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THE EFFECT OF TALL BUILDINGS ON SOLAR ACCESS OF THE ENVIRONMENT, İSTANBUL LEVENT AS CASE

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INTRODUCTION

Two basic social impetuses, the desire to live together and the conviction to build structures ever larger, have affected the development of historical urban life. Today, modern skyscrapers (tall buildings) in many ways the symbol of modern life, introduce modernity and wealth to a city. However, tall buildings, although they are mostly well-known symbolic figures of metropolises, have been criticised since their first development. Primarily, opponents to tall building construction cite their huge mass as contrary to human nature; with their excessive energy consumption; the extra pressure they cause on city infrastructure; and the exacerbation of already-difficult issues such as traffic and parking. Further, opponents object to their unnatural indoor conditions that adversely affect occupant health, and their role in the lowering of the economic viability of surrounding land by blocking the light, air, and view (Bronin, 2009). Tall buildings block the sun of their surrounding environment and change their 'solar access', properties. Reduction at sun light is an important issue for energy efficiency, vegetation, and daylight properties of indoors.

With the growing interest in sustainability, the use of sunlight has begun to play a major role in building design and green architectural strategy. Designation of the solar access of a region or a building is vital for design issues such as the determination of basic design goals, development of first schemes, optimisation of the building's energy efficiency, integration of solar active systems, and taking proper vegetation plans (Mardalijevic, 2004). Sustainable buildings are designed according to the promise that they will have the same solar exposure for the life of the building, even though this is not a permanent fact of developing cities.

Although 'solar access guarantee for life time' has vital importance for the future of green buildings energy dynamics, this subject is still not a design issue at urban planning. Regulations force designers to use solar energy effectively in new construction and there are many advancements in solar technologies that integrate with the architecture but all these are meaningless if a consistent level of sunlight cannot be ensured over the life of a building.

In this paper, we examine the effect of tall buildings on solar access in the Levent region of İstanbul, Turkey. Our findings emphasize the need to consider the impact of solar radiation on urban planning and the effects of unplanned urbanisation on solar rights. These types of studies are necessary for proper environmental assessment, the development of proper regularly precautions, and the development of design approaches during this age of green consciousness.

ASSESSING THE AFFECTS OF TALL BUILDINGS TO SOLAR ACCESS OF THEIR ENVIRONMENT

Solar access is the amount of solar radiation that reaches a building (Bronin, 2009) or the amount of direct solar energy on a building, and it is measured by the means of annual solar radiation and the amount of sun light hour (Anon., 2005).

The solar rays that reach indoors reduce the demand for artificial light and heat energy and increase the property value by enriching the quality of space. Similarly, the access of sunlight in outdoor areas is necessary and valuable for the growth of vegetation, quality of public space, and the encouragement of social activities. Solar access and its continuity are vital for systems reliant on solar energy and for the development of solar technologies (DOE, 1993). Furthermore, access to sunlight enables the users of a building to perceive time and space by the sun's rhythmic movements. (Knowles, 2003) In short, beyond its rationalist benefits, sun provides significant value in a built environment, both for the functioning of the building and for the people who use its spaces. Solar access depends not only on the design of a certain building but also on adjacent construction that can interfere with access to sunlight. Preserving access to the sun, then, by controlling environmental shadowing is a key concern for the future (Rafiadeh, 2005).

As tall buildings have great mass, they reduce the solar access of their surrounding environment by overshadowing adjacent properties. Evaluating the effect of tall buildings on an environment's solar access will have great importance on the future adjudication of solar right regulations.

There are many factors like;

- Geographical location,
- The rhythmic movements of sun,
- Topographical properties of the area,
- The height difference between tall buildings and surrounding buildings,
- The directional position of tall buildings according to surrounding buildings,
- The distance between tall buildings and surrounding buildings,
- The form of the tall buildings' mass,

that determine the overshadow properties of tall buildings. Because of the dynamic shadow regime and climatic, atmospheric conditions, it is usually hard to perceive the effects that shadowing can have on daily life. However, assessing the quantity and the characteristics of shadowing is vital for understanding the effects of tall buildings on the solar access of their surrounding environment. Because shadows have a moving and changing character, it is important to analyse shadows with a holistic way in order to evaluate changes at the solar access.

To assess the total impact of overshadowing it is important to find dimension, direction and duration of shadows on surrounding environment through the whole year and evaluate the findings all together.

İSTANBUL LEVENT REGION, THE CASE STUDY

The Levent district of Istanbul opened to settlement in the early 1950s with low-rise housing developments and from the 1950s to 1970s, the region expanded with new sites. The district, was a quiet and peaceful settlement, plush with greenery until 1980s. However, in sync with the development of İstanbul itself, the area changed rapidly and grew into one characterised by masses of tall buildings crowded along the main traffic artery on its western border (**Figure 1**).

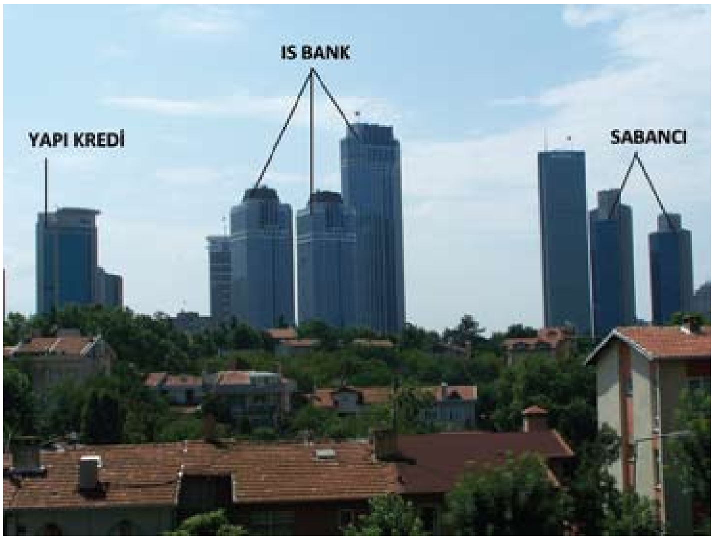
Study Area

There are approximately 290 residential buildings in the study area, eighteen of them are multi-storied, comprising between four and twelve stories. The northwest section of the study area is the intersection point of tall and low-rise buildings (**Figure 1**).

In the area there about 8 tall buildings, but only six of them with elevations over 100m are taken into consideration, as these are adjacent to low rise buildings.

These buildings are;

- İş Bank towers (IS): three towers, one is 181m and the two others are 117m.
- Sabancı Centre towers (SB): two towers, one is 150m and the other is 140m.
- Yapı Kredi Head Office building (YK): One building that is 110m [a]:



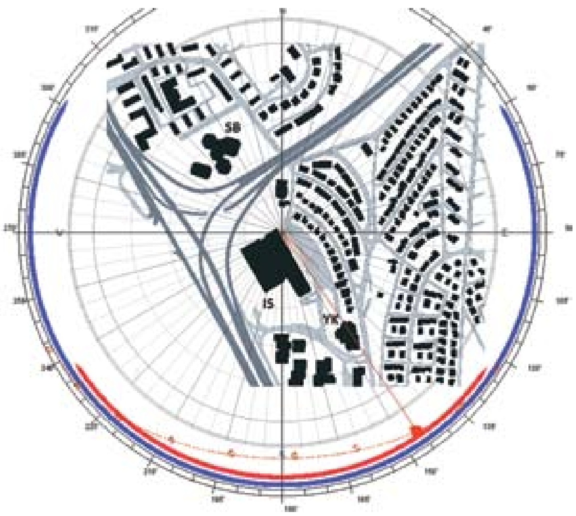


Figure 1. Tall buildings and the study area.

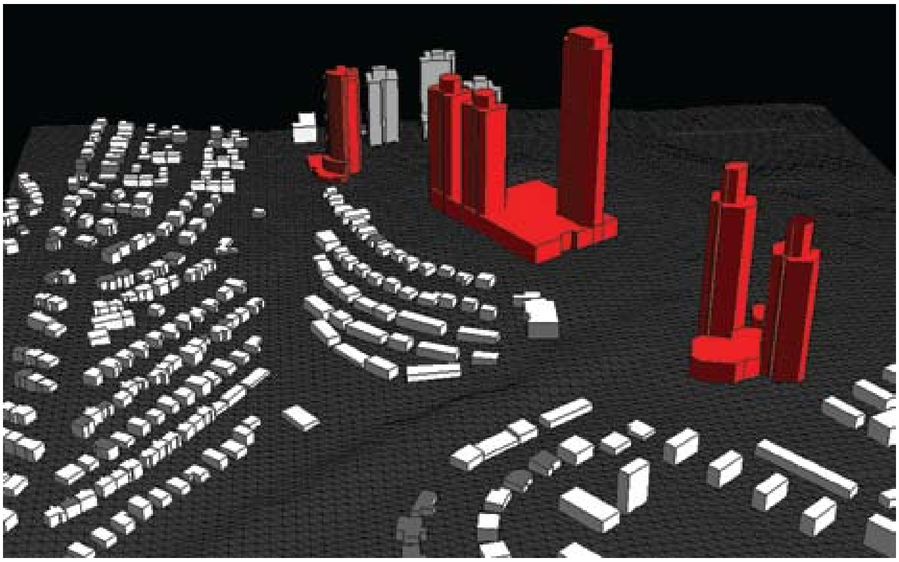


Figure 2. 3D simulation model of study area.

Method of Analysis

In order to analyze solar access variations, in terms of dimension, direction and duration of shadows, the study method has three basic stages;

1. Shadow domain of tall buildings,
2. Quantity of overshadowing within the study area,
3. Solar access properties of surrounding buildings.

As the study area is a hilltop with slope, proper modelling of the topography within the area was critically important for the veracity of our results. The topography and height of the buildings, too, have been modelled by Ecotect simulation tool according to data that was taken from the municipality's digital drawings (**Figure 2**).

The Shadow Domain of Tall Buildings

Between summer and winter seasons, the dimensions of the shadows and the area that is covered by shadows changes from least to greatest during year. Therefore, 'shadow domain' can be defined as "the limits of total area affected by shadows during the year". In this study, shadow domain of tall buildings has been evaluated by shadow lengths and shadow diagrams together.

Shadow Lengths of Tall Buildings

As the shadows of tall buildings stretch far, especially during the early morning and late afternoon hours, in winter they exceed the boundaries of the study area. For having numeric data to determine the limits of the shaded area, the minimum and maximum shadow lengths of tall buildings for June 21 at 12:00 and for December 21 at 16:30 have been calculated by simple equations of a and b. The results can be seen in **Table 1.**

Table 1. The minimum and the maximum shadow lengths of tall buildings (m).

c = 1 / tan δ (1)
b = c . H (2)
δ: altitude angle of sun (◦)
c: shadow length of 1 m stick (m)
b: shadow length of the building(m)
H: height of the building (m)

Time	Altitude (°) δ	IS Towers'		SB Towers'		YK
		181m	**117m**	**158m**	**140m**	**110m**
21 Jun 12:00	73,3	54,30	35,10	47,40	42,00	33,00
21 Dec 16:30	1,7	6098,53	3942,14	5323,57	4717,09	3706,29

According to these results, which are approximate due to the topographical conditions, shadows lengthen and shorten between 6098m to 33m during a year.

Shadow Diagrams

Shadow diagrams have been produced in order to understand the dimensions of shadows in terms of form, direction, and total extent. As the shadows are visible on the study zone after 12:00, shadow diagrams for the 21st days of December, June, and March at 12:00, 14:00,16:00, and shadow range diagrams for same days has been generated between the hours of 8:00 and 16:00 (**Figure 3**).

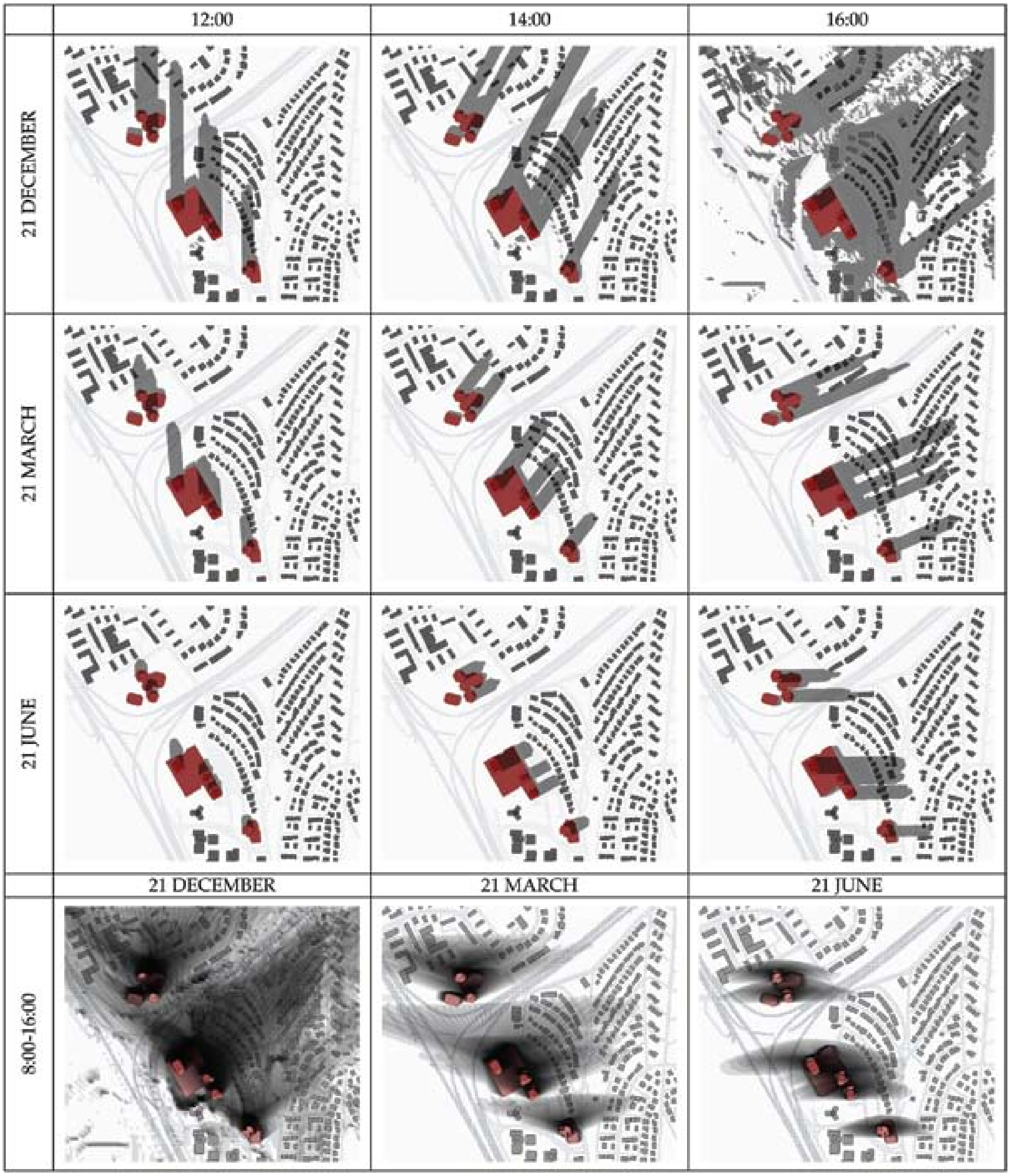


Figure 3. Shadow diagrams within the study area.

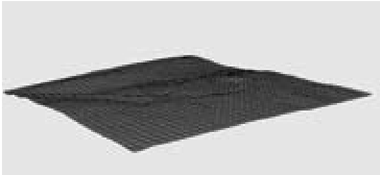


Figure 4. The analyse grid.

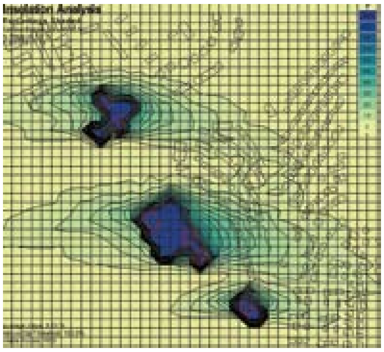
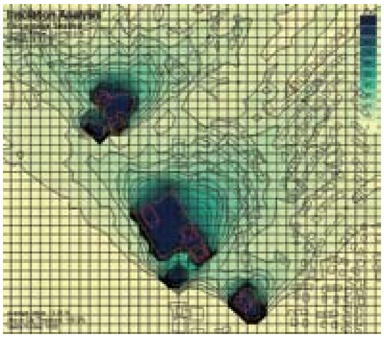


Figure 5. Summer Period percentage shaded (%)



.**Figure 6.** Winter Period percentage shaded (%).

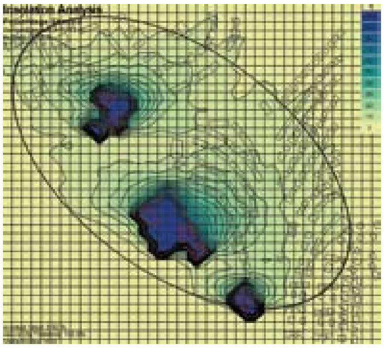


Figure 7. Annual percentage shaded (%).

As seen in the diagrams, the northern and northeast areas of the study zone have effective shading, nearly entire study zone has shading during winter and a limited area between west and east has shading during summer.

Overshadowing Quantity

Shadow diagrams in **Figure 7** display the dimensions of shadows and limits of the affected area. Nevertheless, to evaluate the effects of shadows in a holistic way, we should also know 'how much solar energy is blocked in total during a year'. Overshadowing quantity, total amount of shading on a surface during a period, gives a cumulative value for the reduction at the solar access of a surface. In this step, whole study zone has been analyzed in means of shading percentages (%) in order to determine the most affected areas from shading. For calculations, analysis grid of 10m x 10m sizes, which has the same physical properties with the study zone has been used (**Figure 4**).

The Shading Percentages within the Study Area

The percentages and the limits of shaded area for:

a) Summer period (1 April – 1 October between 6:00 – 18:00) (**Figure 5**)

b) Winter period (1 October – 1 April between 7:00 – 17:00) (**Figure 6**)

c) Annual (1 January – 1 December between 7:00 -- 17:00) (**Figure 7**) are as they are seen in **Figure 5-7**.

According to these calculations,

- overshadowing affects an area of approximately 260m wide,
- northeast side of tall buildings is the most affected area, and
- the average shading percentages are; 8.61% in summer, 13.35% in winter, and 9.92% per annum.

However, as it is clearly seen in these graphics, shading percentages in the study area are ranging from 5% to 40% which means overshadows affects some buildings more than others. In order to understand how the overshadowing of tall buildings is affecting the area, the study zone has been analyzed in means of blocks, (A,B,C,D....N) as seen in **Figure 8**.

The number of houses that have same shading percentages and the total number of house units that are affected from shading in each block in different periods, are given in **Table 2.**

Based on the information obtained from **Table 2**, exposure rate of blocks (in means of buildings) from shadows is given in Table 3. As it is seen, nearly all study area is affected from shading during winter and blocks A, B, C that are the most affected areas.

As it is seen in **Figure 5-7**, and in **Table 1**, houses in the study zone have different shading quantity. In order to understand the effectiveness of shading percentages in the study zone, table 4 is produced which gives the number of houses that have the same shading rate, the effectiveness of shading rates and shading percentage of the study zone in total.

During winter season, nearly all (84%) of the zone is affected from overshadowing while 45% of the zone is affected during summer and tall buildings are overshadowing half of the zone (58 %) throughout the year. While very limited number of houses have 40, 35, 30 % shading, the 10% and 5% are most effective shading percentages.

The number of houses in the blocks.
A: 14
B: 33
C: 33
D: 30
E: 30
F: 25
G: 9
H: 24
I: 8
J: 7
K: 4 (4-6 flats)
L: 18 (4-6 flats)
M: 28
N: 29
TOTAL 292

Figure 8. Blocking properties of buildings in the study area.

Blocks	SUMMER						WINTER									ANNUAL						
	Shading %					total	Shading %								total	Shading%						total
	25	20	15	10	5		40	35	30	25	20	15	10	5		30	25	20	15	10	5	
A	5	1	2	3	3	**14**	3	2	2	1	2	4	-	-	**14**	4	3	3	2	2	-	**14**
B	-	4	1	2	13	**20**	-	-	3	10	13	7	-	-	**33**	-	-	2	16	11	4	**33**
C	-	-	-	6	25	**31**	-	-	-	-	9	9	15	-	**33**	-	-	-	-	10	23	**33**
D	-	-	-	-	-	**0**	-	-	-	-	-	-	11	8	**19**	-	-	-	-	-	12	**12**
E	-	-	-	-	6	**6**	-	-	-	-	-	4	11	15	**30**	-	-	-	-	-	16	**16**
F	-	-	-	-	5	**5**	-	-	-	-	-	3	5	17	**25**	-	-	-	-	-	14	**14**
G	-	-	-	-	5	**5**	-	-	-	-	-	-	-	9	**9**	-	-	-	-	-	9	**9**
H	-	-	-	7	12	**19**	-	-	-	-	-	-	3	7	**10**	-	-	-	-	-	10	**10**
I	-	-	-	1	2	**3**	-	-	-	-	-	4	4		**8**	-	-	-	-	2	4	**6**
J	-	-	-	-	1	**1**	-	-	-	-	2	2	3	-	**7**	-	-	-	-	3	3	**6**
K	-	-	-	-	-	**0**	-	-	-	-	1	1	-	2	**4**	-	-	-	-	1	1	**2**
L	-	-	2	3	1	**6**	-	-	-	2	1	3	6	6	**18**	-	-	-	2	3	8	**13**
M	-	-	-	-	19	**19**	-	-	-	-	-	-	-	4	**4**	-	-	-	-	-	-	**-**
N	-	-	-	-	-	**0**	-	-	-	-	-	-	-	29	**29**	-	-	-	-	-	-	**-**

Table 2. The number of houses that have same shading percentages in each block.

Period	Affecting percentage from overshadowing (%)													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Summer	100	61	94	0	20	20	56	79	38	14	0	33	68	0
Winter	100	100	100	63	100	100	100	42	100	100	100	100	14	100
Annual	100	100	100	40	53	56	100	42	75	86	50	72	0	0

Table 3. Shading rates of blocks in means of building unit.

The effectiveness of shading percentages (number of houses and %)									
	40	35	30	25	20	15	10	5	Total
Summer	-	-	-	5 (%2)	5 (%2)	5 (%2)	22 (%8)	92 (%32)	**129 (%45)**
Winter	3 (%1)	2 (%1)	5 (%2)	14 (%4)	28 (%10)	37 (%13)	60 (%20)	101 (%34)	**250** (%84)
Annual	-	-	4 (%1)	3 (%1)	5 (%2)	20 (%7)	33 (%11)	104 (%36)	**169** (%58)

Table 4. The effectiveness of shading percentages by means of house unit (%).

	The shading percentages of the roof surface									total shading
H1	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	
Decem.	0%	100%	100%	100%	51%	100%	100%	100%	-	3 hr
March	0%	100%	100%	51%	100%	100%	38%	0%	92%	2,5 hr
June	0%	0%	0%	0%	100%	100%	100%	59%	0%	1,5 hr
	The shading percentages of the roof surface									
H2	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	
Decem.	0%	0%	30%	100%	100%	100%	100%	100%		2,5 hr
March	0%	0%	1%	19%	78%	75%	0%	63%	100%	2,5 hr
June	0%	0%	0%	0%	0%	100%	21%	0%	0%	0,5 hr
	The shading percentages of the roof surface									
H3	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	
Decem.	0%	0%	0%	100%	75%	78%	100%	93%		2 hr
March	0%	0%	0%	0%	96%	50%	100%	93%	0%	1,5 hr
June	0%	0%	0%	0%	0%	0%	0%	0%	0%	-
	The shading percentages of the roof surface									
H4	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	
Decem.	0%	0%	0%	70%	81%	100%	100%	100%		2 hr
March	0%	0%	0%	0%	0%	100%	77%	0%	0%	0,5 hr
June	0%	0%	0%	0%	0%	0%	0%	0%	0%	-
	The shading percentages of the roof surface									
H5	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	
Decem.	100%	100%	100%	0%	0%	0%	0%	0%	0%	1 hr
March	94%	100%	100%	100%	0%	0%	0%	0%	0%	1,5 hr
June	0%	5%	5%	14%	0%	0%	0%	0%	0%	1 hr
	The shading percentages of the roof surface									
H6	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	
Decem.	0%	0%	0%	98%	100%	100%	100%	100%	-	2 hr
March	0%	0%	0%	0%	0%	100%	57%	0%	0%	0,5 hr
June	0%	0%	0%	0%	0%	0%	0%	0%	0%	-
	The shading percentages of the roof surface									
H7	12:00	12:30	13:00	13:30	14:00	14:30	15:00	16:00	16:30	
Decem.	47%	100%	100%	100%	100%	100%	60%	0%	100%	3,5 hr
March	21%	100%	100%	93%	7%	0%	0%	100%	33%	2 hr
June	0%	0%	0%	0%	0%	0%	0%	0%	0%	-
	The shading percentages of the roof surface									
H8	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	
Decem.	0%	0%	0%	0%	0%	0%	80%	100%	-	0,5 hr
March	0%	0%	0%	0%	0%	21%	100%	100%	100%	1,5 hr
June	0%	0%	0%	0%	0%	0%	0%	0%	0%	-

Table 5. The duration and quantity of shadows on the roof surfaces of the selected eight building at 21st of December, March, and June.

Solar Access Properties of Surrounding Buildings

As seen in the analyses above, the shading percentages of the buildings differ significantly depending on location properties with tall building. Therefore, determining to the time and duration of the shadows on the surfaces is important to understand how tall buildings affect the solar access of houses. It is clear that surfaces of low-rise buildings have different shading properties according to their directions, slopes, and dimensions. Therefore, only the tops of the low-rise buildings are taken into consideration as if they are flat roofs.

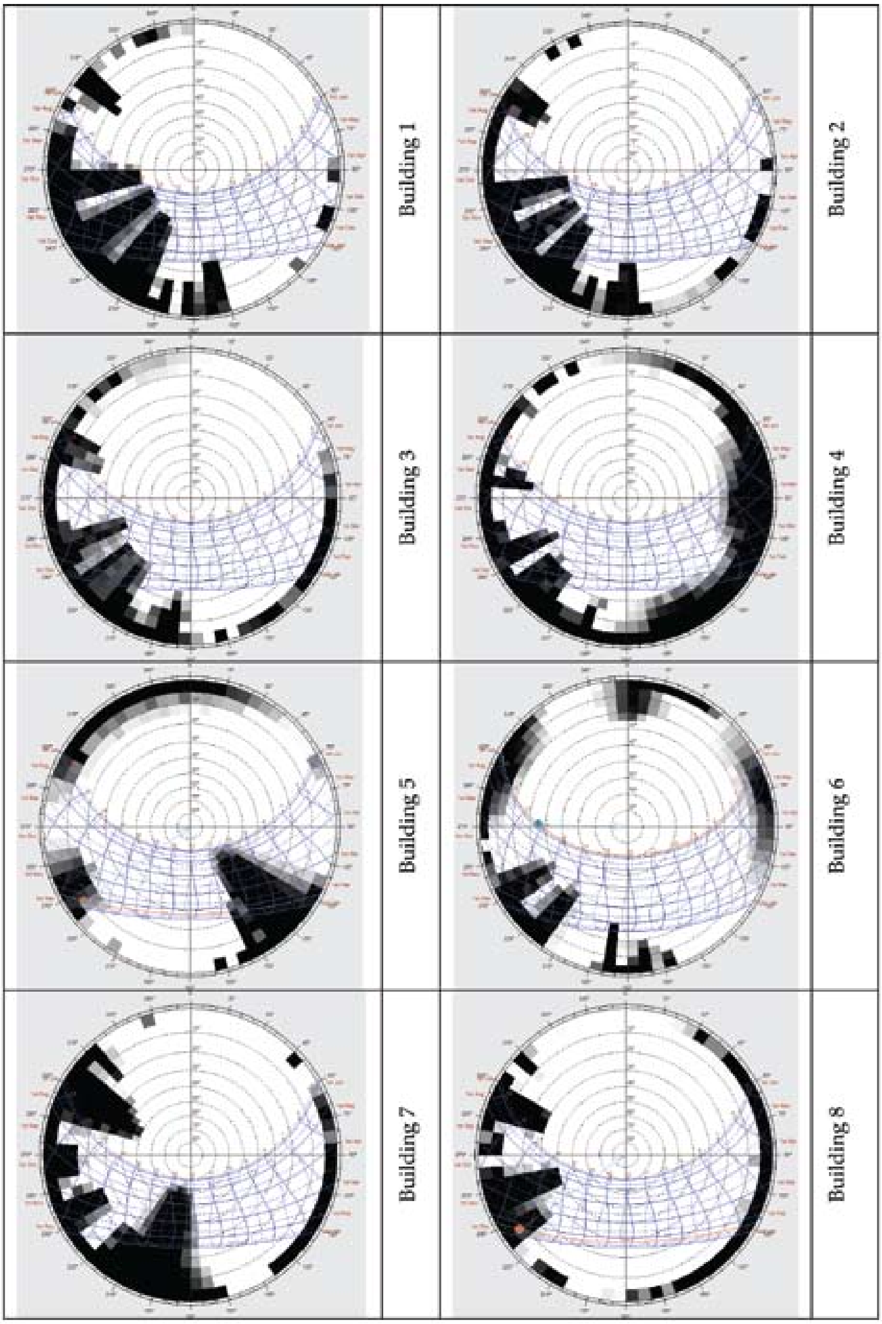


Figure 9. The shading properties of eight building.

In the scope of this study, the roofs of eight houses in different blocks (**B1** in A, **B2** in B, **B3** in C, **B4** in D, **B5** in L, **B6** in J, **B7** in A, **B8** in H, see fig. 12), have been analysed by the stereographic sun path tool and tabular data of Ecotect. Duration and the quantity (%) of shadow on these surfaces, for the 21st of December, March, and June are given in Table 5. In addition, the stereographic sun path diagrams that show the shading properties of the roofs are given in **Figure 9**.

As seen in **Table 5** and on the provided sun path diagrams, tall buildings are changing the solar access properties of surrounding buildings significantly. For example, building 1 and 3 or building 7 and 8 has totally different solar access properties and quantity although they are close neighbours. This proves that the buildings near tall buildings do not have equal solar access.

As a result, the analyses and calculations in this study show that;

- The shadow domain of tall buildings can reach very far away from their location,
- Tall building overshadowing affects a geographically wide area.
- The northeast sides of tall buildings are the most effected zones.
- The solar access of buildings located close to tall buildings is obstructed up to 30 - 40%, resulting in serious reductions of solar energy.
- The construction of tall buildings in close proximity to one another causes their shadow zone to be both wider and stronger.

CONCLUSION

Although critics argue that tall buildings no longer make economic sense and thus validity, tall buildings are indispensable elements of modern cities. As the proliferation of tall buildings comes with many problems, it is important to investigate and evaluate the full scope of properties, and the potential effects on surrounding structures, before construction. Otherwise, it is impossible to prevent tall buildings from being detrimental to urban environments. The effect of tall buildings on solar accessibility should be evaluated in this context. Moreover, the fact that solar access is variable and dependent on both natural and manmade factors makes it a serious problem, one that could have insidious affects on energy usage in the future.

As the results of this study show, tall buildings are reducing the solar access of neighbouring structures by measurable levels. When reductions of solar access as great as 40% are taken into consideration, it is an evident to claim that tall buildings are disturbing the equal solar utilisation of other structures in their immediate area. Despite this, individuals who lose their 'solar property' because of these developments, have no legal basis to demand their rights back. This situation needs to be considered for the application of future regulation as it affects the entire community, not simply landowners.

While population growth, urbanisation, technology, and modernity are forcing cities grow upwards, environmental problems, sustainability, and social consciousness are putting 'solar rights' in the forefront of urban planning discussions. The seemingly uncompromising paradox and conflict of interest between the desire to modernise and the will to protect the environment, can be mitigated with proper planning, innovative design, scientific studies, and use of technological tools. For the healthy and fair development of cities in the future, studies on solar access of settlements should be an integral part to modern urban planning.

In conclusion, studies concerning solar rights are necessary to prevent cities from unknowingly or improperly infringing upon these rights. Otherwise, we will not only transgress the principle of 'equal access to natural resources' but also leave cities without light, air, and views for future generations to enjoy.

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Anahtar Sözcükler: güneş erişimi; güneş hakkı; gölge; yüksek yapılar.

YÜKSEK YAPILARIN ÇEVRE BİNALARIN GÜNEŞ ERİŞİMİNE ETKİLERİ: İSTANBUL LEVENT ÖRNEĞİ

Çağımızın bilim ve teknoloji alanındaki ilerlemeleri, yapı ve yapım sistemlerindeki gelişmeler, küreselleşme sonucu olan uluslararası etkileşimler ve yatırımcı yaklaşımları, yüksek yapıların, kentin doğal bir oluşumu olarak algılanmasına, büyüklük ve sayılarının gün geçtikçe artmasına neden olmaktadır. Günümüzde İstanbul gibi tarihi köklü olan kentlerde bile bu tür yapıların arttığı ve yaygınlaştığı yadsınmaz bir biçimde gözlenmektedir.

Bir tür gelişmişlik, zenginlik ve modernlik göstergesi olan bu yapıların, inşa edildikleri yerin doğal yaşamı üzerinde etkili oldukları ve beraberlerinde, kaynak tüketimi, kirlilik, atık yönetimi, yaya ve araç yoğunluğu gibi birçok sorunu da getirdiği bilinen bir gerçektir. Bu durum, özellikle işlev, boyut, biçim açısından kendine benzemeyen yerleşim dokuları içinde yer aldığında yüksek yapıları, bulundukları çevre üzerinde bir baskı unsuruna dönüştürmektedir.

Yüksek yapıların, çevrelerindeki kent dokusu üzerindeki baskı ve etki boyutlarının birçok değişik açıdan incelenebileceği açıktır. Bu çalışmada, yüksek yapıların, çevresindeki yapıların güneşlenme özellikleri üzerindeki etkileri, İstanbul'da alçak konut yerleşimleri ile yüksek ticari binaların kesiştiği Levent bölgesi bağlamında ele alınarak incelenmiştir. Bu çalışma ile yüksek yapıların yıl boyunca attıkları gölgelerin özellikle yakın binaların güneş erişiminde ciddi azalmalara neden olduğu, çevre binaların güneşlenme özelliklerini nasıl değiştirdiği belirlenmiş ve plansız kentleşmenin doğal kaynaklardan eşit yararlanma ilkesini zedeleyecek sonuçlar da doğurduğu ortaya konmuştur.

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