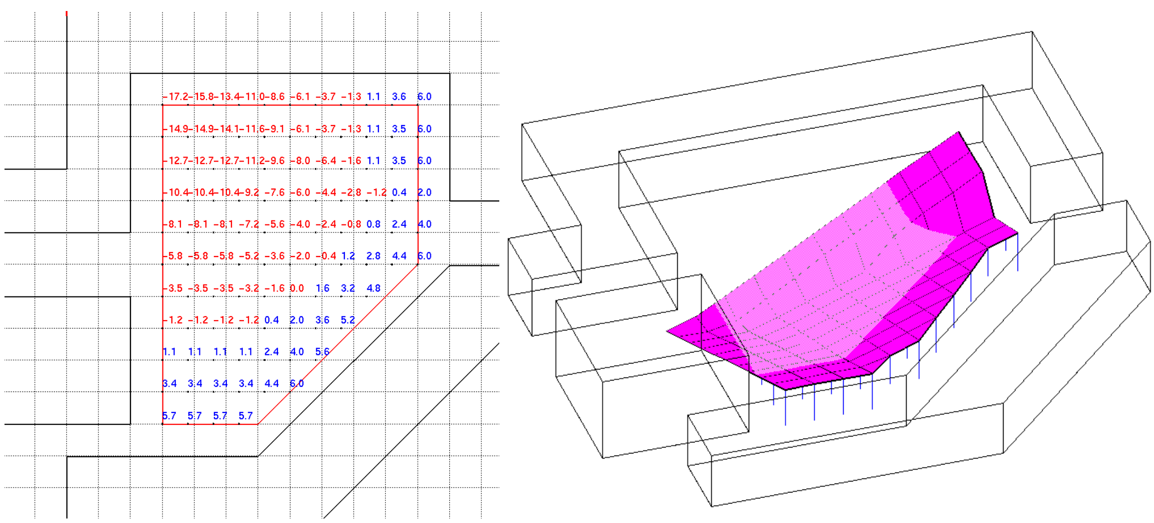

Figure 2. The Solar Collection Envelope (SCE)

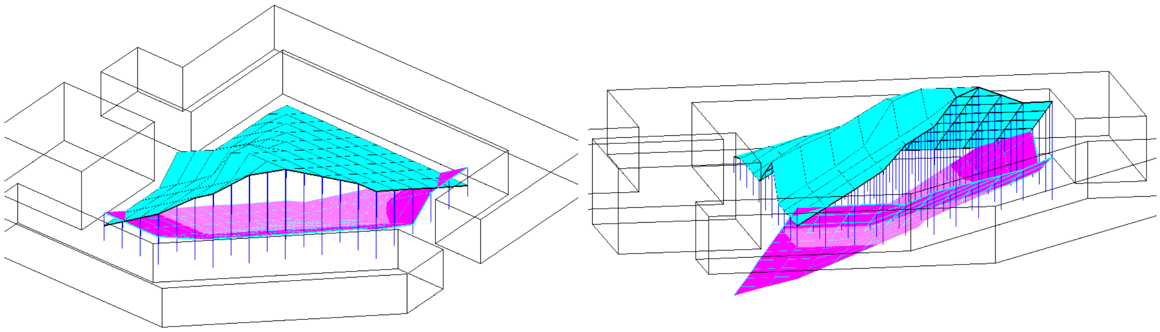

Figure 3. The Solar Volume

analysis of various envelopes allowing daylight access. Schiller and Uen-Fang (1993) developed a computer program for generation of solar envelopes for flat-rectangular sites based on Knowles work, and Koester (1994) presented energy armatures using passive resources like winds and rain water, for urban sustainable development.

In contrast to other works that deal only with Solar Rights Envelopes, in this model we deal with the creation of two different types of solar envelopes: "Solar Rights Envelope" and "Solar Collect Envelope". On top of it we define the Solar Volume. We define these envelopes and the Solar Volume as:

The Solar Rights Envelope (SRE)

The Solar Rights Envelope presents the maximum heights of buildings that do not violate the solar rights of any of the existing buildings during a given period of the year (See Fig. 1). In contrast to other CAD tools (Shaviv, 1984b, Schiler and Ueng-Fang, 1993), the model can treat any arbitrary geometry of subdivision at any sloped terrain.

Solar Collection Envelope (SCE)

The Solar Collection Envelope presents the lowest possible locus of windows and passive solar collectors, on the elevation of the building, such that they will be exposed to the sun during a given period of winter, but will be shaded in summer (see Fig. 2). In fact, this envelope represents the shading cone casts by existing buildings that constitute the built environment. The size of this shading cone depends on the prescribed examined period.

The Solar Volume

Obviously, it is possible to determine the volume included between both envelopes. This volume contains all the buildings heights that allow solar access to each surrounding building, and at the same time are not shaded by the neighboring buildings (see Fig. 3). We call this volume the “Solar Volume”. Using these envelopes, the designer may determine, quite easily, what is the preferred geometry and orientations of side-walks, open spaces and buildings' configuration, so as to assure their exposure to the winter sun, and to achieve the desired protection from the undesirable summer sun.

It is not clear a priory that solutions, which satisfy both conditions, exists. As a matter of fact, when for a specific point, the calculated height for collecting solar radiation is higher than the height for assuring solar rights, there is no solution. However, there is a possibility that only in parts of the examined area both conditions can be satisfied. An example of such a case is shown in figure 3.

THE DETERMINATION OF THE “SOLAR VOLUME”

On the basis of a method developed by Shaviv [2], the building height h is determined according to the height of a pole located at the mesh point P, so that its shade will reach exactly the lower part of the neighboring building boarder, or sidewalk (see Fig. 4). This guarantees that the height of the pole will be the maximum allowed one without ever casting a shade (during the defined period) that reaches this line.

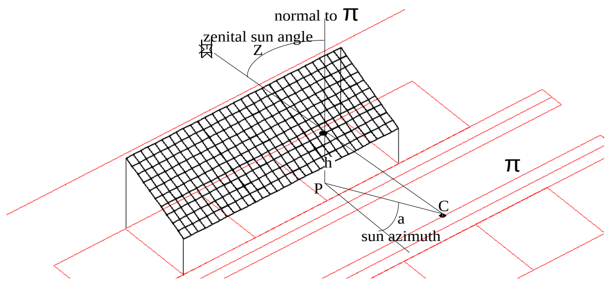

Figure 4. The determination of the building height h at the mesh point P, so that the sidewalk at the point C is not shaded

The method takes into account the height of each building with respect to its ground level. It is possible, therefore, to analyze any irregular geometry of subdivision located on any arbitrary sloped terrain.

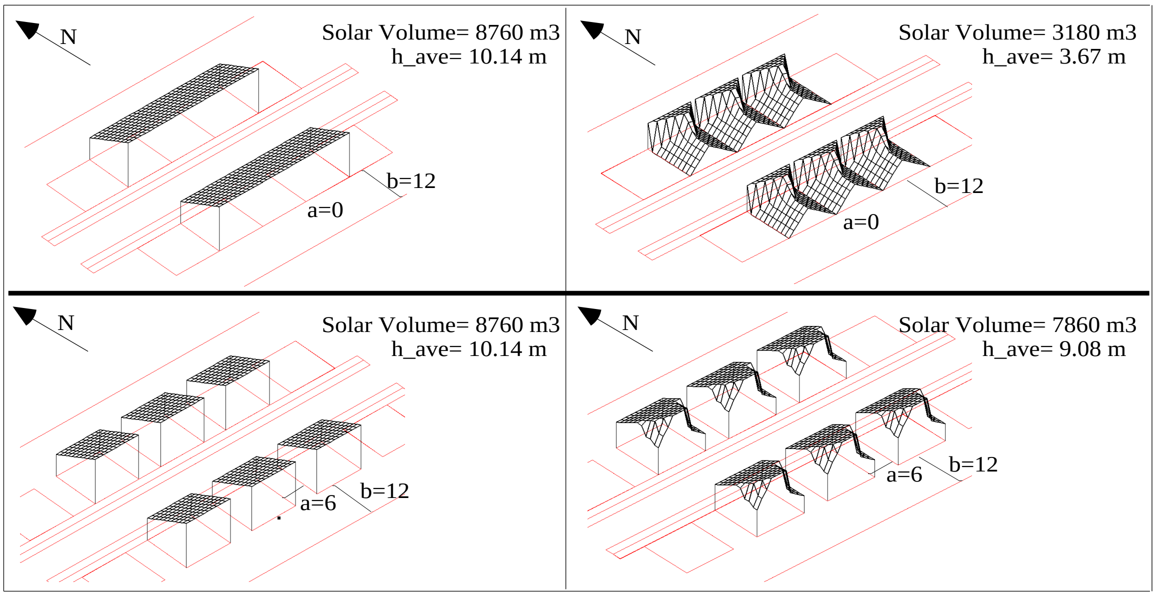

Figure 5. The "Solar Volume".
Right: Solar access to all facades. Left: Solar access to the southern facade only

The calculations are carried out for the entire required period. The minimum height value over the entire period, is the maximum possible height for construction at that point during the predefined insolation period. The period required for insolation should be determined according to the severness of the winter and summer. The longer the period is, the lowest will be the SV that will be obtained as well as the achieved urban density. The detailed discussion about the determination of the required period of insolation will be done elsewhere.

The insolated areas can be the pedestrian sidewalks, open spaces, or the buildings facades. In the particular case that will be discussed in the next paragraph, we decided the following: I. If the street has two pedestrian sidewalks, we required that only one of them will be insolated and II. The demand for not violating the solar access from the buildings includes only facades that face south, southeast or southwest orientation, avoiding the requirement for solar access to all facades, without a real need for such a demand. One should remember that the eastern and western facades get the maximum solar radiation in summer when it is undesired, and much less in winter. In hot countries, like Israel, it seems more logical not to demand solar exposure from these elevations (see Fig. 5).

To calculate the realistic urban density, we check if the height of each grid point defined by the SV fits the height of a floor. In case it does not, the extra height above an integer number of floors is not considered. The height of each point is kept,

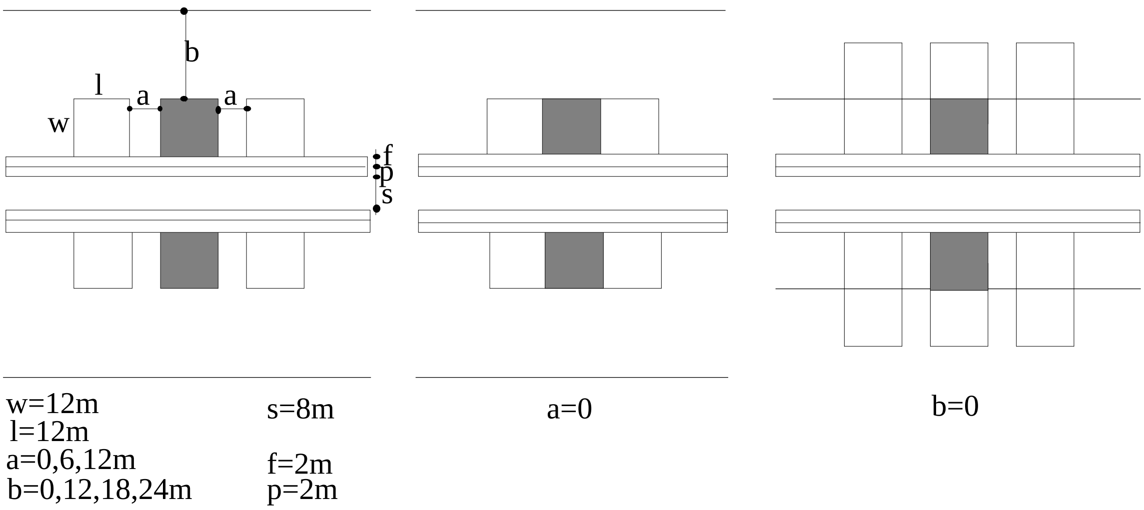

Figure 6. The different configurations for the urban fabric

therefore, in units of floors.

THE SIMULATION STUDY

Figure 6 presents the systematic study we have performed in order to determine the urban fabric that allows us to achieve high urban density under optimal solar insolation conditions. The study was done for the city of Tel Aviv-Israel, located at 32 degrees North latitude and 35 degrees longitude. The design objectives of this study were:

1) Expose the buildings' southern elevation to the winter sun to allow passive solar heating.

2) Create a sunny sidewalk in winter, at least in one side of the street.

The parametric study includes the street orientation together with the buildings along them and the distances between the buildings "a" and "b" in Fig. 6. The other design parameters, like the width of the street and the angle between the building facade and the pedestrian line, will be discussed elsewhere. We assumed in this work the following:

a) The width of the street including the two sidewalks is 12m, and the building facade is in a distance of 2m from the sidewalk.

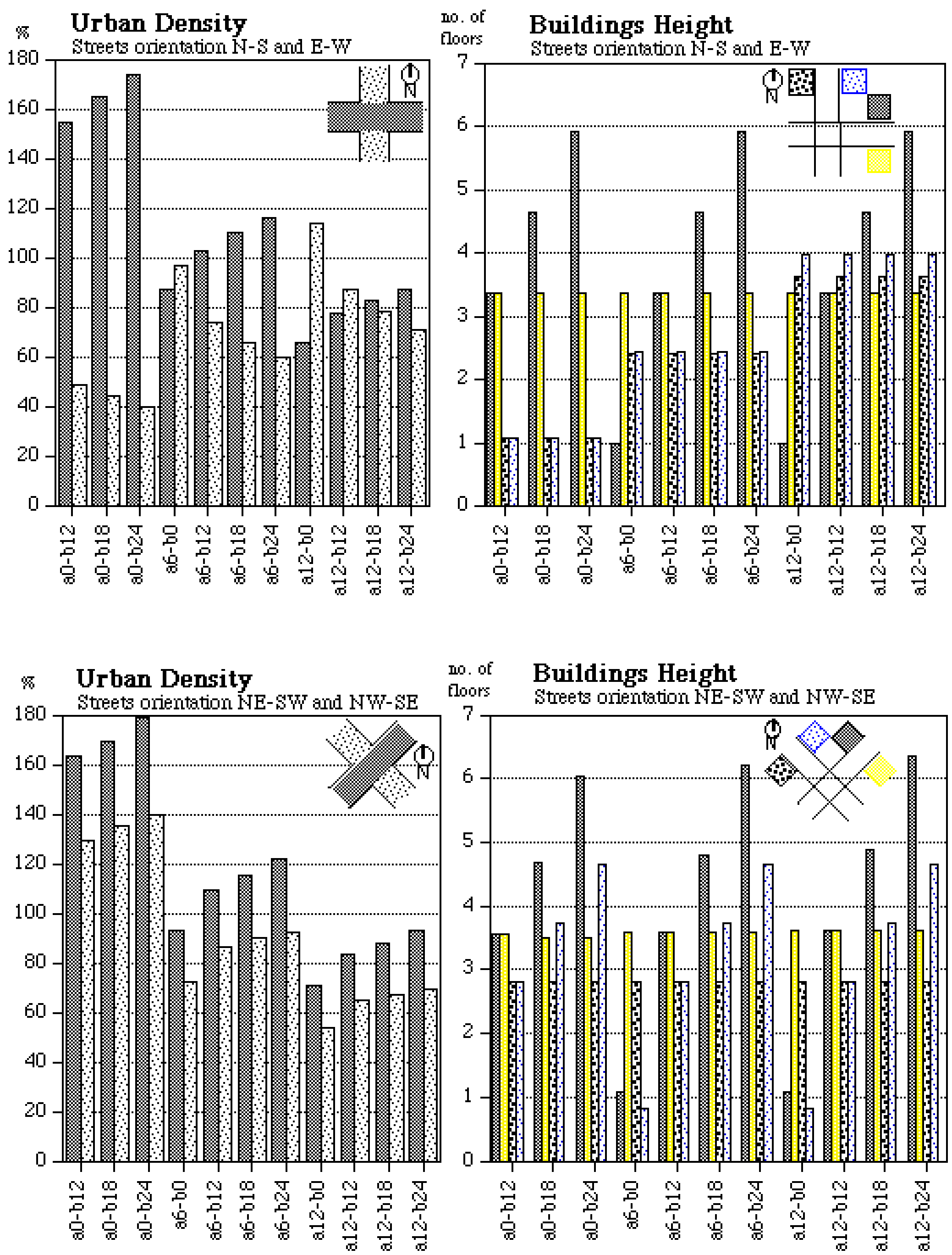

Figure 7. The urban density and the buildings height obtained in the simulation study

b) The building facade is parallel to the street.
c) The insolation period includes all winter months during the hours 10.00 to 14.00.
d) The height of the floor should be 2.80m and only below the roof it can be reduced to 2.00m.
e) The size of each unit is 12m*12m, which gives a maximum gross area of 144 sqm including the area of the staircases and walls. This is a typical size of a large flat in Israel. However, it can be also the area of two small units. When "a" or "b" are equal zero (see Fig. 6) than the area of the two squares is 288 sqm, which is a typical area of three medium size flats in Israel.

RESULTS AND CONCLUSIONS

The results of the simulation study are presented in Fig. 7. On the left side, we show the urban density, which is the built floor area divided by the gross area that includes the street, sidewalks, and the open spaces. On the right side, we present the average number of floors in the buildings from both sides of the street.

From the results presented in Fig. 7, we can conclude the following:
1. It is possible to achieve a high urban density of about 160% to 180% while keeping the solar rights of all buildings in the neighborhood, as well as achieving insolated sidewalks.
2. Slightly higher density can be achieved in the grid of streets that is in 45 degrees to the north.
3. The highest density can be achieved along NE-SW oriented street. Second to it is the E-W street. Third is the NW-SE street. The lowest density is achieved along the N-S street.
4. Along the E-W, NE-SW and NW-SE oriented streets, we get that the smaller "a" is, higher density may be obtained. Row buildings, in which "a"=0 gives the highest density compare with other configurations, in which all parameters are the same except that "a">0. However, along the N-S street we get opposite results. On the other hand increasing "b" gives higher urban density in all streets, except in the N-S oriented street.
5. The highest density is obtained for the configuration a0-b24 along the NE-SW oriented street. Second to it, is the same configuration, but in the E-W oriented street. In both cases, the average height of the buildings is about 6 floors. The density obtained is around 180%.
6. The configuration a0-b12 gives a high density of about 160% with buildings that are only 3 to 4 floors high.
7. Different height of buildings are required, depends on the orientation of the street along which they are located.

To summarize, it is possible to achieve high-density solar communities, where all south facades have solar access, as well as the sidewalks. To achieve this, one should follow the best possible configuration for creating the urban fabric as is presented in Fig. 7.

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