Solar Rights in the Design of Urban Spaces

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ABSTRACT: The consideration of solar rights in urban design is essential in order to allow passive heating of buildings in winter and to improve the comfort conditions of people in the street, sidewalks and open spaces. A design that doesn't consider the solar rights of buildings and open spaces may cause uncomfortable conditions inside the buildings and outdoors. This work presents a simple design tool for the consideration of solar rights in urban design that was developed by the use of the computer model SustArc. This tool allows the generation and evaluation of building configurations, ensuring solar rights of each neighbouring building, as well as the open spaces among them, by using the concept of solar envelopes, but without the need to use any specialized software. The goal of the present work is to provide the architect with simple and easy to use nomograms that can help him during the early design stages to determine the right proportions and geometry of open spaces and streets profile, based on the desired density level, project location and orientation. The nomograms are based on objective criteria for solar exposure of building facades for different zones of the city like the center, or the periphery. The paper presents the creation process of the nomograms, and demonstrates the application of these nomograms by two case studies.

Keywords: solar rights, solar envelopes, nomograms

1. INTRODUCTION

The importance of solar insolation in winter has been studied in many research works. It can reduce the energy consumption of the building if used indoors [1,2], while insolation of exterior spaces may create climatically comfortable areas which can be used in winter [3,4,5,6]. Nevertheless, ensuring proper insolation and an adequate amount of radiation is not an easy task, and a simple method is required to implement such regulations.

Many cities and countries in the world defined regulations to keep solar rights. Some were created from a public point of view to keep open spaces and sidewalks insolated as defined in cities such as New York [7], San Francisco [8], Toronto [3,5] and Tel Aviv [9,10]. In other places, regulations were defined to ensure the full use of private properties such as private open spaces and solar collectors. The cities also differ in their approach for application of the regulations. There are two approaches:

- The performance method which defines the requirements that should be encountered such as the number of insolation hours needed, defined, for example, in Melbourne [11,12].
- The descriptive method in which the geometry of the buildings is defined by regulating building heights as in San Francisco, or in a new business area in Tel Aviv [9,10].

At present, there are no general regulations in Israel to ensure solar rights for either public or private properties, although environmental assessment is required when tall buildings are designed [13]. However, no objective criteria were defined and the acceptance of the proposed plans is based on negotiation. It is worth to mention that keeping solar rights is most important in Israel, since solar collectors for water heating are mandatory. Moreover, the climatic conditions in Israel allow outdoor use in winter, providing that there is enough solar exposure. Nevertheless, one cannot simply apply criteria and regulations proposed elsewhere, and proper adaptation should take place.

A new energy code for residential buildings that award green stars to the buildings is based on the percentage of solar insolation needed in winter to reduce energy consumption [1]. These insolation requirements are the basis for the objective criteria on which regulations for solar rights are proposed according to three criteria:

- The climatic zone (four zones) – insolation percentage according to the severity of winter.
- The orientation of the elevation (from east to west through the south) – the effect of insolation is higher for southern elevations, and lower for the eastern and western ones.
- The urban location of the building (two locations) - higher insolation percentage is required in the periphery of the cities to maintain high-quality climatic conditions, while lower percentage is allowed in central areas where higher density is required.

This paper presents the suggested regulations for solar rights in Israel, and focuses on presenting the method and tool that were developed to apply them [14]. Two case studies are presented, which show that the use of the suggested method can ensure solar rights for residential buildings, sidewalks and open spaces, while keeping high urban density.

2. METHODS OF APPLICATION

The solar rights regulation can be applied in three levels based on the two approaches mentioned above:

1. The basic level based on the performance approach, defines the required amount of solar radiation for each orientation, urban location and climatic zone (Table 1). It allows freedom in design. However, a designer using this method must prove meeting the requirements.

2. The second level, also based on the performance approach, indicates the insolation hours which meet the solar radiation requirements (Table 2). The designer has to present the proof of keeping the surrounding buildings exposed to the sun during that time.

3. The third level is a descriptive/prescriptive method, based on the insolation hours indicated. It presents the use of solar section lines as a simple tool for solar rights design (Fig. 1). Designing according to these section lines ensures the solar rights of the surrounding buildings and open spaces, without the need to demonstrate further requirements.

The energy code was defined for buildings only. This work presents the use of the application methods for ensuring solar rights of public open spaces, streets and sidewalks as well. In these cases, the amount of radiation is irrelevant. Therefore designing for keeping solar rights of outdoor spaces must rely on either the defined insolation hours or the descriptive method.

Table 1: Required radiation for each orientation, urban location and climatic zone (irradiation values are in kWh/m^2, SC=Shading Coefficient)

		Azim=90		Azim=135		Azim=180		Azim=225		Azim=270	
		Periphery	Center	Periphery	Center	Periphery	Center	Periphery	Center	Periphery	Center
Tel-Aviv	Total	0.68		1.76		2.51		2.09		0.78	
	SC(%)	50	30	60	40	70	50	60	40	50	30
	required	**0.34**	**0.20**	**1.06**	**0.70**	**1.76**	**1.26**	**1.25**	**0.84**	**0.39**	**0.23**
BeerSheva	Total	0.70		1.81		2.59		1.94		0.82	
	SC(%)	50	40	60	45	70	55	60	45	50	40
	required	**0.35**	**0.28**	**1.09**	**0.81**	**1.81**	**1.42**	**1.16**	**0.87**	**0.41**	**0.33**
Jerusalem	Total	0.70		1.81		2.59		1.94		0.82	
	SC(%)	50	40	70	55	80	65	70	55	50	40
	required	**0.35**	**0.28**	**1.27**	**1.00**	**2.07**	**1.68**	**1.36**	**1.07**	**0.41**	**0.33**
Eilat	Total	0.68		1.74		2.47		1.84		0.78	
	SC(%)	60	30	50	30	50	30	50	30	50	30
	required	**0.34**	**0.20**	**0.87**	**0.52**	**1.24**	**0.74**	**0.92**	**0.55**	**0.39**	**0.23**

Table 2: Required hours of insolation (in grey) for the coastal plain area (Tel-Aviv). Dotted pattern represents half-hour (irradiation values are in kWh/m^2, typical day, December)

Tel-Aviv	Azim=90	sc50/40	Azim=135	sc80/65	Azim=180	sc80/65	Azim=225	sc80/65	Azim=270	sc50/40
	sc 50	sc 30	sc 60	sc40	sc 70	sc50	sc 60	sc40	sc 50	sc 30
required	0.34	0.204	1.056	0.704	1.757	1.255	1.254	0.836	0.39	0.234
December	9.30-11	10.30-11	10-13	11-13	10-14	10.30-13	10-13.30	10-12.30	12-14	13-13.30
6:00	0	0	0	0	0	0	0	0	0	0
7:00	0.04	0.04	0.05	0.05	0.03	0.03	0	0	0	0
8:00	0.16	0.16	0.21	0.21	0.14	0.14	0	0	0	0
9:00	0.23	0.23	0.36	0.36	0.28	0.28	0.01	0.01	0	0
10:00	0.18	0.18	0.39	0.39	0.37	0.37	0.11	0.11	0	0
11:00	0.07	0.07	0.33	0.33	0.4	0.4	0.22	0.22	0	0
12:00	0	0	0.23	0.23	0.38	0.38	0.31	0.31	0.05	0.05
13:00	0	0	0.14	0.14	0.33	0.33	0.37	0.37	0.14	0.14
14:00	0	0	0.05	0.05	0.28	0.28	0.42	0.42	0.21	0.21
15:00	0	0	0	0	0.2	0.2	0.39	0.39	0.22	0.22
16:00	0	0	0	0	0.1	0.1	0.26	0.26	0.16	0.16
17:00	0	0	0	0	0	0	0	0	0	0
18:00	0	0	0	0	0	0	0	0	0	0
19:00	0	0	0	0	0	0	0	0	0	0
Total	0.68	0.68	1.76	1.76	2.51	2.51	2.09	2.09	0.78	0.78
obtained	*0.365*	*0.16*	*1.09*	*0.7*	*1.76*	*1.295*	*1.22*	*0.825*	*0.4*	*0.245*

3. THE SIMPLE DESIGN TOOL

The section lines defined for the descriptive method are based on the solar envelopes [15, 16 that were created according to the required hours of insolation for each orientation for the four different climatic zones in Israel and for both central and peripheral areas. The section lines represent the critical (lowest) sun angle for the time period needed. Buildings that are lower than these section lines will not block the sun at least during the required hours (Fig. 1).

The use of these section lines is different for keeping solar rights of buildings, sidewalks or public open spaces.

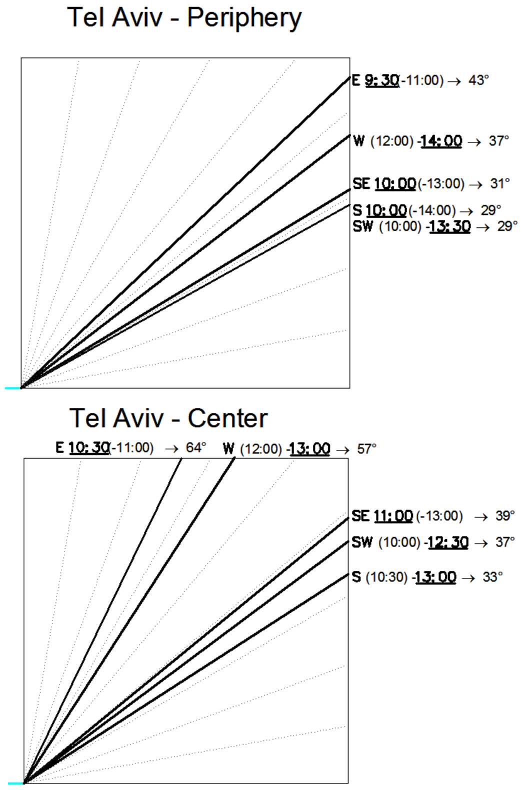

Figure 1: Section lines for the coastal plain area, represented by Tel Aviv, for central and peripheral locations. The hours of insolation required are indicated next to each line. The critical hours are underlined.

3.1 Keeping solar rights of residential buildings

The section lines' angles for each orientation allow the clear definition of building heights. The base point of the lines should be at the lower part of the first residential floor (Fig. 2). This means that in central areas, where lower floors may be used for commercial purposes the base point of the section lines will rise up, allowing higher buildings.

3.2 Keeping solar rights of sidewalks

The requirement for sidewalk insolation is that at least 1 to 2 meters of its width will be insolated. The demand is for only one sidewalk to be exposed at a time. It is recommended to keep 2 meters exposed to the sun. However in central areas, were higher density is required, it is possible, within the limits of the local planning regulations, to ensure insolation of only 1 meter.

The application of the section lines for sidewalks is the same as for buildings, except that the base point should be positioned 1 or 2 meters from the building (Fig. 3).

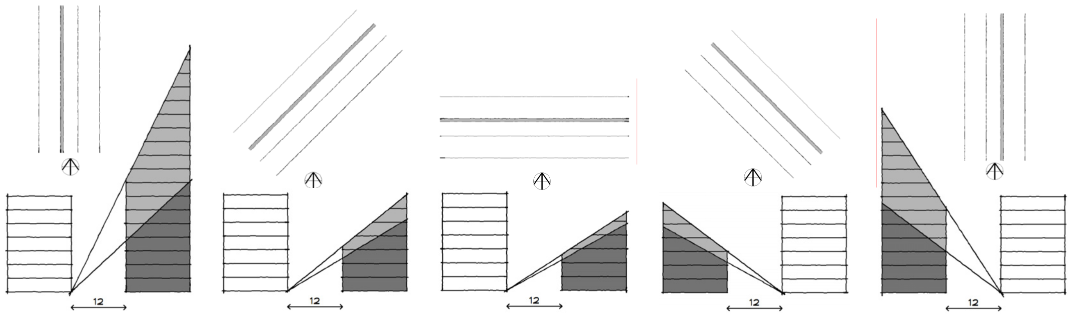

Figure 2: Building heights allowed in differently oriented streets in Tel Aviv for keeping solar rights of buildings' façades. The distance between buildings is 12m. The first floor is residential. The dark spot is for the peripheral areas and the light one is for the central areas.

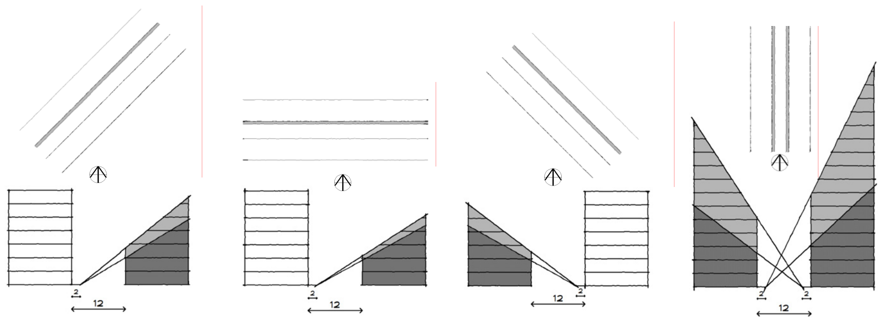

Figure 3: Building heights allowed in differently oriented streets in Tel Aviv for keeping solar rights of sidewalks. The distance between buildings is 12m. 2m of the sidewalk should be exposed. The dark spot is for the peripheral areas and the light one is for the central areas.

3.3 Keeping solar rights of public open spaces

The application of the design tool for keeping solar right of open spaces is more complex than for buildings and sidewalks. This is due to the fact that the buildings surround the open space from all directions; therefore keeping the critical hours of each orientation is not enough, mainly because east and west orientations allow higher buildings.

Keeping solar rights of open spaces is done in three steps as follows (Fig. 4):

1. Defining the area needed to be insolated in the North-East and North-West side of it. This would be a triangle with the area of 30% (for central locations) or 40% (for peripheral locations) of the open space [6]. The triangle's hypotenuse should be parallel to the open space's diagonal.
2. Defining the base points for the section lines in the middle of the triangle's hypotenuse.
3. Creating the section lines from the base points, using the angle of the south to limit the buildings on the east, south and west sides of the space.

In cases where the open space is positioned 45^0 from the main orientations, there would be only one triangle in the north, and the section lines of the south would limit the buildings on the south-east and south-west sides.

4. CASE STUDIES

Several basic examples and some case studies were performed in order to evaluate the density that may be achieved keeping the regulations of solar rights, and in order to appraise the easiness of using the new tool.

4.1 Urban density of different urban tissues

Different relations of buildings and streets were studied, to assess the urban density that can be achieved in the climate of the coastal plain of Tel Aviv and of the mountain climate of Jerusalem.

4.1.1 Description of urban tissues examined

For the study, an urban tissue of crossing streets was defined. The streets were of different widths:

- Street 20m wide, including the road, sidewalks and parking on both sides.
- Street 12m wide, including the road and sidewalks but no parking.

The different situations examined 2 crossing streets in 4 different orientations. In each case a wide street is perpendicular to a narrow one.

The lots were defined as 30m*67m, each with a 14m*56m row building, which is a typical building block in Israel (Fig. 5b). Each of the situations examined included 2 lots perpendicular to each side of one street (A), 2 lots parallel to each side of the other street (B), and 4 corner lots in the intersection of the streets (C).

4.1.2 Exposure requirements

In these examples the first floor of the buildings is residential; therefore the requirement is to keep the solar rights of the first floor of neighbouring buildings.

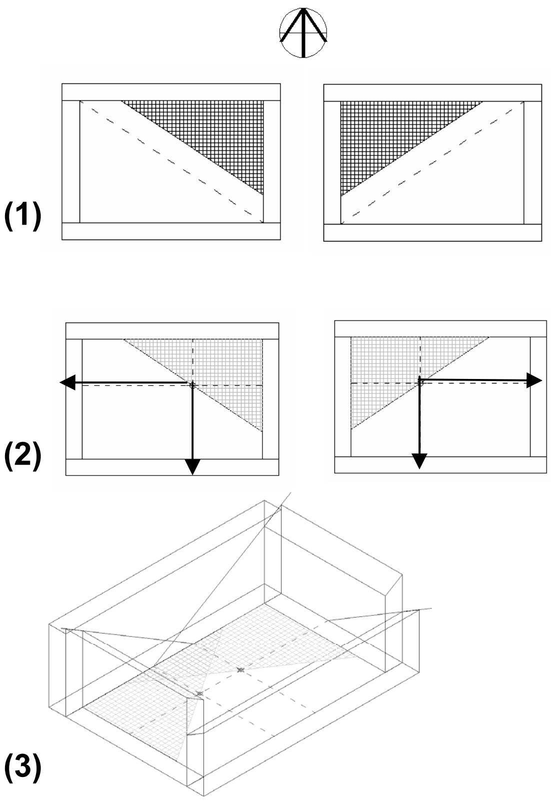

Figure 4: Three steps of keeping solar rights in open spaces: 1) defining the area of exposure, 2) defining base points for section lines, and 3) limiting building heights on the east, south and west sides.

In the streets, a width of 1m of one sidewalk at a time must be exposed.

4.1.3 Results – the urban density obtained in Tel Aviv

Fig. 5 shows that the building heights obtained are in the range of 6 to 15 stories, with FAR (Floor Area Ratio) rates of 190% to 380% depending on the orientation. In most cases where buildings were perpendicular to the street, the neighbouring buildings affected the allowed height of the buildings, compared with the street width that has little influence on them. However, for buildings parallel to the street, wider streets resulted in higher buildings.

The buildings with their long elevation facing east and west gave the densest urban texture (Fig. 5). Nevertheless, these orientations are not recommended for residential buildings. Placing the buildings with their long elevation facing south and north is climatically better, but results in lower buildings and less FAR rates. Streets running 45^0 from the main orientations, especially if the main elevations of the buildings face south-east and north-west, give high FAR rate with good orientations.

4.1.4 Urban density in different climates

The densities achieved for Tel Aviv were compared with densities achieved for Jerusalem on the same urban situations [17].

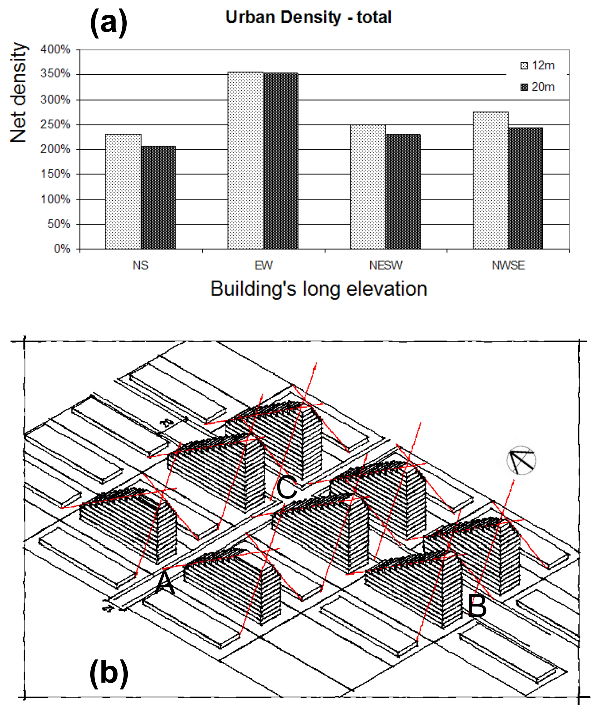

Figure 5: (a) Total net urban density for the example in Tel Aviv, categories represent the orientation of the long facade of the buildings, and series represent the width of the street perpendicular to them. (b) Example of one of the densest situations – buildings positioned with long elevation facing east-west, with a 12m street perpendicular to them, going east-west (EW-12m in the graph).

The solar section lines for the coastal plain climate allow higher buildings than those for the colder mountain climate of Jerusalem that requires better solar exposure to winter radiation. Consequently, the achievable FAR rates are higher for Tel Aviv than for Jerusalem. Moreover, in Jerusalem positioning the buildings with main elevation facing south-east was found to be as good as orienting it south-west, whereas in Tel Aviv there is a clear preference for the south-east orientation (buildings perpendicular to streets going along the axes north-west to south-east) (Fig. 6).

4.2 Regular vs. Solar Rights planning

The second case study examined the application of the tool on a selected group of buildings designed in a new neighbourhood along the coastal plan (Fig. 7). The group of buildings required a step by step application of the tool for ensuring solar rights of public open spaces, sidewalks and residential buildings, according to the climatic zone (coastal plain) and urban location (center of city).

The steps include:

1. Definition of the open spaces (Fig. 8a) and definition of the areas for exposure (Fig. 8b).

2. Limiting the surrounding buildings using the solar section lines of the south (33^0) to ensure an exposure of 30% of the open spaces (Fig 8c).

3. Ensuring the solar rights of the northern and eastern sidewalks with the section lines of the south (33^0) and of the west (57^0) (Fig 8d).

4. Ensuring the solar rights of neighbour buildings with the section lines of the south (33^0), the west (57^0) and the east (64^0) (Fig. 8e).

5. Ensuring the solar rights of the buildings by limiting parts of buildings that face other parts of it (Fig. 8f).

The FAR rates for each lot were calculated along with the average density of the four buildings. This was compared with the FAR rates of the original plan (Fig 9). A density of 324% could be achieved while still keeping solar rights. The average density of the original buildings was 197%.

The buildings in this example were positioned exactly the same as originally planned. We believe that even higher densities would be achieved if the two southern buildings were rotated creating the open space to their north, thus extending the distance between the southern and northern buildings.

5. SUMMARY AND CONCLUSIONS

The work presented here was intended to define clear and simple methods, based on objective criteria, to keep solar rights of residential buildings, sidewalks and public open spaces. The basis for the objective criteria is the new energy code for buildings that defines the needed exposure to winter solar radiation in each orientation and climatic zone, required to reduce energy consumption in residential buildings. The methods follow two approaches for keeping solar rights: the performance approach and the descriptive one. Two of the methods are based on the performance approach. The first defines the amount of solar radiation needed to achieve the exposure presented by the code. The second defines the specific hours that meet that amount. Both methods require the designer to submit a proof of meeting the regulations, but allow more freedom in the design. The third method presents a set of section lines which define the solar envelope that keep the exposure hours needed in every orientation. This method is simple and straightforward, and makes it easy for both designers and authorities to maintain as shown in Fig. 10.

The work presents the simple way of using the proposed method that can be applied in every situation, design, or evaluation by the authorities, rather than give out only performance recommendations. Several examples and case studies showed that limiting buildings' heights using the suggested section lines allows the sun exposure required. Moreover, the study showed that designing by these section lines could lead to achieve quite high FAR rates in all orientations.

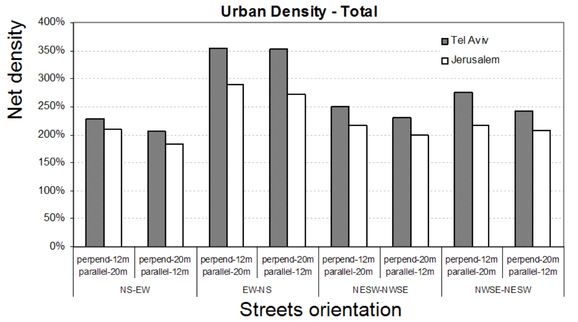

Figure 6: Net urban density obtained in Tel Aviv and Jerusalem.

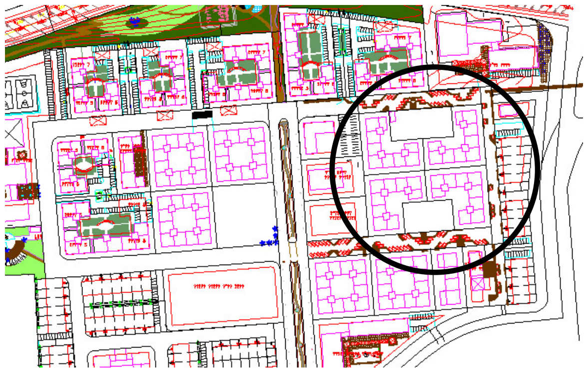

Figure 7: The selected group of buildings for the case study.

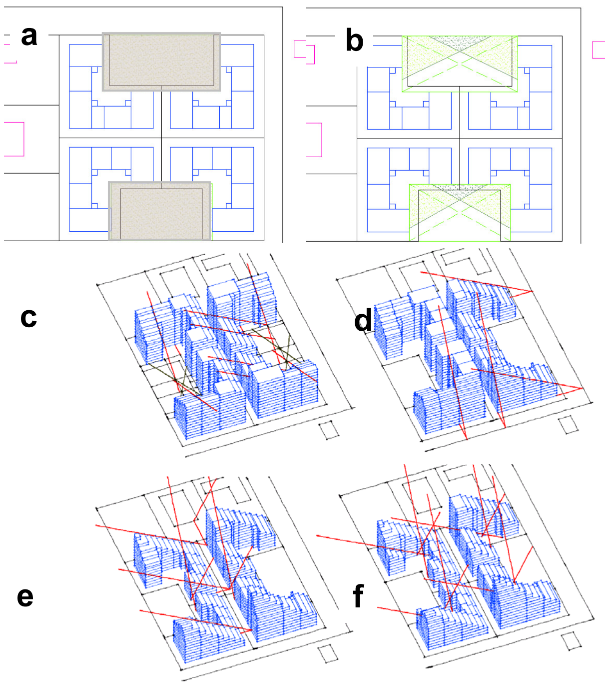

Figure 8: Steps for applying solar section lines in the case study.

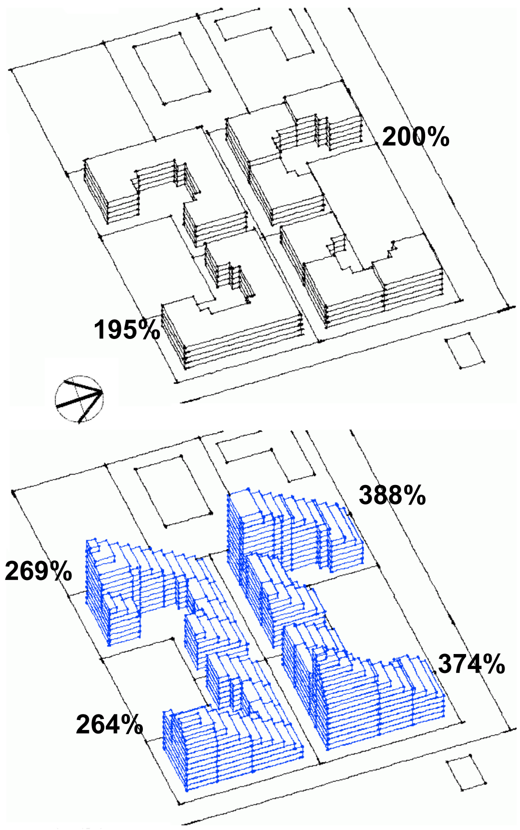

Figure 9: FAR rates compared between keeping solar rights planning (down) and regular planning (up).

Figure 10: Control by planning authorities.

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