SOLAR ENVELOPE AND
FORM GENERATION IN ARCHITECTURE

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ABSTRACT

SOLAR ENVELOPE AND FORM GENERATION IN ARCHITECTURE

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This thesis analyses the issue of solar access in environmentally sensitive attitudes to architecture. The primary intention of the study is to scrutinize the relationship between solar access and building form (volume) and investigate the efficiency of solar control on / by this form by means of 'solar envelope' technique which is, first, defined by Knowles and developed in different ways in the last 30 years.

Solar envelope in Knowles' terms can be defined as the building volume resulting from shadow casting restrictions and must be recognized as a both theoretical and technical method in the form generation of any building. Similar to the concept of maximum developable volume allowed under height restrictions or floor area ratios, solar envelope is, rather, defined by solar access concerns. This method is applicable on single buildings as well as dense urban areas (residential and mix use areas) and is a supportive tool in the form generation in any stage of design.

Buildings constructed without exceeding the abstract solar envelope that is constructed on the basis of solar access will be successful in the means of passive solar and low-energy design. Such a success will supply a sustainable development, which is globally discussed as a result of environmental and energy crisis.

The aim of this thesis is to represent the method of constructing solar envelope, in case study, with its fundamental aspects and tools. Odtükent residences will be the objects of this study. Results of this application will be tested with shadow maps and evaluations both for the existing situation and the proposed envelopes will be developed.

Key words: environment, solar access, solar envelope, form, quality of life.

ÖZ

GÜNEŞ HACMİ VE MİMARİ FORM OLUŞUMU

Topaloğlu, Birol
Yüksek Lisans, Mimarlık Bölümü
Tez Yöneticisi: Doç. Dr. Mualla Erkılıç

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Bu tez, çevreye duyarlı mimari tutumların güneşe erişimle ilişkisini inceler. Bu çalışmanın temel eğilimi güneşe erişim ve bina formu (hacmi) arasındaki ilişkiye dikkatlice bakmak ve Knowles tarafından son 30 yılda çeşitli şekilde geliştirilen ‘güneş hacmi’ tekniğinin yardımı ile güneş kontrolünün form üzerine etkilerini araştırmaktır.

Knowles’a göre güneş hacmi, gölge düşürme sınırlamalarından kaynaklanan bina hacmidir ve bütün bina formu oluşturma çalışmalarında teorik ve teknik bir metot olarak kullanılmalıdır. Güneş hacmi, yükseklik sınırlamaları ve kat alanı katsayıları ile benzer şekilde, azami inşa edilebilir bina hacmini sınırlar ancak güneşe erişim prensipleriyle tanımlanır. Bu metot tek binalara olduğu gibi yoğun kentsel alanlara da uygulanabilir (konut ve çoklu kullanım) ve tasarımın her aşamasında destekleyici bir metottur.

Güneşe erişim temel alınarak, güneş hacmini aşmayacak binalar pasif ve düşük enerjili tasarım konularında başarılı olacaklardır. Bu başarı, çevre ve enerji krizlerinden beri küresel olarak tartışılan, sürdürülebilir gelişimi destekleyecektir.

Bu çalışmanın amacı güneş hacmi metodunu temel yönleri ve araçları ile, sunmak ve uygulamaktır. Odtükent lojmanları bu uygulamanın konusu olacaktır. Çalışmanın sonuçları gölge analizleriyle test edilecek ve halihazır durum ve önerilen güneş hacimleri için değerlendirmeler yapılacaktır.

Anahtar Kelimeler: çevre, güneşe erişim, güneş hacmi, biçim, yaşam kalitesi.

to my family

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CHAPTER 1

INTRODUCTION

1.1. Definition of the problem:

The recent environmentally sensitive attitudes in architecture are important responses, found in the interdisciplinary communication, to the critical statement of the man-made built environment, to the crisis of contemporary architecture, and to the changing society. The aim of this study is to introduce and discuss -in a conceptual and technical sense- an environmentally sensitive approach to architecture, which takes into account more aspects influencing the 'form generation process' of architectural design. The original intent in this work is to make the relationship between the concepts of 'solar access', 'solar envelope' and 'architectural form' literally and experimentally clear. The query is about the possibility of controlling solar access by the help of solar envelope as a technical support while responding to the functional, structural and aesthetic requirements of a building during the 'form generation process' of design.

Form in architecture is an end product that is reached after different decision stages. The sub stages, which shape the final form, can be listed as such:

- Site analysis, orientation, and topography
- Design ideas (conceptual, practical, analytical)
- Functional organizations and schema
- Geometric morphological organizations
- Formal, symbolic and aesthetic intentions and formations
- Materials, structural and constructional aspects

They are all considered to make the whole building to serve for the betterment of human life. The role of an environmentally sensitive approach as well as techniques developed in this approach will be a subordinate in the decision making process of architectural form. To clarify the position of environmental sensitivity, which will be perceived as an architectural attitude rather than a style or mode, under the broadest field of ecological building, some other related terms and subtitles should be mentioned.

Ecology is defined in Webster's as a branch of science concerned with the interrelationship of organisms and their environments. A clearer view is stated by Klaus Daniels "Ecology in Greek means; the study of the interaction of living organisms with their inanimate (e.g. climate, soil) and their animate environment, as well as the study of resource and energy management in the biosphere and its sub-categories. Ecological building aims to create environmentally friendly, energy-efficient buildings and developments by effectively managing natural resources. This entails passively and actively harnessing solar energy and using materials which, in their manufacture, application, and disposal, do the least possible damage to the so-called "free resources" water, ground, and air" (Daniels 1997, p.06).

Climate conscious design considers the season and temperature changes, which are the parts of inanimate environment of a living organism (Bozkurt 2000, p.19). The aim of climate conscious design is to provide protection from the negative factors of climate and take the advantage of the positive factors in order to reduce energy consumption and environmental impact caused by buildings and provides thermal comfort of the inhabitants (Goulding, 1992; p.14).

Bioclimatic design tries to satisfy the human's biological needs (health, comfort) both physically and mentally considering the climatic conditions as the predecessor. Development of the adaptive behaviour of the artificial environment is one of the main motives of bioclimatic design. Olgyay brothers have set the principles of bioclimatic design.

Sustainable design assumes evaluation of material source and output crucial. The application that is to be sustainable, it must take account not just of economic factors, but also environmental and social factors, and must assess long term consequences as well as short term results (Bozkurt 2000, p.23).

Energy conscious design needs to adjust the energy consumption in the building with minimal effect on occupant's thermal and visual comfort. Materials source and input is important, but it is not crucial. Energy use is crucial for the design, so renewable energies should be introduced if energy is needed. Energy conscious design aims to use as much passive methods as possible (Bozkurt 2000, p.28).

Solar design assumes the sun as the most effective climatic factor in the scope of architecture. Solar design strategies are defined on the relative movement of sun and effects of it on human and their environment.

Function based form generation dominated the global architectural atmosphere. Building structure, material and cost are the other directing concepts, which turned architecture into a mass-product of the consuming society. Consumption is perceived as a part of functional necessity of a built object. Temporality of consumption conflicts with the permanency of the architecture. The instructors of FASTU Bratislava Dep. of Experimental and Ecologically Determined Design manifest this consequence as:

> "According to our beliefs, an environmental approach to architectural design helps to solve the conflict between stability and transition, which is very characteristic for our world, and could not lead towards new architecture - an architecture of in formative society or synergetic architecture for sustainable future based more on quality of life than the quantity of consumption." (www.fa.stuba.sk)

Quality of life is the fundamental aspect of environmental sensitivity and missing property of the contemporary architecture and man-made environment. Human comfort is a part of the definition of functional architecture, which aims to serve people. That's why solar access proves its necessity as it has an irreplaceable importance both for physical and psychological comfort of human. Assured access to the sun is thus important to the quality of our lives (Knowles 1981, p.04). As a technical method structured on the foundations of solar access considerations, solar envelope may be the guide, leading us to the spaces manifesting desired level of life quality.

1.2. Aim and boundary of the study:

Solar access considerations have a potential to shape architectural and urban form, which will be the issue of this study. This potential turned into an objective design tool by Ralph Knowles called as solar envelope. This approach stands on the need of solar access and supports itself with the ethical principle of everybody needs sun. In this study the purpose is to question the place of quality of life in the definition of function and the formal potential of environmentally sensitive attitudes.

In this thesis the significance of solar access, will be underlined to reach resource conservation and a higher average of life quality. For this purpose the role of solar access will be examined under with its roles in improving life quality, in energy conversion, in solar rights concept and in form generation. As a result the method of solar envelope is presented as a design assistant. The constructed envelopes will be evaluated with their formal aspects. These evaluations will be the shadowing relations of the produced volumes with their surroundings.

The study can be elaborated in a further analytical survey related to energy conversion performance of solar envelope including thermal efficiency evaluations with specified materials and techniques, which goes beyond the thesis.

1.3 Methodology of the study:

In his early studies, Knowles looked for the footprints of solar access in ancient societies (Knowles 1974). He ended with concrete evidences of effects of sun in their construction practices. To emphasize the significance of solar access in architecture and urban planning a similar method is followed in this thesis. In chapter 2 construction facilities of human history is divided in to two periods depending on the production modes of human societies as: Agricultural and Industrial Societies. Relations of these societies with their environment and their perceptions of sun and solar access are briefly acknowledged. In the following sections of the same chapter solar access is analyzed with anthropo-centric (quality of life, solar rights), global (energy source), and architectural (building form) aspects.

The third chapter, which is developed under the guidance of Knowles's studies, formulates solar envelope generation with solar access considerations. At the end of the chapter three exemplary works, two of which are accomplished under the supervision of Knowles in Los Angeles, are presented. The last example, which is chosen as a model for the case study of this thesis, is developed in Brazil.

Odtükent is analyzed in the terms of shadowing performance and tested with the solar envelopes proposed for the site. The study developed in the fourth chapter is experimental and the results were not predicted in the beginning.

CHAPTER 2

IDEA OF SOLAR ACCESS IN BUILT ENVIRONMENT

After placing the solar architecture in the discussions of current architectural debates and before starting to construct the direct relation of sun and quality of life a historical survey on this relation will be obliging.

The purpose of this section is to locate the sun, which plays important role in the perception of the environment throughout the history between the phenomena of nature. Besides the benefits of seeing the prehistoric and antique use and prominence of sun, considering the phenomenological value of sun realizes the place of sun in the psychological comfort issue, which will be one of the following issues. On the other hand another purpose of this historical survey is to highlight some concepts, which emerged long before the popular topic of energy crisis is placed in the center of environmental sensitivity, issues such as hygiene and bioclimatics. Finally the footprints of "environmental sensitivity" will be searched in the history of modern architecture, which has sometimes been blamed to be responsible for the current environmental problems in architecture.

2.A. HISTORY OF SUN IN ARCHITECTURE AND URBAN PLANNING

2.A.1. Agricultural Ages

By ancient civilizations sun is considered as an object of worship and is given a personality when it was not known as a source of light and heat. Prehistoric era is rich about sun symbols. In Egypt worship to sun started during 4. Dynasty in Heliopolis and went on for hundreds of years (Figure 2.1.A). Sunrays became the symbol of monotheistic belief called Atonism during the kingdom of Akhenaton. For the Hitittis sun was one of the two important gods with the storm god. They represented sun with discs that are considered as the symbol of their civilisization (Figure 2.1.B). In Greek, Apollon was the sun god before helios. At the end of paganism, helios is identified with sol in Latin world and considered as eminent god. So sun replaced many gods and seen as the protector of emperor crowned with sunrays (Larousse 1986, pg. 436-438).

Indian mythology explains the creation of earth with sun. According to this belief, at first there was only sun swimming on the water in space. Desire of living existed in the sun and the earth is born from this desire. Moreover the trilogy of Vedism; Piaus Pitar, Varuna, Pragidpati are the symbols of sun. Usas, Savitar, Surya, Pusan, Visnu are sun gods living in god's palace. Recent American Indies call god as, "our father". Mayas' believe that all the gods come from the sun. Japanese people consider themselves coming from sun, that's why they call their emperor as "son of sun" (Hançerlioğlu, 1993, p.201).

Besides the mythological and iconographic view, all the urban settlements in pre-historic era shared a dependence upon a clear interaction between human activity and nature. Sophia and Stephen Behling call these early urban settlements as "the city as accumulator of solar-derived resources".

> "…they all emerged in regions experiencing comparable climatic influences that lay between the Tropic Cancer and a latitude of 30° north…proximity to a large river was important, providing a means of irrigation, transport, and use of its fertile floodplain for agriculture…Solar energy assisted by irrigation techniques provided the necessary conditions for crop growth and the continuing supply of fuel woods. The river valleys of the Tigris and Euphrates (Mesopotamia), Nile (Egypt), Indus (India), and Wei-Huang (China) provided ideal conditions for the early civilizations to establish cities."(Behling 1996, p. 78)

Mesopotamia and Egypt are very typical examples of this definition. Hanging Gardens of Babylon were built on a series of elevated terraces irrigated from the Euphrates and assisted by a pump system. This garden may be considered as one of the first and spectacular examples of solar architecture (Figure 2.1.C). This adaptive behavior, demonstrated in city of Kahun in Egypt as social divisions. The slaves were housed in windy western quarter to act as a human buffer, protecting the wealthier residents of the east (Figure 2.1.D). Another result of this adaptive behavior shows similar results in three different civilizations: Harappa and Mohenjo-Daro in Indus Valley (Figure 2.1.E), Beijing and the Forbidden City and Gardens of China (figure 2.1.F) and Mayan city of Teotihuacan (Figure 2.1.G) applies the grid of cardinal directions. In Greek cities (Figure 2.1.H), in addition to grid the location on south slope shows it-self (Behling 1996, p.86). Moreover, public baths and gymnasiums introduce health and hygiene in the raising quality of life of people. Some concrete examples of the adaptive behavior are seen in another geography, North America. Ralph Knowles interperets this behavior, in Mesa Verde in Colorado (Figure 2.1.I) and Pueblo Bonito in Chaco Canyon of New Mexico (Figure 2.1.J) as the ability to mitigate seasonal variations in the thermal environments (Knowles 1974, p.20).

If we consider the production modes, the place of the sun and climate in the life of people, they were the same when we come to Antique Greek and subsequent civilizations. Dependence on agriculture; in other words, accumulation and consumption of solar energy directly or indirectly was the general character of all societies. Transformation is about the place and perception of nature in social life. This transformation shows itself in secular architecture, whereas vernacular architecture showed few reflections.

In antique Greek megaron was the definition of basic building type some have credited Socrates with the invention of the first solar house but it is more likely that what he was really describing in his writings was a well-oriented megaron (figure 2.1.K). In general the difference of Greeks from the former civilizations is their ability to systematize the inherited knowledge in a way to create a foundation for the forthcoming societies. Romans have given the spectacular examples of secular architecture, by connecting their technical abilities with the knowledge basis of Greeks. Addition of environmental control systems, such as hypocaust that is a hot water supply and distribution system used in roman baths (figure 2.1.L) (Behling, 1996; p.96), to the directional perfection of architecture was their success in solar architectural applications.

After Romans accepted Christianity and the appearance of global domination of monotheistic beliefs, icons of nature lost their religious importance. But this time the use of daylight in secular architecture to create holy spaces became a symbol of mastership (figure 2.1.M-N). The Renaissance brought the light, openness, and solar sophistication to the Classical Architecture to European building. The most dramatic examples of Mastership of light were produced during the baroque period when it turned to be creating special effects (figure 2.1.O).

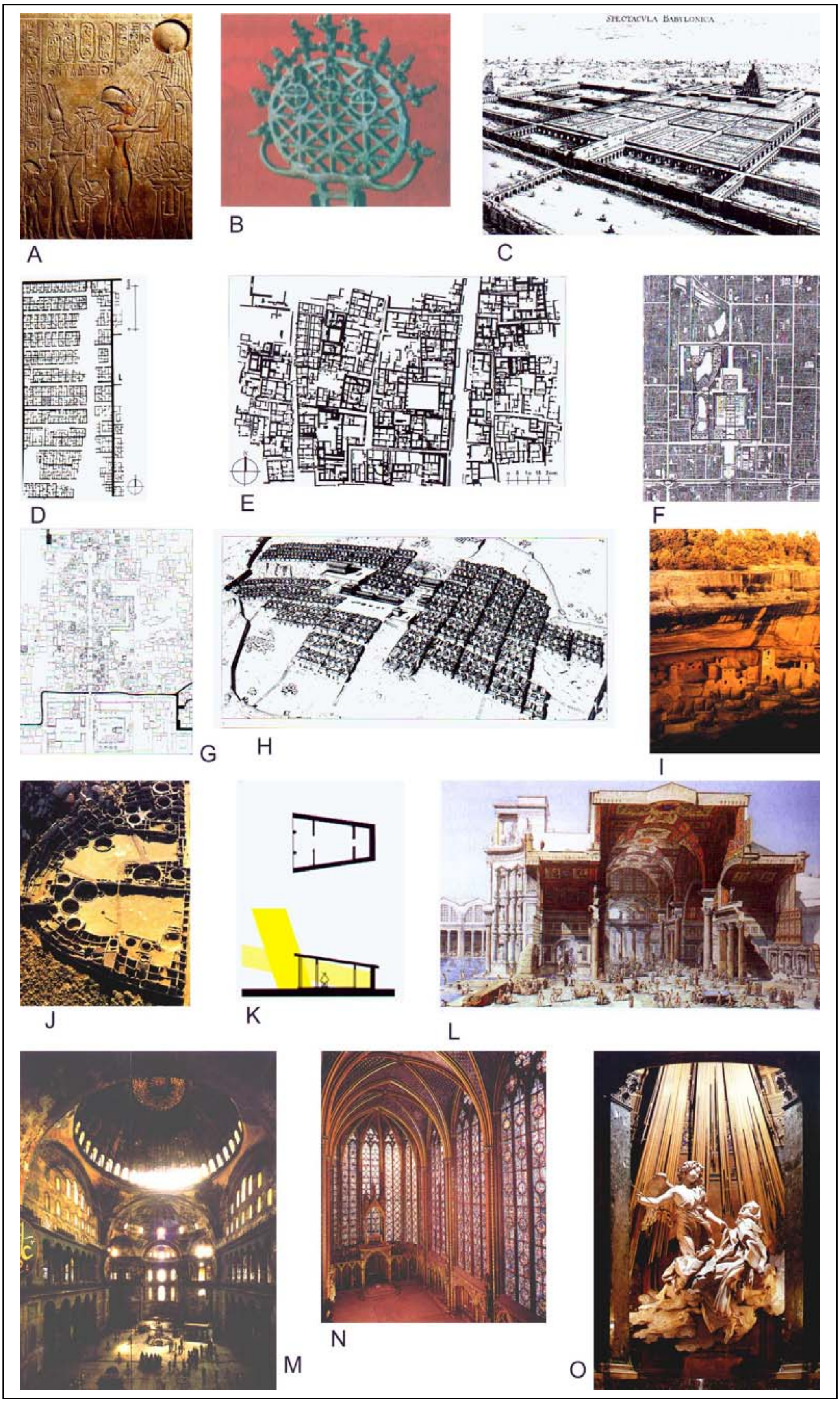


Figure 2.1. Historical examples of solar consciousness in architecture and planning

Both for the east and west civilizations, solar energy was a clear symbol of sensual comfort, luxury and richness. Luxury and comfort were, not made available to a broader section of the population until the advent of the Industrial Revolution. It was only then that mass production turned comfort into a marketable commodity (Behling 1996, p.91).

2.A.2. Industrial Ages:

Mass production identifies itself with the industrial revolution, which marked a significant transition in the world history, as a number of societies began to shift from agrarian to industrial economies. As a production style industrial manufacturing had expanded gradually prior to the second half the 18th century, but it was at the end of the 19th century that the scale and nature of production underwent a transformation, with increasing circuits of capital and associated new forms of spatial organization. Interacting with this, Enlightenment thought reflected a desire to break with history and tradition in the pursuit of progress, modernization, and human emancipation. Reason, based upon objective, demystified, and desacralised science, provided a new logic for the project of modernity. The separation of religion from the realm of objective science enabled the Enlightenment thinkers to embrace rational forms of social organization and justify the scientific domination of nature. The removal of natural limits from human progress promised freedom from scarcity and want, and supported the goal of the greatest possible happiness and comfort for the greatest number of people (Behling 1996, p.128).

In his paper entitled, “Who is the first solar architect?” Donald Watson makes a query to find clear evidence of passive solar design in the modern era from the year 1910 (Watson 1998, p.213). William Atkinson is the first architect who produced ideas for creating spaces with sunlight after his studies on hospital architecture. He mentioned solar orientation and sunlight for hygienic reasons. Hygiene would be a key concept in the establishment of bioclimatic design discipline, referring to the germicidal properties of daylight, which set the notion that tuberculosis could be alleviated by exposure to sunlight (Lima 1998, p.629-632) (Figure 2.2). Atkinson’s efforts led to the first documented “sun rights” legislation that limited the height of buildings for sunlight access in 1904. He built an experimental sun house in 1911 (Butti Perlin 1980, p. 178). According to Watson in the same years F.L. Wright and his predecessor Richardson understood climate, breeze, sun, and orientation as part of their vernacular architecture. But in Wright's early writings, he did not explicitly state that he was designing houses to be warmed by sun in the winters as he did, much later in 1930's when the principles of passive solar design was explored and promulgated by other architects. Watson gives credit to Tony Garnier because of climate consciousness in his housing projects and ideas about "45 degree rule" (Simoes 1998, p.603). As it is seen generally in the early modernists, his climate responsiveness was for hygiene rather than heating. 45 degrees rule offers locating the south façade of the building at a distance equal to the height of the nearest unit in the south and mentioned in Cite Industrielle but because of poor adaptability to different altitudes, it couldn't reach a great accomplishment (Watson 1998, p.214).

Figure 2.2. Tuberculosis cure with sunbath (Behling 1996, p.157)

Stamos Papadaki's houses in Athens (in 1921) showed the early applications of brise soleil and roof gardens. Le Corbusier didn't mention climate or sun in his earliest manifesto "Towards a New Architecture" (1920-1927), despite his interest that can be understood from sun-path diagrams of him (Watson 1998, p.214). The manifesto showing utmost sensitivity to the environment was Hannes Meyer's published in1928 between modernist manifestoes (Conrads 1970, p.117). He was controversial to the former Bauhaus theoreticians because he propagated social aspects rather than aesthetic aspects (Frampton 1996, p.129). In fact their disagreement was not about environmental or climatic consciousness, thus in the following years both Gropius and Breuer gave evidence to sun climate in their design practices in the United States (Watson 1998, p.214). Lastly in this decade

Alvar Aalto deserves to be mentioned for his elegant use of daylight. Mostly natural lighting was for the sake of hygienic reasons but consequently it was a part of overall aesthetic (Watson 1998, p.215).

In the 1930s Richard Neutra comes in to scene with his conception of nature. His designs in California achieve the understanding and inspiration of climatic response. He developed his idea with the term "biorealism" including a concern for the conditions of well-being of people, but also the inspiration to "bring human habitation into an intimate, stimulating rapport with the expressive process and cycles of natural growth, and to vivify our everyday awareness of man's inextricable bond with the natural environment" (Watson 1998, p.215) Before the rise of Nazism in 1934, Hugo Haring, a founder of CIAM, drew attention with his solar houses and housing estates. He was the first of European architects to argue for a change in the prevailing convention to face housing estates "west-east" to "due-south" orientation (Butti Perlin 1980, p. 169). On the other side of the Atlantic, the Keck brothers were the first to profess solar design with their descriptions of how they discovered the winter heating effect of sun in glass houses while building their 1932-33 "Crystal House" pavilions (Watson 1998, p.215).

The Great War dominated 1940s atmosphere but from the solar design point of view emergence of Olgyay Brothers is significant. While building the Stuhmer Chocolate factory in Hungary in 1941 they called their approach to solar design "Corbu with numbers". "They undertook architectural design with the tools of the formative science of building climatology" (Watson 1998, p.215). They would formulize bioclimatology and bioregionalism during their studies in United States based upon the physiology of human comfort and extending beyond solar design, to include ventilation and day lighting (Design With Climate: Bioclimatic Approach to Architectural Regionalism)

These developments marked the rise of qualitative aspects of human life, however the quantitative methods, used to satisfy the urgent needs of post-war society, recessed them.

> "The pressure for post-war construction and reconstruction placed a great demand on the architects. It led in the 1950's and early 1960's to an extravagant activity. On a scale probably never experienced before. The ever-increasing flow of new industrial products and techniques, readily responding to the demands of an

> increasing affluent society, drove the architectural interests more and more within the influence of quantity.” (Lima 1998, p.630)

Aside from quality-quantity debate D. Watson summarizes the post war atmosphere as:

> “…with the era of inexpensive energy of the 1950s and the development of compact heating and air-conditioning equipment, climate-responsive design was hardly in evidence in the subsequent “main stream” of the 1950s and 60s. The exceptions of this general plethora of interest include the work of an diffuse but important group of University based architects and building scientists, such as Ralph Knowles, George Lof, William Caudill, Ben Evans, Baruch Givoni and various practitioners and regionalists…” (Watson 1998, p.215)

When we come to the 70s world faced with an energy crisis which defines the place of sun in architecture and city planning in a different context. It was a sign of the post-industrial society. Public life and population distributions were altered radically with the change in production style change in industrialization. Reduced need to manpower in agricultural production and the shift of this potential to industrial area resulted in the accumulation of population in cities. Klaus Daniels states the main characteristics of the urbanization in post-industrial society as:

- The concentration of workplaces in small areas,
- The shortening of distances for communication and information,
- The maximized utilization of available space. (Daniels 1997, p.14)

Unfortunately these urban parameters were far from the ideals of modernism that promised comfort to everybody. From a wider perspective the parameters that create the post-industrial revolution can be summarized as fallows:

- World population growth
- Globalization of the economy
- Worldwide information networks
- Increasing gap between rich and poor
- Emerging markets
- Environmental pollution
- Ressource exploitation (Daniels 1998, p.10)

Increasing population is the basic parameter, which directly or indirectly affect the others (Figure 2.3). According to the graphs in Figure 2.3, projections foresee a multiplying number of people that will be sustained by earth, which is a closed system. From a different point of view the production capacity of people seems to be more than the consumption capacity. That’s why an increasing population is not a catastrophe. Already having an unsaturated population, some developing countries are welcomed by industrialized ones for the same reason. This is a proof of the globalizing economy but does not guarantee an equitable distribution of world treasury (Figure2.4). Better-distributed treasure is knowledge that is almost accessible at anytime, anywhere, through the worldwide network. The problem areas of environmental pollution and resource exploitation persist; problems that affect humanity as a whole and that are allowed to slip into the background from time to time, unless extraordinary events and natural phenomena converge, resulting in "ecological catastrophes".

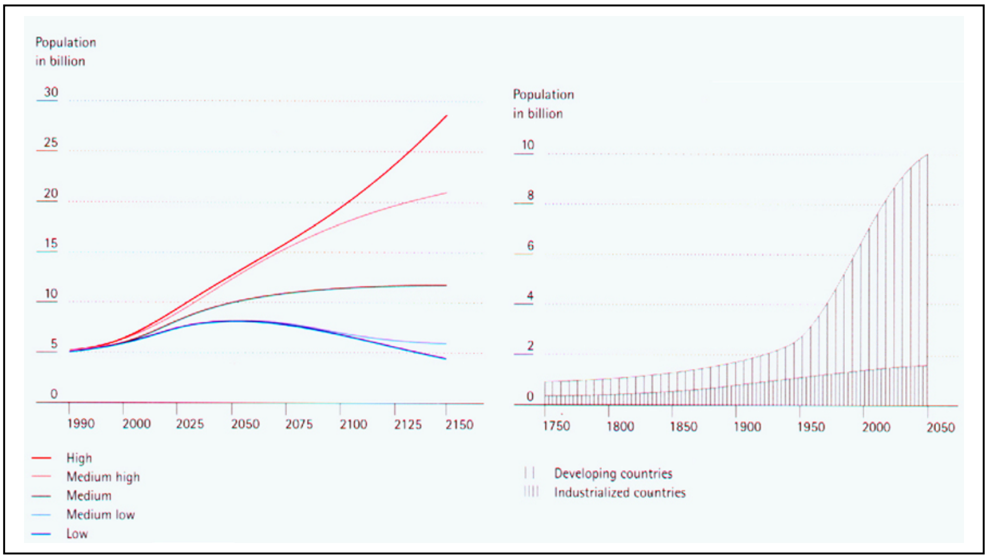


Figure 2.3. Estimations about the world population (K. Daniels, 1998; p.10)

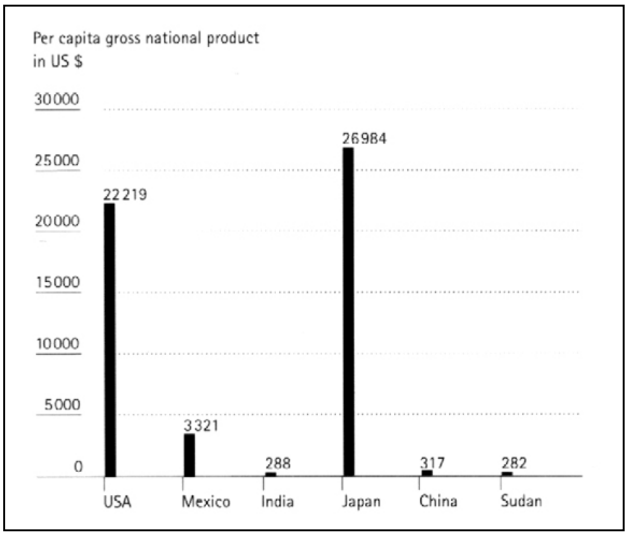


Figure 2.4. Graph of gross national product according to developed and developing countries (Daniels, 1998; p.10)

2.B. SIGNIFICANCE OF SOLAR ACCESS IN ARCHITECTURE

After the brief history of the role of the sun in architectural history it is better now to place the solar access in daily debates. The definitions of Knowles about the quality of life will be underlined with the help of Maslow's and Olgyays' ideas about life quality and comfort respectively. Furthermore sun will be analyzed as the energy source. In addition to these, the concept of solar rights will be added to the frame of the study. Finally the previous studies on building shape, perceiving the sun and solar access, as a parameter will be summarized.

2.B.1. Quality of Life:

Every individual may develop subjective definitions about the quality of life, but examining in social level and making researches in different civilizations and on thousands of people, it is observed that some common parameters are acquired. That's why quality of life is a social term than an individual intention and sociologists and economists develop a lot of theories.

In his researches, Maslow realized that people bring forward different needs in different times. He structured his theory of needs by listing these needs respectively as:

1- Physical needs (nutrition, dwelling…)
2- Security needs (safety, protection, health…)
3- Social needs (feeling of belonging to a society, love…)
4- Need of being respected (social status)
5- Need of developing personal interests, ideas, ideals (individual development, enrichment of personal life, accomplishing the personal goals) (Maslow, 1970, p.35-47)

According to this theory, people try to satisfy the needs starting from the first level and pass to the next when accomplished in one level. Consequently the quality of life is the totality of features and characteristics of the varying environments and changing conditions/circumstances that bear on their ability to satisfy the human needs for actualization at four level of awareness; Physical, Emotional, Mental, Spiritual.

If we want the good architecture in this quality of life argument we realize that architecture has various contributions, on various levels of awareness. As a subset, architecture has it's own parameters of quality which were once set by Vitruvious. According to European Commission (EC) quality of architecture involves:

> "…suitability, firmness and durability, and delight. Suitability for use rooms which are the correct size and scale for individual or group use: a place to sleep which is quiet, warm or cool as appropriate for the time of year, with fresh air and somewhere secure to rest; an office which is bright, practical, and which allows us to do good work; a suitable place for ritual or social interaction; a place which can adapt over time to changing functions and needs: and a place which is ecologically sound, with a healthy built environment. Durability in performance; buildings must be dry, economic in energy consumption and maintenance, last for a satisfactory life span, and function without defect. Delight: elegance of proportion, a joy in good craftsmanship, an awareness of the possibilities of color, light and shade, form and outline, and cultural appropriateness and significance through respect for the past and for regional identity, and through belief in the cultural legitimacy of the present" (ACE, 1999, p.02)

As a synthesis the quality of architecture is the totality of features and characteristics of the non varying environments and changing conditions/ circumstances (daily and seasonal) that bear on their ability to satisfy the human needs for actualization at three levels of awareness: suitability, firmness and durability, and delight.

Similarly Knowles says that the process of accommodation to change can define the quality of our lives (Knowles 1981, p.4). He finds this change in the variableness of solar access and defines as the paths of daily and seasonal variation in the sun's relationship to earth. Furthermore he sets the components of the quality of life related to sun as physical comfort, choice, sense of well-being, and joy.

> "Physical comfort: It is generally expressed in numerical ranges of temperature, humidity, air movement, light and sound levels, and other properties of physical environment that impinge directly on our bodies. Access to the sun has a direct impact on at least the thermal and luminous components of this complex set and a secondary relationship to most of the rest.
>
> Choice: For the designer, solar access provides a broader range of options because solar heat and light are assured for the future. For the user, solar access keeps future options open in the event that changing technologies and aesthetics make the sun more, not less, valuable. To the extend that solar access provides more designer and user choices, it clearly contributes to the quality of life.
>
> Sense of well-being: It is the reason we seek comfort and choice. Well-being is the sense of a condition rather than the reason itself. Yet even with such a vogue understanding, we must satisfy

> ourselves that a sense of well-being is the minimum basis for an aesthetic and for a both value system in building.
>
> Joy: It is the superlative form of well-being. We experience joy itself. It may result from external stimuli, but it is inside us and it is excessive! To the extent that solar access provides comfort, choice, and sense of well-being, it provides the potential for joy. Perhaps joy lies in the sun's warm rays as they strike our outstretched bodies, or it may lie in the reflections from a flower or a child's face. But in joy may lie the greatest justification for access to the sun."(Knowles 1981, p.4-5)

Sense of well-being and joy are subjective and relative components of the sun and quality of life relation. As Knowles has mentioned they have deterministic relations with the choice and physical comfort. Further explanations require psychological and perceptional perspectives, which are not issues of the study but physical comfort and choice should be examined with the perspectives of the suns effect on climatic and environmental design.

2.B.1.1. Physical Comfort:

Comfort is subjective and depends on age, gender, culture, and financial conditions. In practice designers aim to provide conditions that are acceptable to a majority of the users. According to EC comfort is affected by many factors, such as the activity, clothing, age and gender of the individual, and aspects of the internal environment such as air temperature, surface temperature, humidity, air movement, noise, light and odors. So they fragment comfort as thermal comfort, visual comfort, in door air quality and acoustic quality (ACE, 1999, p.25). Considering the sun as a heat and light source first two of them are directly related to solar access.

<u>Thermal comfort:</u> For the building design and engineering purposes, human comfort can be defined as the state of mind, which expresses satisfaction with the thermal environment (Watson 1983, p.26). In other words thermal comfort can be defined as the sense of well being with respect to temperature. Givoni enlarges the definition by adding the human body temperature and states that maintenance of thermal equilibrium between the human body temperature and its environment is fundamental. It involves keeping the temperature of the core tissues of the body within narrow range, regardless of the relatively wide variations in the external environment (Givoni, 1976, p.19).

Olgyays have defined these narrow ranges that human can bare. They started categorizing the major elements of climatic environment as: air temperature, radiation, air movement, and humidity. The schematic results of these elements' bearable limits are shown in the bioclimatic chart (figure 2.5).

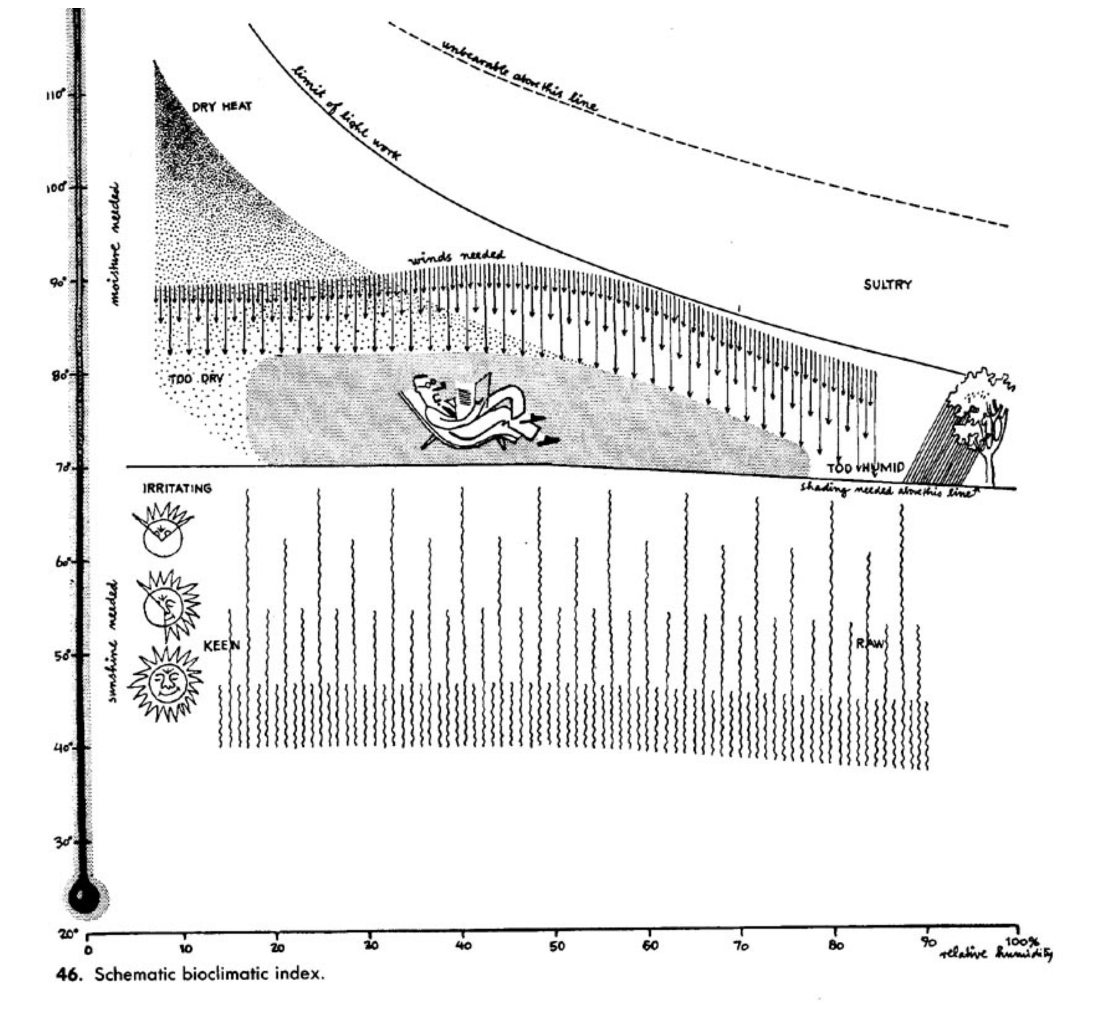


Figure 2.5. Bioclimatic chart showing the optimum values for human comfort (Olgyay 1992. p.23).

Visual comfort: The aim of good lighting practice should be to provide lighting, which is both qualitatively and quantitatively adequate. In all climates a balance needs to be maintained between natural lighting requirements and the requirement for thermal comfort. According to EC the objectives of visual comfort are:

- Good orientation and correct spacing of buildings can enhance natural lighting.

- Glazing ratio and window design should ensure that building interiors receive adequate natural lighting.

- To ensure an appropriate distribution of daylight, aim to have some sky visible from most places within the room.

- The spectrum of daytime artificial lighting should resemble that of daylight.

- Natural and artificial lighting should both meet physiological and health requirements optimum intensity, similar brightness, protection against glare, avoidance of shadows, adequate contrast.

- Wherever feasible rooms should have roof lights or windows, giving occupants some visual contact (ACE, 1999, p.33)

2.B.1.2. Choice :

A comfortable mind is not guaranteed by a comfortable mind. To explain this Givoni mentions the self-evaluation of man in a given environment:

> "In contrast with the physiological responses, which may be measured objectively, the determination of the subjective sensory responses depends on the self-evaluation of a man exposed to a given environment. This evaluation is not unequivocal but varies with different individuals, and also with the same individual at different times." (Givoni 1967, p.53-54)

From the users point of view, a reasonable comfort level can only be sustained by having the chance to arrange one's own comfort conditions. A very exciting example of this condition is encountered by Dean Hawkes during the studies on comfort in selective environment (Hawkes 1996, p.31-32). This study is based upon specific 'teaching spaces'. All, except one, were distinct classrooms, in five primary schools. Each was equipped with an extensive monitoring installation to record the major variables of the physical environment – temperatures, lighting levels, etc. – throughout a full annual cycle. These were supplemented by further manual measurements and, most important, by observations of the activities and responses of the occupants.

According to the user priorities stated on the results of this study, mechanically controlled environments caused the greatest dissatisfaction and rather than fixed standards a variable environment is preferred. User control is said to be indicative in evaluation of the performance of the parts. Additionally he stated that

‘…a shut-off sensor might have to be combined with the user switch…’ which underlines the importance of user demands in design of the control mechanisms.

An architecture, which guarantees solar access, manifests wider ranges of options for future to develop selective environments. A formation causing lack of solar access would result with an exclusive attitude towards environment.

Another aspect of the choice is the situation of designer. In Experiencing Architecture Rasmussen says that:

> “Daylight is constantly changing. The other elements of architecture we have considered can exactly be determined… Daylight alone he cannot control. It changes from morning to evening, from day to day, both intensity and color. How is it possible to work with such a capricious factor? How can it be utilized artistically?” (Rasmussen 1993, p.186)

He mentions the decisive importance of light in experiencing architecture. Amazement in the variety of design in the existence of daylight may turn into disappointment in the dullness of architecture in the lack of solar access. The seasonal and daily dynamism of the sun should be conceived as the source of rhythm instead of caprice. This potential of rhythm may result with aesthetic consequences that coincide with the functional necessities.

2.B.2. Sun as an Energy Source:

In physics energy is defined as the ability to do work. According to the first law of thermodynamics, which is the science that keeps track of energy as it undergoes various transformations from one type to another, energy may not be created or destroyed but is always conserved (Botkin Keller, 1995, p.299). Thomas Herzog examines the energy in three aspects; use, form and quality, in order to develop strategies in relation to buildings and urban structures.

Energy is used in the stages of material production, operation (maintenance) and construction (induced energy) when buildings are taken in to concern. For all of these stages, energy passes through various states. Considering the primary forms, energy can be examined as; fossil fuels, nuclear energy, and alternative energy sources.

Fossil fuels have high environmental impact during production, transport and consumption, and they are non-renewable. According to the projections estimated lifespan is 45 years for crude oil, 60 years for natural gas, 250 years for coal (Botkin Keller, 1995, p.313-328). In the case of nuclear power from the mining and processing of uranium to controlled fission, the processing of spent nuclear fuel, the decommissioning of power plants, and the disposal of radioactive waste, various amounts of radiation may enter and affect the environment. Nuclear power is non-renewable and estimated life for the existing uranium reserves is less than 100 years, in respect to the current consumption values.

Alternative energy sources are biomass, solar energy, wind energy, waterpower (hydroelectric) and geothermal energy. Only geothermal energy is non-renewable and they all have negligible environmental impact in contrast with fossil fuels and nuclear power.

To realize the significance of solar energy in all these energy sources, the third aspect of the energy should be mentioned; quality. If the amount of energy is fixed (1^{st} law of thermodynamics), what is being used up, is the energy quality, or the availability of the energy to perform work. The higher the quality of the energy, the more easily it can be converted to work; the lower the energy quality, the more difficult it is to convert to work. Energy always tends to go from a more usable (higher quality) form to a less usable (lower quality) form. This statement, the second law of thermodynamics, means that, when you use energy, you lower the quality (Botkin Keller, 1995, p.299). Consequently Thomas Herzog emphasizes the importance of solar energy as:

> "Man can merely retard the process of fragmentation, therefore, by conserving resources and recycling materials in a sensible manner. He cannot halt it completely or reverse it. The physical-biological process of natural evolution alone is capable of doing this – not by reversing the second law of thermodynamics, but with the help of a practically inexhaustible source of energy outside the closed system of our planet, i.e. sun."(Thomas Herzog 1996, p.32)

Solar energy is utilized mainly in two ways; actively and passively. Active solar energy systems are solar collectors, photovoltaic panels, power towers, solar ponds, hydrogen generating solar centrals and ocean thermal conversion centrals. Last two of them are theoretical methods of energy generation but others are known for many years and applied where available. Passive utilization of solar energy requires improving the energy performance of buildings in three areas; heating, lighting and cooling. Solar access is the precondition for both active and passive solar design strategies.

2.B.3. Solar Rights:

Solar access is necessary to make use of it. If the answer of the question "Who does the sun belongs to?" is everybody, then the next question rises as "How can people equally benefit from the sun?" In a fair society freedom of an individual ends where the freedom of the other individual starts. In the context of solar access two individuals are you and your neighbor. Your neighbor's actions – the placement of his house, outbuildings, and vegetation, and their size and height – will determine the extent of your access to sunlight. Similarly, your actions will determine your neighbor's access. These two perspectives represent not only different ethical foundations but also different legal and design issues as well.

In the previous sections, the historical review of the solar rights, which starts with height limitations, set back legislations and proportioning the height of the building with distance of units, to the three dimensional approach that is the issue of this study, are mentioned. One popular issue is the 45º rule of Tony Garnier. During the post-war period this rule was applied around Europe. Sometimes the principle is applied in different angles to reach higher densities; 63º in Portugal (Simoes 1998, p.603), 75º in New York.

Fausto Simoes introduces a modified version of this method. For him the specific angle supplied from this method should be applied only on south facing façade and designated as:

> "…from the general equation for the solar altitude at noon:
>
> $$hn = 90.0^\circ - \alpha + \theta$$
>
> we can have the solar altitude at noon in the winter solstice hnw, taking it as the solar access angle:
>
> $$hnw = 66.5^\circ - \alpha$$
>
> where α = latitude and θ = declination. With this rule, the average loss of exposed area between 9:00 AM and 15:00 PM at the winter solstice is, in the worst case of latitude 42ºN (for Portugal), less than 0.13 for a wall oriented due South." (Simoes 1998, p.605)

This method is exciting with its sensitivity to the change in latitude. But solar access requires more parameters, which will be mentioned in the next chapter.

Other than technical methods, in some states of US the solar rights are the parts of laws and legislations whereas EU is very poor in such approaches (Simoes 1998, p.603). California (www.eere.energy.gov), Florida (www.flaseia.org), and New Mexico (www.emnrd.state.nm.us), are some states that have significant approaches to solar rights. California Solar Rights Act of 1978 declares that:

> "It is the policy of the State of California to promote and encourage the use of solar energy systems and to remove regulatory obstacles to their use. The California Solar Rights Act (Section 714 of the Civil Code) was enacted in 1978 to ensure that any covenant, restriction, or condition contained in any deed or other contractual restriction, which affects the sale or value of real property, does not limit the installation or use of a solar energy system." (www.eere.energy.gov),

This act seems to be promoting the active uses of sun, where as Knowles states a more comprehensive approach to solar rights mentioning the similarities of sunlight and water rights with reference of Mary R. White (Knowles 1981, p.27). First both are used rather than captured and sold; both may be consumed, but both are renewable. In addition, there is equivalence between upstream and down stream in water law and the geometry of solar shadowing.

A rough example of how the law worked can be described as follows: Settler A establishes his residence along a river and puts the water to beneficial use by diverting some of it for irrigation. Subsequently, settler B takes up residence downstream while settler C locates upstream from A. Under the prior appropriation doctrine, both B and C, who presumably settle with foreknowledge of A's prior claim to the river, do so acknowledging that claim and agreeing to endure without protest A's continued use of the river. On the other hand, A has some responsibilities in the matter and cannot significantly change the conditions accepted by B and C when they first settled. There the matter lies, unless some prior agreement among the three or subsequent court action taken by one of the parties effects a change in the pattern of use (figure 2.6).

The other accepts the doctrine of “Every body has the equal share”. It made no difference where or when A, B, or C acquired ownership along the river (Figure 2.6).

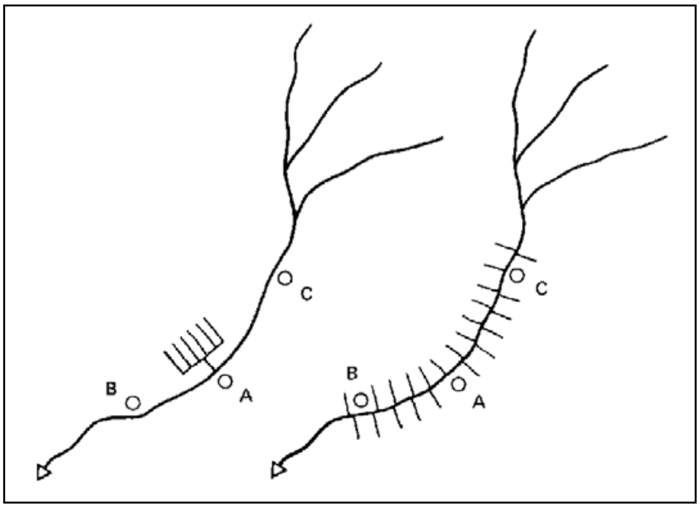


Figure 2.6. Application of water law according to two opposing doctrines (Knowles, 1981; p.27-28)

Neither of them is applicable to solar access but the spirit of these doctrines may be the issue of an analogy. Consider first the solar analogy to prior appropriation. Developer A sites a building that casts shadows to the north. Sometime later developer B locates his building to the north (downstream). Developer B, like settler B in our frontier example, must contend in some way with an a priori appropriation of the resource. Under present law, B would have no right to receive solar energy that crossed A's airspace. His only right would have been to sunlight falling perpendicularly onto his land. On the other hand if A's prior appropriation of the sun is guaranteed by law, developer C, who comes along later, would have to accept the limitations of a building envelope with a bottom and no top. Unfortunately, it cannot be offered to C the same option of differentiating function to fill in the missing portion of volume, because however this were done would deny A's access to the sun (Knowles, 1981; p.29).

The application of the equal share doctrine requires three-dimensional approach to zoning. Each piece of property could be assured equal access under the law. The result would be an envelope of developable volume that would derive its size and shape from the size, shape, slope, and orientation of the property (Figure 2.7).

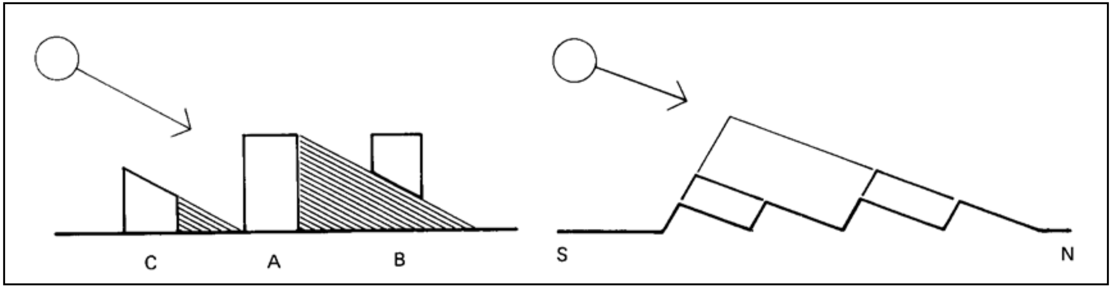


Figure 2.7. Solar application of water law (Knowles 1981, p.28-29)

To clarify the three-dimensional approach, that guarantees the solar rights we can make some definitions. Briefly these definitions are about the effect of us to environing sites, effect of environing buildings on our site and a combination of them (Capeluto, Shaviv 2001, p.276).

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.

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. 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.

2.B.4. Building Form:

This section will be a reminder about fundamentals of form generation regarding the energy conversion performance of a building. For this purpose the results of Olgyays' bioclimatic approach and surface-to-volume ratio concept are very primary and helpful to mention.

Olgyays' inspiration is the adaptation capability of organisms. They realized that this capability gave formal results. Considering the thermal performance of the buildings, they made their optimizations on the horizontal dimensions of buildings in different climates (Figure 2.8). In general their results are:

- The square is not the optimal form in any location.
- All shapes elongated on the north-south axis work both in winter and summer with less efficiency than the square one.
- The optimal shape in all climates is a form elongated along the east-west direction.
- In most commercial buildings, in most climates, the principal penalty of a north-south axis is increased operational costs due to higher peak cooling loads; however, using a saw-toothed east-west envelope can reduce penalties.
- At all latitudes, although buildings elongated along the east-west axis are the most efficient, optimal elongation depends on the climate. Some general principles can be stated for different climates. In cool and hot-dry climates, a compact building form, exposing a minimum of surface area to a harsh environment, is desirable. In temperate climates, there is more freedom of building shape without severe penalty (excessive heat gain or loss).
- In addition to elongating the building, the plan may open to a courtyard, allowing a more central solar penetration. Although additional perimeter wall is required in buildings with totally enclosed courtyards or atriums, the additional wall is exposed to less severe exterior conditions. Since there would be relatively little energy loss through the windows or openings on the courtyard side, there can be considerably more glass or openings here. The courtyard itself could be naturally lit with skylights, wall glazing or a well-insulated clerestory. If solar heat gain is required, passive collection from south-facing windows is possible.

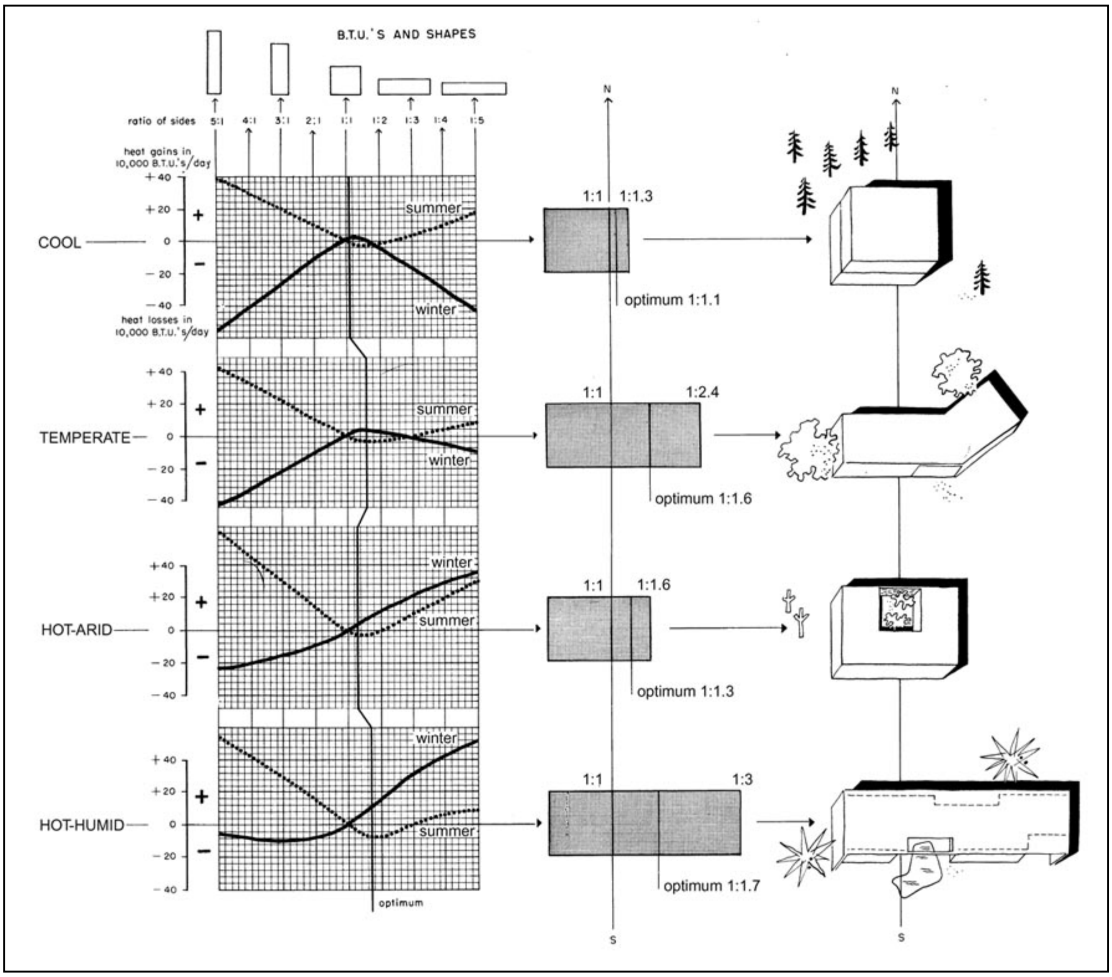


Figure 2.8. Building shapes in different climate regions (Olgyay, 1992, p.89)

In addition to these an evaluation about the building form considering the surface-to-volume ratio is developed by Knowles. He names the function of this ratio as susceptibility coefficient. The more the exposed surface to the contained volume, the more susceptible the arrangement (Figure 2.9) (Knowles, 1974, p.67). In other words a structure with high surface-to-volume gains and losses energy rapidly which is not preferable, but on the other hand with low coefficient high-energy conversion capability, structure should be supported with climate control devices. In a further study entitled “On Being the Right Size”, he reached an optimal susceptibility coefficient of 0,1 for Los Angeles’s urban context, to provide good solar access and cross-ventilation.

The cut-off value provides a simple but powerful design tool. At very early stages of planning, a simple calculation, carried out on alternative massing schemes, provides a clear basis for comparing the final character of their energy usage.

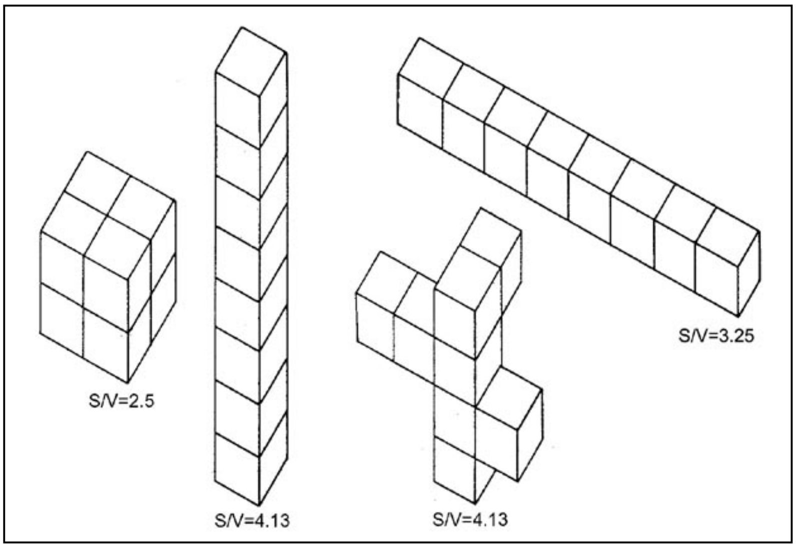


Figure 2.9. S/V ratios of forms having the same volume but different shape (Knowles, 1974. p.68)

CHAPTER 3

SOLAR ENVELOPE AS A FORM GIVING TECHNIQUE IN ARCHITECTURE AND URBAN DESIGN:

3.A. DEFINITION AND RULES FOR ENVELOPE GENERATION:

Knowles started his studies, which led him to formulize solar envelope, investigating the natural forces on buildings. The subject of the book titled “Energy and Form: an ecological approach to urban growth” (1974) is energy conservation through design. In this book, he followed a three-part investigation of building requires; historical analysis, application of modern techniques, and suggestions for future building strategies (Knowles 1974, p.1-2). In this study he developed pyramidal shapes for parcels that are parts of a site. Attitude to construct these pyramidal shapes was the building limited with it, located on these sites should not shade adjacent sites. Definition for them was the maximum allowable volume that could be built without extending shadows beyond the parcel during the critical insolation period of each day (Knowles 1974, p.115-123). He didn’t name these pyramidal shapes as solar envelope till 1981.

In his book “Sun, Rhythm, Form”, he declared his view of solar design on the basis of environmental impact on buildings. He perceives the action of construction as an adaptation to environmental conditions. For him this adaptation has three steps; selection of location, shaping of form and developing the metabolism (Knowles 1981, p.141-158). These three stages imply each other as; “location sets rhythm, rhythm sets form, and form sets metabolism” (Knowles 1981, p.159-169). Site selection designates the environing impacts, which requires different rhythmic elements like sun, wind, and topography. Adapting to them ends with a form having the signs of surrounding. According to the form the final stage of adaptation is guided that is metabolism, which requires the sum of all chemical and mechanical processes that provide energy for environmental regulation within buildings (Knowles 1981, p.149).

Since then Knowles has been teaching at University of South California. Studies developed in design studios turned in to a digital design assistant in 1992, by the followers of Knowles; M. Schiler and U. P. Yeh as a result of a thesis research. They called this program as Solvelope, which will be explained and used in the following sections and chapters. D. Noble and K. Kansek advanced the studies on solar envelope in digital media and ended with an Autolisp application, which is compatible with the popular drafting medium Autocad (Noble, Kansek 1998). Realization of the potential of solar envelope in computer based building design let Knowles to represent the solar envelope with online papers between the years 1998 and 2002 (www-rcf.usc.edu). These papers include previous studies, introduce current debates and make projections to future. Finally he discussed the sustainability dimension of solar envelope in his paper “The solar envelope: its meaning for energy and buildings” (Knowles 2003, p.15-25).

Knowles finds rhythm in daily and seasonal migration of sun. He advises to obey the limits of solar envelope, which is derived from the relative motion of the sun. Development within this container will not shadow its surrounding during critical periods of the day. As the solar envelope describes the volumetric limits of the building that will not shadow surroundings at specified times it must be constructed from data based on the sun’s movement (time) relative to the location and geometry of a site (space). The solar envelope is thus a constructed synthesis of time and space (Knowles 1981, p.51).

3.A.1. Time:

The time data for constructing a solar envelope derive from the perceived movement of the sun from one celestial region to another. This movement is defined by a daily path, from east in the morning to west in the afternoon, and by a seasonal path, from south in the winter to the north in the summer. These apparent solar migrations by day and season describe the boundaries of the solar envelope and therefore the limits of development within.

3.A.1.1. Solar path by day and season:

Daily limits: The apparent migration of the sun from east to west at daily intervals describes the east and west boundaries of the solar envelope.

Yearly limits: The yearly, or seasonal, migration of the sun describes the north and the south boundaries of the envelope. The winter sun cast shadows to the north on the other hand the summer sun, to the south at certain times of the day.

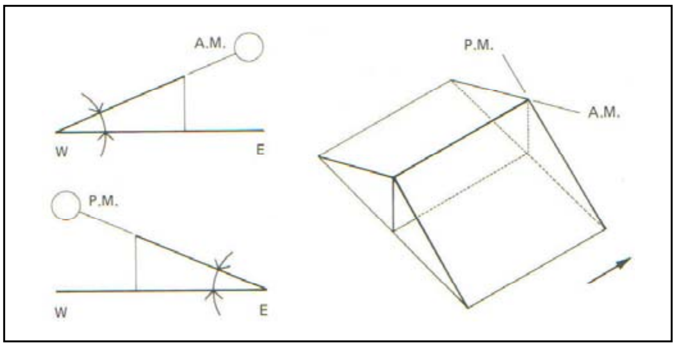


Figure 3.1. Volume generated from daily limits (Knowles 1981, p.54)

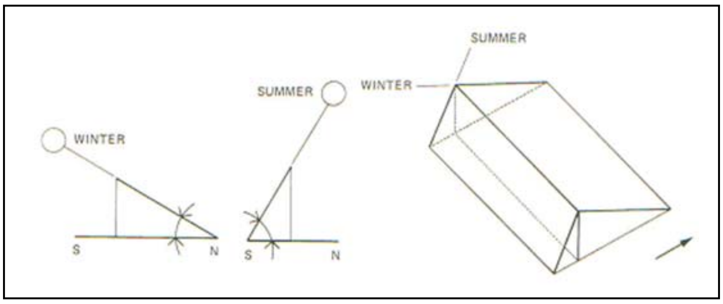


Figure 3.2. Volume generated from annual limits (Knowles 1981, p.55)

Integration of daily and yearly limits:

The combined effect of daily and seasonal migrations of the sun would result in shadows that define sloping limits to all the boundaries of a rectilinear site. The combined effect of those limits would be a solar envelope enclosed on all four sides.

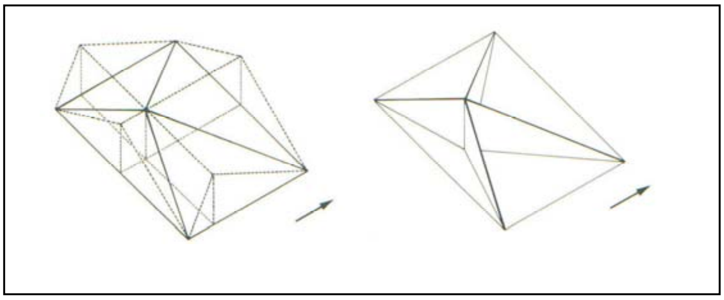


Figure 3.3. Integrated volume (Knowles 1981, p.55-56)

3.A.1.2. Periods of useful insolation:

Solar envelope is defined by daily and seasonal limits of the sun's movement. These limits should be a party of an evaluation of useful insolation. It can be designated by deciding, when do we need solar access and when we don't. The sun's energy is not equally distributed throughout the day and year, because of atmospheric attenuation. Everyone has had the experience of receiving reduced heat and light from the rising and setting sun. The first red glow of sunrise is usually a promise of heat that is not fulfilled until later in the day. This is because the sunlight penetrates less atmosphere as the sun rises toward the zenith, At sunrise and sunset, the rays of light are tangent to the earth at the site. Consequently, they pass through so much atmosphere.

This perceived difference in the amount of energy that gets through the atmosphere can be approximated by the sine of the sun's altitude α. At sunrise, $\sin \alpha = \sin 0° = 0.0$. If the sine function is used as a multiplier of the maximum possible irradiation, the product is then 0 at sunrise and sunset. As the sun rises overhead, the altitude angle approaches 90° as $\sin \alpha = \sin 90\ 0 = 1.0$. Used as a multiplier, the received energy would be closer to 100 percent of the maximum possible (Figure 3.4).

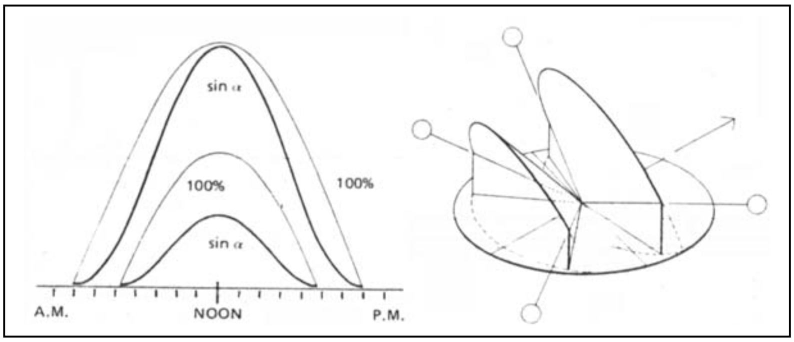


Figure 3.4. 100% summer and winter solar radiation (Knowles 1981, p.57)

To clarify the relation between the cutoff times and the desired solar energy we can check an example (34N Los Angeles) given by R. Knowles with the help of energy time graphs:

a) Consider the cutoff time constant: Assuming that the minimum duration of access is about six hours for useful energy conversion, access would be required from 9 A.M. to 3 P.M. each day of the year. The hours before and after are less useful for energy conversion and are therefore excluded from periods of assured solar access. On the other hand, the sun's altitude angle at 9 A.M. in the summer is greater than during the same time in winter. Only 52 percent of the sun's energy is available at noon on a winter day (sin 31.5° = 0.52) compared with 98 percent of the sun's energy at noon on a summer day (sin 78.5° = 0.98). (Figure 3.5 a)

b) Fix the percentage of the desired energy level: If access were to be determined by some fixed percentage of available energy, cutoff times would change over the course of the year. Those hours when less useful amounts of energy can penetrate the atmosphere would be excluded from periods of assured access. For example, if the desired energy level were 30 percent of maximum available energy at 34 N, the sun would have to rise 17.46° above the horizon on any day of the year. When the sun passed below that angle in the afternoon, we might also be willing to give up access. The times of the day that correspond to α = 17.46° would then limit the duration of access. For Los Angeles, those times are 6:24 A.M. and 5:36 P.M. in summer and 8:54 A.M. and 3:06 P.M. in winter. (Figure 3.5 b)

c) Increase the energy level: It is again important to note that useful amounts of energy are available for more hours of the summer than the winter day. If we define "useful" to be 40 percent of maximum available solar energy instead of 30 percent, we reduce the period of assured access by about 50 minutes in summer. But we reduce it by about twice that amount in winter, or about 110 minutes. (Figure 3.5.c)

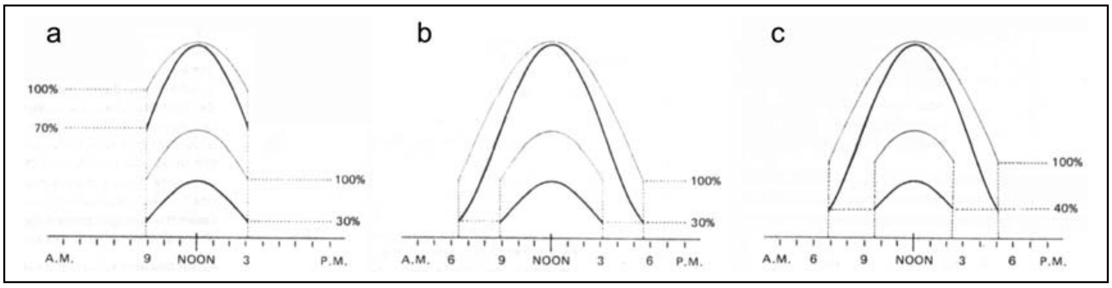


Figure 3.5. Graphs showing the change in energy during different time zones, having daily symmetry (Knowles 1981, p.58)

d) Try different energy levels in different seasons: It is conceivable that some seasons may require higher percentages than others. If only 30 percent is required at cutoff in summer and 40 percent in winter, the period of critical solar access will be much greater in summer than in winter (Figure 3.6 d).

e) Try different energy levels for morning and afternoon: If higher percentages are required for morning cutoff than for the afternoon, the period will start later in the morning and end later in the afternoon. (Figure 3.6 e)

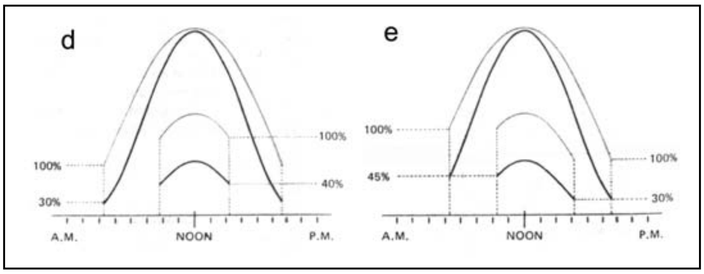


Figure 3.6. Graphs showing the change in energy in different time zones, having seasonal and daily asymmetry (Knowles 1981, p.59)

3.A.1.3. Residential and commercial applications:

Dissimilar functions suggest different periods of solar access. Housing seems to lead the list of functions requiring access to the sun, which may relate to perceived as well as actual need. People behave differently when they are at home. Their attitudes about where they live, opposed to where they shop or work, are more proprietary and they exercise more control, Their perceived and actual rights are defended more vociferously where they live. This is true regardless of the actual time spent at home.

Shopping and working, at least in our culture, are perceived to be independent of the outside world. Consequently, our sense of the sun's importance to these pursuits is less well developed.

The greater value of solar access for housing suggests the possibility of vertical differentiation in mixed-use development. For example, within the pyramidal shape of a solar envelope, a greater duration of solar access can be attained toward the top. This fact, in combination with other design criteria for good housing, may be used to distinguish function.

Housing can be zoned in the upper regions of the envelope in urban areas where land is at a premium, while commercial functions occupy those regions farther down. Of course, this arrangement assumes a certain notion about housing and commerce and their relationship to each other. Such notions may vary regionally, but in instances where they are acceptable, they form a basis for interesting prototypes.

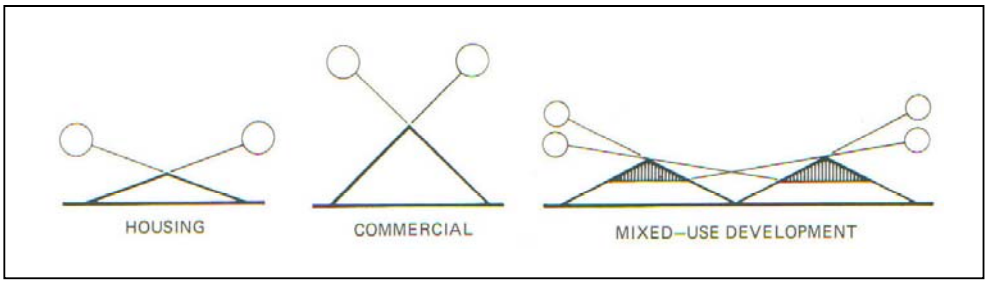


Figure 3.7. Effect of function of building on developable volume (Knowles 1981, p.60)

A counterargument is that many residences are unoccupied during daylight hours, while work, recreation, commercial, and institutional spaces are occupied mostly during that time. This assumes a different notion about housing that may, under certain conditions, require regions of the solar envelope to be carefully planned three-dimensionally for mixed-use access to the sun. This is a particularly useful concept when the envelope is of urban-design scale.

The consideration of useful solar access, particularly at urban scale, must also be sensitive to surrounding development. The land uses surrounding a site, the type of buildings, and the nature of human activities and desires obviously affect decisions about optimum periods and uses of solar energy.

3.A.2 Space:

There are five generalized spatial constraints delimiting the solar envelope.

3.A.2.1. Latitude: Latitude affects the height, and therefore the volume, of a given solar envelope for a site of a given size and shape. If the cutoff times are held constant, the envelope height decreases as the latitude increases, primarily because of the critical effect of winter sun on the envelope's north slope.

Consequently, the volume of a solar envelope increases with proximity to the equator; the volume decreases toward the north and south poles.

3.A.2.2. Size: Sites of different size but similar proportion will have solar envelopes of different size but similar proportions, given the same time constraints. Increasing the size of the envelope will also decrease its surface-to-volume ratio (Knowles 1974, p.68), with resulting design implications for building development and energy performance within.

3.A.2.3. Shape: A change in the shape of the site will change the envelope shape, even when time constraints are the same. Because of the nature of the method, which is the three-dimensional rendering of a site with the help of solar radiation without casting shadows, shape is a constraining element.

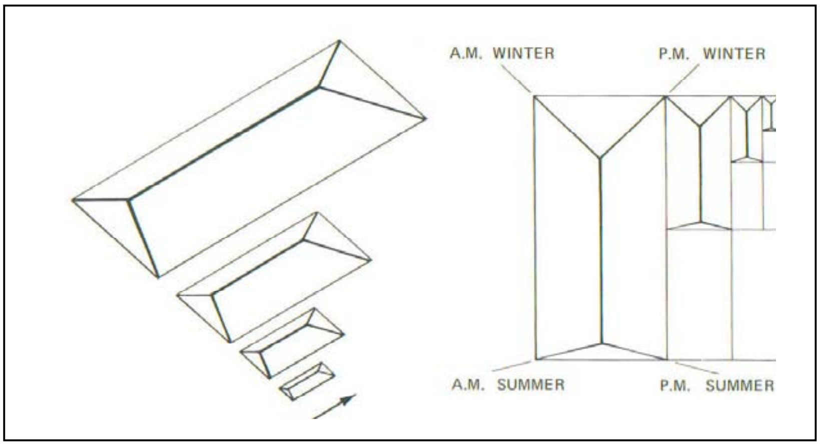


Figure 3.8. Effect of shape to developable volume (Knowles 1981, p.65)

3.A.2.4. Slope: The slope of the site affects both the height and the shape of the envelope. The envelopes over south-facing sites will generally be much higher and contain more volume than those on north slopes. Envelopes over east and west sites are somewhat more dependent on parcel shape, but they generally contain a moderate height and volume.

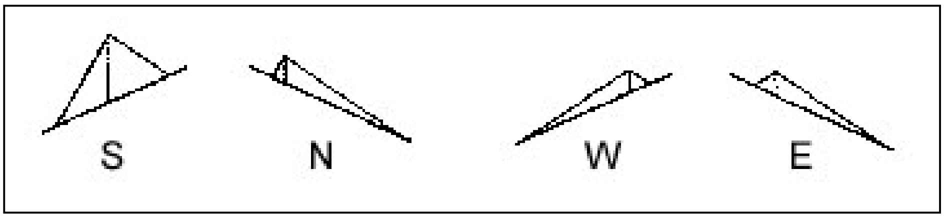


Figure 3.9. Effect of slope to developable volume (Knowles 1981, p.69)

3.A.2.5. Orientation: An angular rotation of the grid will change the height and therefore a solar envelope describes the developable volume. This significant change can be demonstrated by incrementally rotating a model site, of constant size and shape. There are two important observations to be made here. First, an orientation of approximately 60° off the cardinal points does not offer the volumetric possibilities of any other site orientation. Second, sites oriented long in the west-east direction allow a greater volume of development under the solar envelope than sites running north south.

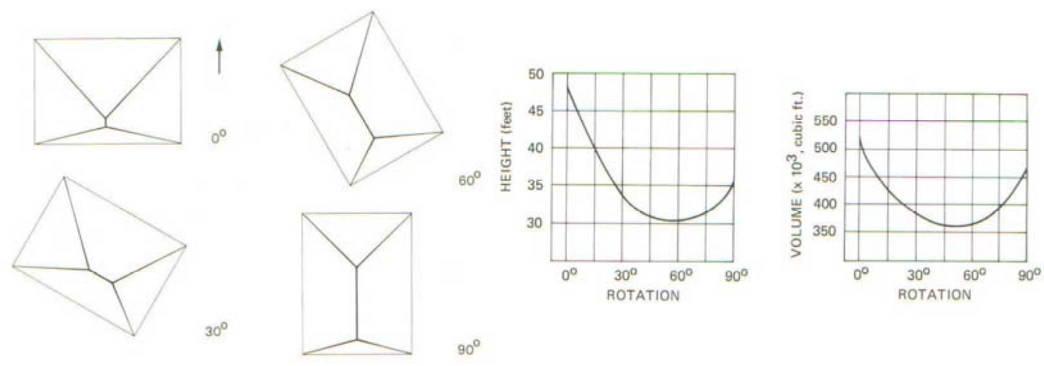


Figure 3.10. Effect of orientation to developable height and volume (Knowles 1981, p.70-71)

3.A.3 Other common environing parameters:

Time and space constraints are the fundamentals of the solar envelope, which is a method defining the developable volume of site considering the solar rights of the site itself and the environing sites. In this concern, some other environing conditions will affect the envelope's size and shape. These conditions may be summarized as setbacks, fences, streets, adjacent buildings and landscape elements. Their impact on envelope depends on our attitudes about private and public space as well as about solar access.

> "Solar access is not an isolated issue. It must be seen in the context of market constraints, land uses, and environmental concerns." (Knowles 1981, p.120)

3.A.3.1. Setbacks: They are generally used to protect the rights of neighbors and public. In Ankara, according to construction regulations set backs are; 5m from neighbors and secondary roads, 10m from primary roads and parks for the buildings up to 4 stories with ground floor (Regulations 1999, p.21). These values are designated by different variables than solar rights but may affect the solar envelope as a constraint. The degree of this effect may change according to our considerations. We can limit our envelope with, our own set back line or extend it to our yard line with our neighbor, or the street in front of our parcel. A more daring attempt would be choosing the limit for the cast shadows as our neighbor's set back line. This progression of expanding shadow limits may continue to include designated parts of the neighbor's building. For example we may be permitted to cast shadows on neighbor's façade till the bottom level of windows. On the other hand in a denser context, we may deal with the amount of shadows cast on a façade from the thermal performance of whole façade. Consequently we may end with a decision of casting shadow on, with a specific percent. Such an approach requires a systematic correlation with land use and building function.

3.A.3.2. Fences: Setbacks become a part of our privacy policy by defining horizontal values where as fences designate vertical limits. In Ankara building regulations limit the street façade perimeter walls with 0,5m. An additional 1m of fence that does not prevent vision can be applied over it. This height limit extends up to 2m for neighborhood borders (Regulations 1999, p.63). In case of preferring privacy rights to solar rights, solar envelope will be affected. For a site having 1,5m height perimeter fence, the envelope will be placed 1,5m over the surface, which may significantly change the total volume.

3.A.3.3. Streets: If setbacks and fences define the regulations, about our relation with neighbors, streets are designation of our boundary with public space. If we consider the solar envelope as a result of the interaction of the site with its environment, the existence of the street inevitably affect the solar envelope. The consequence of this effect depends on the physical properties of the street and our attitude towards the insolation of public space. In hot climates, streets needed to be shaded but on the other hand in cooler climates any planning attempts requires as much sunlight as possible, into the street.

Difference of the envelope of corner blocks and others, is an additional point to be mentioned if we consider the enlarging effect of the streets on the envelope. In case of permitting to cast shadows to a certain distance or the entire street, a parcel on the alley will extend the envelope in one dimension whereas the corner parcel will do so in two dimensions. As a result, corner parcels have bigger and higher envelopes.

In urban context streets are main parameter, to define the boundary conditions of a site. In this concern urban planners specify some of the physical variables that we use to define the solar envelope such as size, shape, and orientation in the stage of defining the streets and alleys. As we mentioned before, east-west blocks give higher and bigger envelopes compared with the north-south blocks. Another consequence of east- west blocks is that it gives longer south facades. Fortunately, this result satisfies the exposure to south principle of general solar design policies, which gives positive results for energy conversion (Olgyay 1963, p.53-62).

3.A.3.4. Attached Buildings: Depending on our urban policies another case that affect the solar is attached buildings. Although this type of development is adopted in our conventions, it is debatable. Resulting with high-density urban development, it satisfies market needs, but privacy rights and spatial quality is threatened. From the solar envelope point of view a dilemma can be observed. Comparing with similar sized detached and attached housing units, the latter has bigger habitable volume with the price of decreasing the facades with solar access. One more aspect of attached housing is that it gives positive results in energy conversion. Decreasing the surface of heat loss without decreasing the volume to be heated will increase the thermal performance of any individual building.

3.A.3.5. Landscaping: At first glance it is obvious that landscape elements, which are the elements of environing effects, will be limited with the previously defined envelope. But considering that landscape elements' shadows are not as the same as architectural elements, solar access needs may be redefined. This different shadow character results from seasonal adaptation behavior of plants, especially the deciduous trees in this case (Knowles 1974, p.05). To redefine the solar access needs we should analyze energy conversion in two parts as direct gains and indirect gains. Direct gain is supplied by rooftop solar collectors and photovoltaic panels, which do not bare any shadow because of the permanent need of energy. On the other hand, indirect gains from façade openings may require seasonal variation.

Solar access in winter is necessary when the branches of a deciduous tree are bare, but shading will be crucial in summer, when the trees are in full leaf. So we may extend our solar envelope, which is defined by the setback of our neighbor, till the roof level to define a landscaping envelope, which we use to specify the height of our deciduous trees. In conclusion we should mention that the effects of landscaping elements are relatively depend on solar access policies. Knowles says:

> "The limits of this landscape envelope, like those of the building envelope, are best determined by local zoning policy. They might vary widely from one city to another. Certainly there should be regional diversity… cities will, no doubt, need to work from different limits but the principles will generally apply." (Knowles 1981, p.122)

3.B. SOLAR ENVELOPE GENERATION TECHNIQUES:

Basically there are two ways of generating the solar envelope; computational and non-computational methods. Both of them are the visualization of solar angles that are the data of sun's relative movement according the earth. Considering the speed and visualization opportunities, computer software is the most efficient way of generating the solar envelope. However non-computational methods are fundamental to understand the concept of solar envelope.

3.B.1. Non-computational methods:

As being a mathematical and geometrical study of solar angles, constructing a solar envelope can be done in numerous ways. Here R. Knowles's descriptive method is chosen as a guide. In addition to this, profile angle method is defined in the following sections.

3.B.1.1. Descriptive method:

The method depends on intersecting the site with vertical planes. Each plane is systematically located and shaped in accordance with solar azimuth and altitude angles between the cutoff times. These angles are read from sun chart (Appendix A-B).

In each drawing, the top of a plane represents a solar ray that passes over the site to intersect a predetermined boundary. A number of planes represent selected times of the day and year. When the heights of planes are compared, the lower ones will determine the envelope limits; any taller segment of plane is then removed. The result is systematic definition of the envelope's volumetric boundaries.

The base of each triangle marks the azimuth angle θ, measured counter clock vise from south. The hypotenuse of each triangle marks the sun's altitude angle α, measured above the horizon. In this concern the selected cutoff times, the altitude angles and the azimuth angles (for 40° N latitude) are as follows: 09:00 – 15:00 winter (α = 14°, θ = 42° and 318°), 07:00 – 17:00 summer (α = 26°, θ = 100° and 260°). Site dimensions are; 100 units east-west and 75 north-south and there is no bearing from the south.

Step 1. Use the Morning Cutoff Times:

The summer morning rays (07:00 summer; α = 26°, θ = 100°) approach the site across its north and east boundaries. Planes located at those boundaries and cut to precisely intersect the sun's rays as they enter over the site cast shadows to the opposing south and west boundaries. The winter morning rays (09:00 winter; α = 14°, θ = 42°) approach the site from the south and east. Planes located at those boundaries are shaped to cast shadows to the opposing north and west boundaries.

Step 2: Use the Afternoon Cutoff Times:

The summer afternoon *rays* (17:00 summer α = 26°, θ = 260°) approach the site across its north and west boundaries. Vertical planes at those boundaries are shaped to cast shadows to the opposing south and east boundaries. The winter afternoon rays (15:00 winter α = 14° θ = 318°) approach the site across its south and west boundaries. Vertical planes at those boundaries are shaped to cast shadows to the opposing north and east boundaries.

Step 3: Combine Effects of the Morning and Afternoon Cutoff Times:

The combination of summer rays slopes across the site to strike the south and west boundaries in the morning, the south and east boundaries in the afternoon. The planes all intersect at the same height, midway in the site. The combination of winter rays slopes across the site to strike the north and west boundaries in the morning, the north and east boundaries in the afternoon. The planes intersect at different heights across the site.

Step 4: Indicate Redundancy

That portion of any triangular plane that rises above an intersecting plane casts shadows off the site at one or another of the cutoff times. Such portions, which are descriptively redundant, are shown above the additional lines in the two accompanying drawings.

Step 5: Eliminate Redundancy:

When redundant portions of triangular planes are cut away, the result is a tent-like shape for the summer solstice and an irregular pyramid for the winter solstice. Each is a solar envelope that functions perfectly for one day of the year.

Step 6: Find the Envelope Hips:

External angles, or hips, are defined where two sloping faces of the envelope meet. The triangles that define summer faces also indicate two hips that slope from a vertex ridge to the site's southeast and southwest corners. The triangles that define winter faces also indicate two hips that slope from a vertex to the site's northeast and northwest corners.

Step 7: Delineate Envelope Ridges:

A ridge appears where opposing east and west slopes meet at the envelope's top. One ridge extends north from the vertex of two intersecting summer hips. A second ridge extends south from the vertex of two intersecting winter hips.

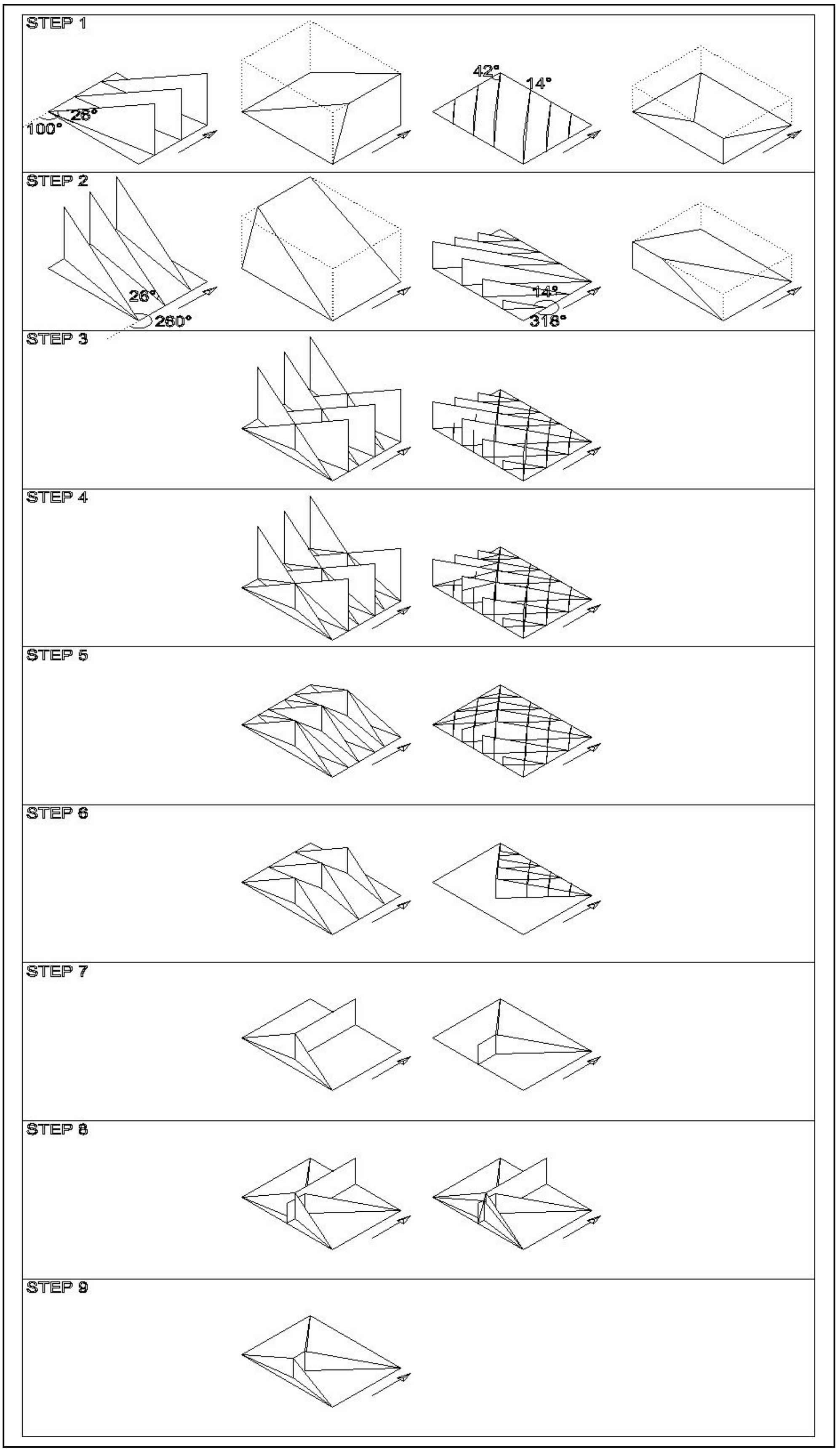
Step 8: Allow the Ridges to Converge:

When the summer and winter ridges are superposed, they precisely contact each other. These summer and winter ridges lie in the same plane. Of course, the plane differs for differing cutoff times and site geometry.

Step 9: Exhibit the Complete Solar Envelope:

The final envelope emerges with four hips that meet a short, north-south ridge. Two hips appear at the site's southern corners. Their top edges follow the sun's rays at the two summer cutoff times. Similarly, two hips appear at the site's northern corners. Their top edges follow the sun's rays at the two winter cutoff times. The volume thus generated could not be larger without casting undesired shadows. (Volume = 50562,33 unit^3)

Table 3.1. Solar envelope generation with descriptive method



3.B.1.2. Profile angle method:

The descriptive method uses the vertical planes to indicate the inclined planes, starting from the bottom line of facades and intersecting with each other on top. The angle of such a surface with the horizontal surface is called profile angle and can easily be read form the sun chart by placing an additional protractor on (Appendix B).

This method simplifies the construction process of envelope whereas increases sun chart reading work or angular calculations in previous stages. To clarify, the site used in descriptive method will be processed once more with the same data.

Step 1: Indicate the Solar Data: Every sun angle shades two different facades. This can be conceived as dividing the vector of sun into its components. So the morning sun defines the profile angle of west façade whereas afternoon sun defines the profile angle of east. Seasonal extremes, defines the north and south profile angles. By taking the minimum angles for every façade, we can start constructing the solar envelope (Table 3.2).

Step 2: Create the Inclined Facades: From the table above the profile angles are, west=20°, east=20°, north=18°, south=70°. Laying the perpendicular surfaces that create a box till they reach these angles will result with solar envelope.

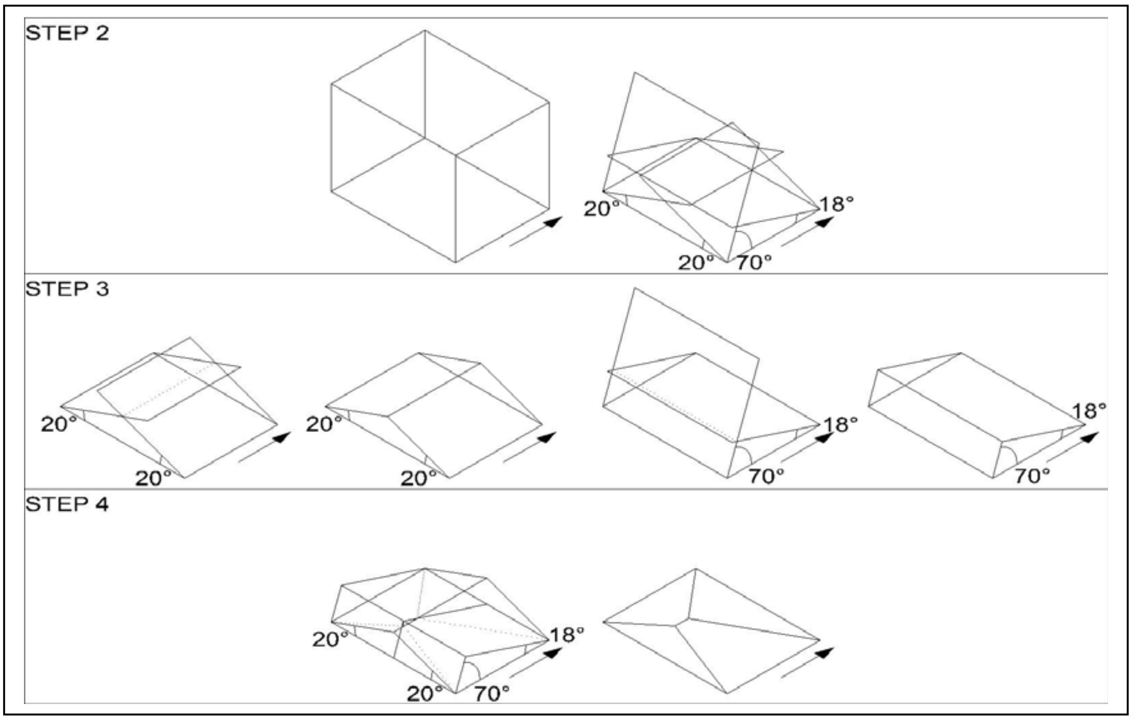
Step 3: Intersect the Planes in Pairs: To indicate the volume under these surfaces handling them in pairs of east-west and north-south is easier. Both pairs create ridges, which are different.

Step 4: Indicate and Eliminate the Redundancies: The intersection of the volumes created by the surface pairs results with the final envelope.

Table 3.2. Angular data of the site

SEASON	APARTURE	SOLAR ALTITUDE	SOLAR AZIMUTH	PROFILE	FAÇADE
WINTER	09:00	14°	42°	20°	West
				18°	North
	15:00	14°	318°	20°	East
				18°	North
SUMMER	07:00	26°	100°	26°	West
				70°	South
	17:00	26°	260°	26°	East
				70°	South

Table 3.3. Solar envelope generation with profile angle method



3.B.1.3. Drafting the solar envelope:

As it is mentioned before, being a three-dimensional visualization of the mathematical data gathered from suns relative movement, there are numerous ways of construction or drafting methods. Considering the computational opportunities that we obtained from cad applications relieve such anxieties. However, considering the conventional methods of education, a two-dimensional orthographic drafting method will be useful.

For this purpose the same site and the same climatic data will be used. Additionally the effect of the change in the orientation will be shown with the same method. As a reminder, it should be told that this two dimensional orthographic approach is available for only rectangular sites whereas descriptive and profile angle methods are efficient in irregular and sloping sites.

Step 1: Set the Two Elevations: From the table 3.2 the profile angles are, west=20°, east=20°, north=18°, south=70°. With the help of these profile angles the facades may be drawn.

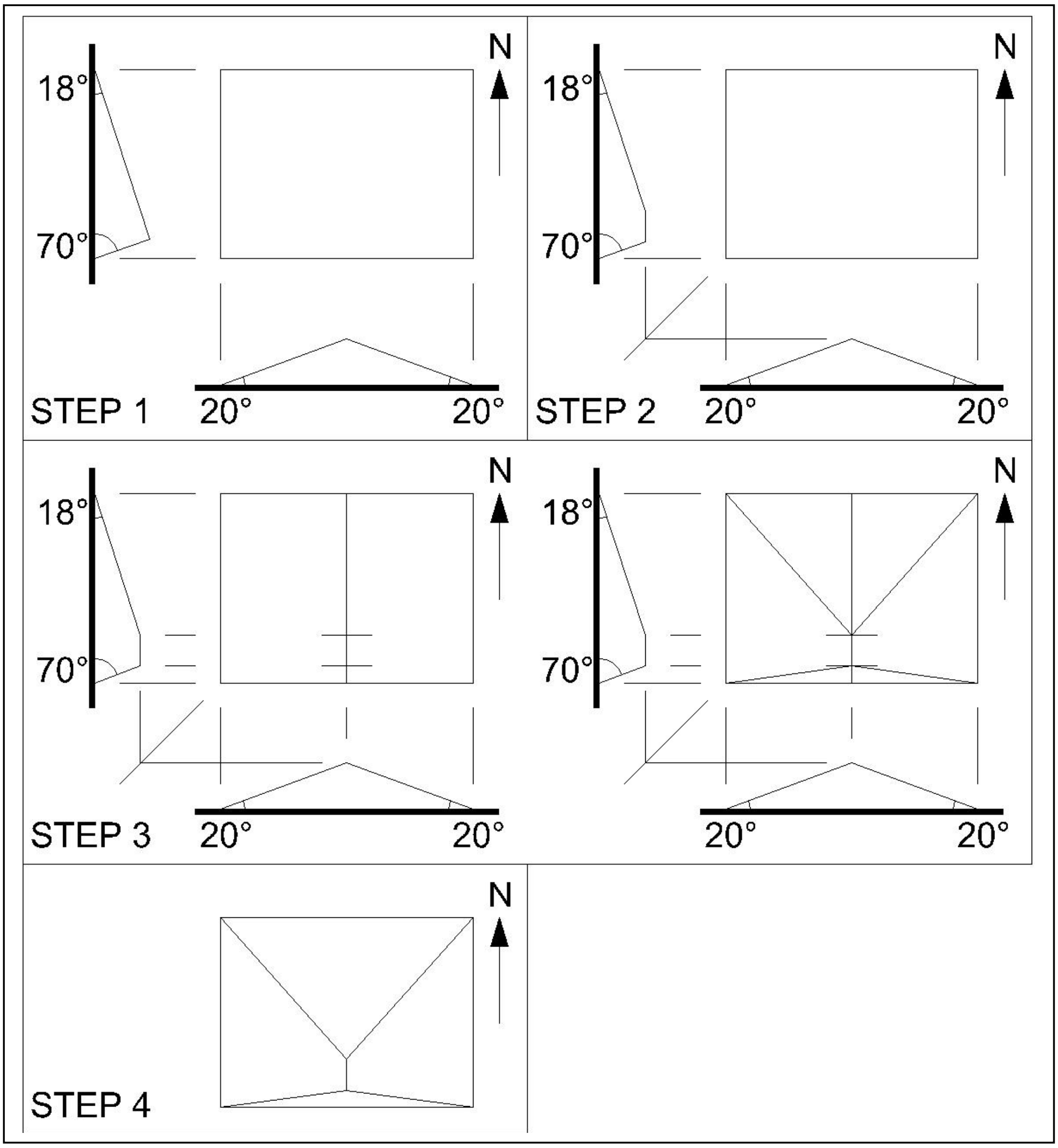
Step 2: Find the Height of the Envelope: Because of the variety of angles that constructed the facades, the heights may be different. For the purpose of obtaining the non-shadowing envelope the lower height will be chosen and the consistency will be supplied.

Step 3: Define the Envelope Ridge and Hips: Carrying the peak points of each façade to the plan drawing, the ridge will be defined. Combining the ridge to the edges, the hips are created.

Step 4: Exhibit the Complete Solar Envelope: After eliminating the guidelines, the top view of the envelope is gathered. Using the height from the façade the three-dimensional envelope can be exhibited.

The envelope has a symmetry axis between east and west facades, which is a result of the symmetry between the morning and afternoon cutoff times according to noontime in December 21st. Other than the change in cutoff times the change in orientation may affect the shape of the envelope. To exemplify such case the same site will be rotated with 20° from south (surface azimuth=20°) (Figure 3.11). So the solar data will result as it is in Table3.5.

Table 3.4. Drafting solar envelope using profile angles



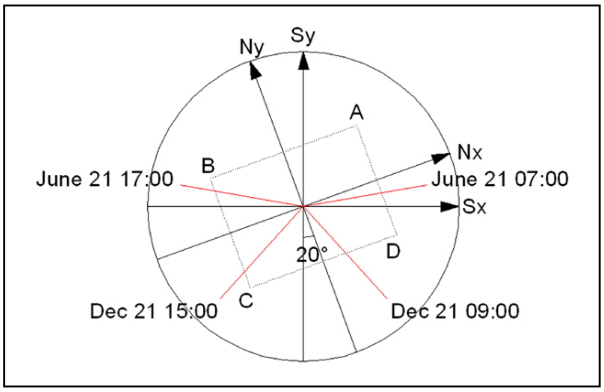


Figure 3.11. Solar angles according to the site

Table 3.5. Angular data of the deflected site

SEASON	APARTURE	SOLAR ALTITUDE	SOLAR AZIMUTH	SURFACE SOLAR AZIMUTH	PROFILE	FAÇADE
WINTER	09:00	14°	42°	22°	15°	AB
					34°	BC
	15:00	14°	318°	298°	28°	AB
					16°	AD
SUMMER	07:00	26°	100°	80°	70°	AB
					27°	BC
	17:00	26°	260°	240°	50°	CD
					30°	AD

Different than the previous example the azimuth angles of the sunrays are changed because of the 20° deflections to east of south. Subtracting 20 from the original solar azimuth the surface solar azimuth angle, which will be used to read profile angles from the sun chart, is supplied.

Step 1: Set the Two Elevations:

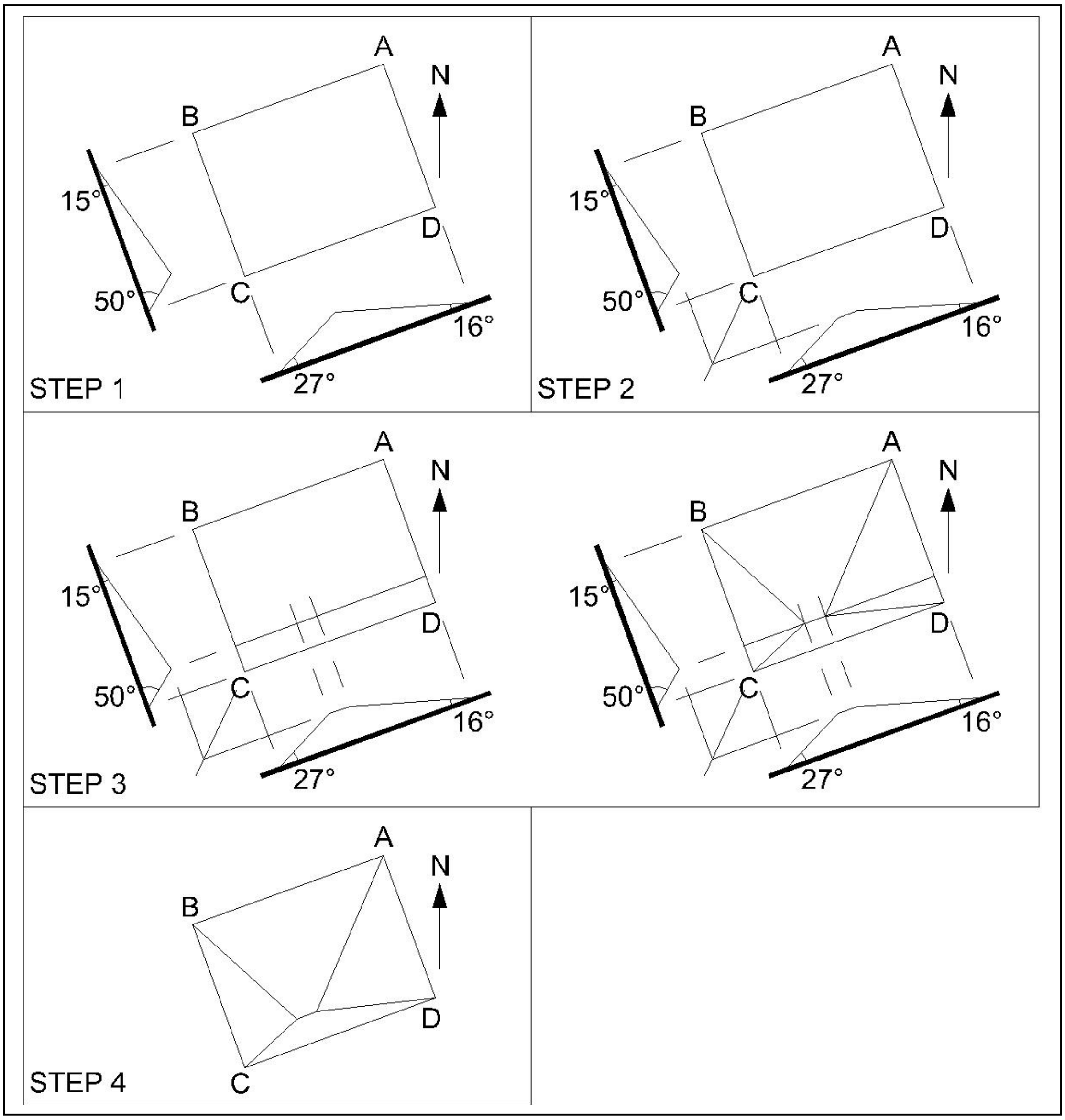
From the table the minimum angles are chosen. As a result the profile angles are AB=15°, AD=16°, BC=27°, CD=50°.

Step 2: Find the Height of the Envelope:

Step 3: Define the Envelope Ridge and Hips:

Step 4: Exhibit the Complete Solar Envelope:

Table 3.6. Drafting solar envelope for a deflected site using profile angles



3.B.2. Computational methods:

Computer soft wares are tools that are used to process mathematical data to accomplish a certain algorithm. Constructing the solar envelope is also an algorithm. Certain popular drafting soft wares easily visualize the solar envelope.

If we briefly fragment the solar envelope generation into two parts, these are data collection and volume visualization. Data collection aims to designate the specific solar angles (azimuth, altitude, profile…) depending on the time and space specifications. In general, soft wares serving for this purpose may be called as digital sun charts some of which will be used in this study to reach precise results (www.susdesign.com).

Volume visualization is a problem of drafting which is familiar to the field of architecture. The developments in the computer hard ware engineering during the last decade in the means of data processing capacity and speed eliminated all the obstacles in modeling and animating architectural designs. These soft wares are generally called CAD applications and various types of them can be sufficient to visualize the solar envelope.

On the other hand, M. Schiler and U. P. Yeh licensed Solvelope, which can convert mathematical data directly into three-dimensional volume, in 1992, in USC. Fundamentally this soft ware processes the space and time data to construct a solar envelope. This time saving tool will be used in the following stages of the study.

Before exemplifying the applications in Solvelope, the algorithm of the program should briefly be stated, to coincide with descriptive method. Solvelope conceives the site as a rectangular grid, to reach a cartesian definition. In the next step the height of every single point of the grid is calculated without casting shadows out of the site. Finally combining the extruded points according to the grid below, solar envelope is constructed. The surfaces of the envelope are defined with series of lines whose projections are the grid stated on site.

Beyond the algorithmic flow, Solvelope processes data under 4 titles: time information, site information, street information, and boundary information.

Remembering the basics of constructing the solar envelope, we can say that first of them consists the time parameters, whereas the others are spatial parameters. As time parameters, the data entered are: month, day, start time, and finish time. The site information consists of; latitude, orientation, site length, and site width. Street information data aims to state the width of the streets surrounding the site. Streets are public areas where the shadows lying on will not break an individuals right of solar access. That's why; the streets around the site enlarge the envelope volume. Boundary information consists of the height of the objects on the defined boundary that are already casting shadows such as fences and walls. Boundary information is also an enlarging factor.

Depending on this data an envelope on a specific day of a specific month will be gathered. But as we know this will be the envelope satisfying one extreme of the annual changes. Entering the data of the other extreme date, with the same spatial information a second envelope can be constructed. Solvelope will intersect these volumes and supply an envelope satisfying the annual needs.

Final envelope can be saved in .dxf format to use in other drafting soft wares. Despite this usefulness and simplicity, solvelope has some disadvantages. It can process only the rectangular sites and surface definition properties are poor. Additionally it should be stated that a sloping site couldn't be studied with this program. To exemplify the results of the program, the site in the table 3.1 will be used to construct summer, winter, and composite envelopes (figure 3.12).

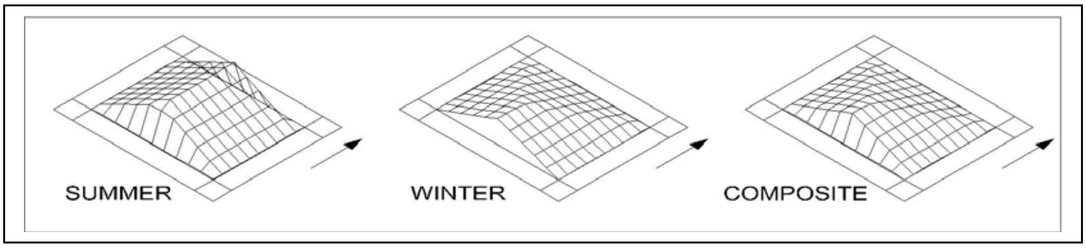


Figure 3.12. Solar envelopes calculated in the Solvelope

More developed software is CalcSolar, which is written in Autolisp by Karen Kansek in USC. The CalcSolar program asks users to input specific data about the site and time constraints; it calculates the appropriate solar geometry values, and outputs the information in the form of a surface portraying the maximum buildable volume given the user's constraints (Noble, and Kansek 1998, p.120).

Two graphic and a minimum of seven numeric values are input. A plan of the land parcel is drawn with north oriented along the positive y-axis in AutoCAD. The user can input sites that are not aligned with the cardinal points. The site must be a closed, rectangular, non-sloping polyline. Then the user draws three-dimensional polylines; these lines (open or closed) may vary in x, y, and z dimensions and represent the shadow-boundaries of surrounding, protected areas. After the two graphic inputs, the program then prompts for numerical information. Fineness of the mesh, height limits, latitude, month, day, start time and ending time are the other numerical inputs to be entered.

This program has two major advantages over earlier approaches. First, it helps visualize the effects of solar zoning; this is especially useful to designers interested in the formal qualities of an urban landscape. And second, it allows early testing of the consequences for density and floor-area ratios of alternative solar-access policies; this is particularly helpful to planners interested in manipulating time and space constraints with a view to matching the largest buildable volume with existing land values. In addition, the results often provide a strong argument that allowing solar access to others does not necessarily diminish buildable volume (Noble, Kansek 1998, p.120).

3.C. EXAMPLARY WORKS:

In this section, the application of solar envelope in building design for different urban contexts will be exemplified. First two of them are examples from Los Angeles, which are in different urban contexts, sizes and densities. These differences cause changing the rules of solar envelope generation, which will be mentioned in each example. The third is an example of analyzing the solar rights performance of an urban housing in Florianopolis of Brazil.

3.C.1. The Wilshire Housing Project:

This is an urban project developed under the supervision of USC in Los Angeles. Data, photos, and figures are taken from “Sun, Rhythm, Form” of Knowles (Knowles 1981, p.234-244). In the case of this project envelopes are defined by sites own boundaries, rather than by adjacencies. Its design concerns are internal; the design of the site is not dependent on another.

The program for design focuses on three primary objectives, consistent with maximizing development potential and assuring pleasant living environments: (1) to provide maximum number of dwelling units, preferably 40 to 60 dwelling units per acre; (2) to provide a living environment with good qualities of sunlight and cross-ventilation with private and shared open space for each unit; and (3) to minimize shadow and to protect the privacy of adjacent single-family houses.

Properties of the site are:

1- several vacant land parcels in close proximity to one another are under extreme pressure for development.

2- the parcels front on or relate to Wilshire Boulevard, which has become an important transit link between downtown Los Angeles and the city of Santa Monica on the ocean. Throughout its history, this boulevard has been the location of prestigious apartment and commercial structures, ranging in height from 1 to 20 stories.

3- the land parcels are surrounded by single-family housing of high quality, and the residents of the area are adamantly opposed to high-or even medium-density development, particularly commercial development. At the same time, developers are exerting enormous pressure on the city planners to allow relatively high-density housing, commensurate with land costs.

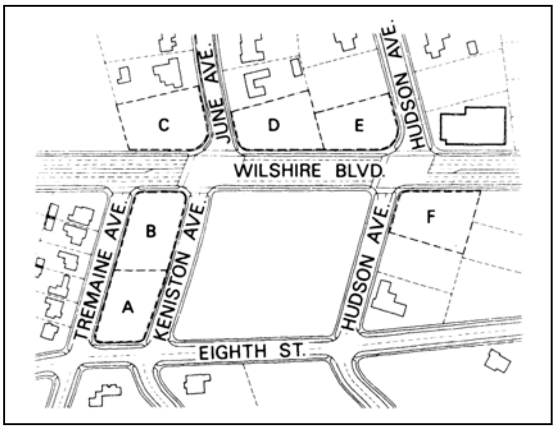


Figure 3.13. Site Plan of Wilshire Housing (Knowles 1981, p.235)

Conditions for generation of envelope are: all edges are the same with reference to an 8-ft. privacy fence (This results in shadowing equivalent to that from a one and a half story detached single-family house with the usual side yards.); public rights-of-way are shadowed; solar access to each site is provided throughout the year from 9 A.M. to 3 P.M. final envelopes are shown in the figure below (Figure 3.14).

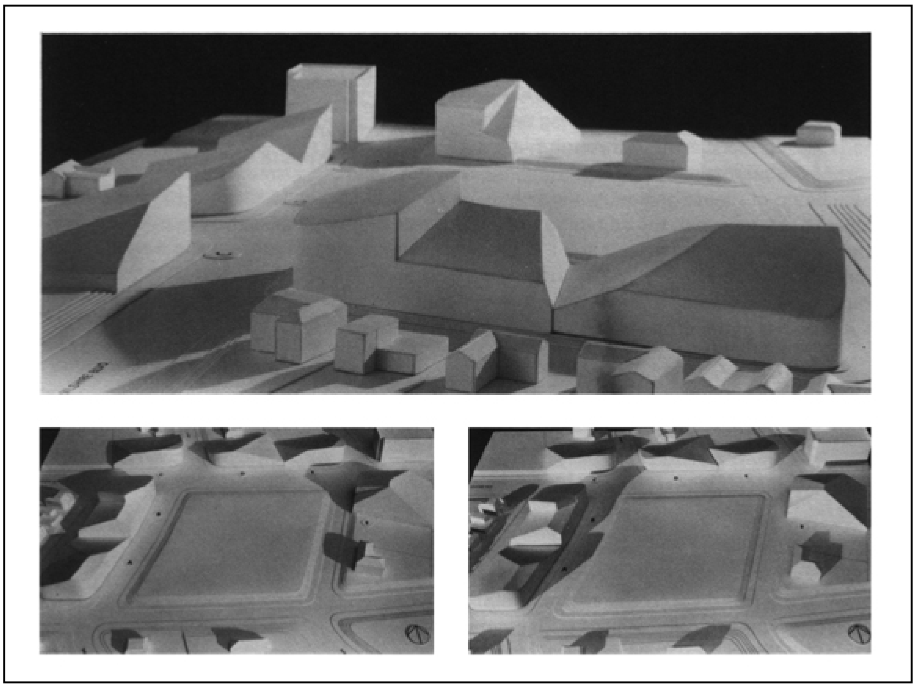


Figure 3.14. View from west 9 A.M. Winter (top), view from south 9 A.M. winter (below left), 3 P.M. winter (below right) (Knowles 1981, p.236)

For the site C designer Janette Quon, arranged two rows of units parallel to Wilshire so that each has south exposure. As the southern units rise to fillthe envelope’s greatest height, the courtyard also broadens, thus assuring sunshine on the back row. This fortuitous relationship of building height to area of shadow is the automatic result of the envelope’s proportional relationship to site dimensions. Twenty-five units are included in this design for a density of 42 dwelling units per acre. A second designer, Paul Gutierez under the same envelope follows a different strategy that provides less south exposure, but greater density. Almost all units are arranged in three north-south rows instead of two east-west rows. By a combination of clerestories and terraces, some south exposure has been provided to every unit, but the rows of units have major east and west exposures. While this orientation does not have the energy-conversion advantage of a south exposure, it does offer development advantages. Twenty-nine units are included in the complex for a density of 48 dwelling units per acre (Figure 3.15).

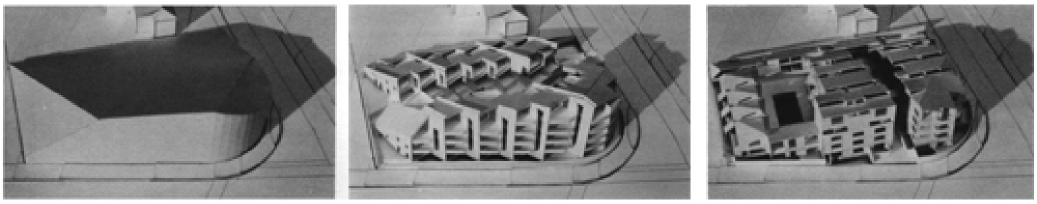


Figure 3.15. View from south 3 P.M. winter envelope, Qoun proposal, Gutierez proposal (Knowles 1981, p.239-241-242)

In the case of site B, the envelope, as it faces north to Wilshire, is relatively high because shadows may extend quite far. Across Tremaine to the west are single-family residences that must be protected; a similar condition, for future development, occurs across Keniston to the east. These two situations require that the envelope's southern portions be dropped below the northern portion. Michael Gehring’s project includes 32 units, for a density of 58 dwelling units per acre, a characteristic number for sites to the south of Wilshire, where envelope bulk is greater than it is on the north.

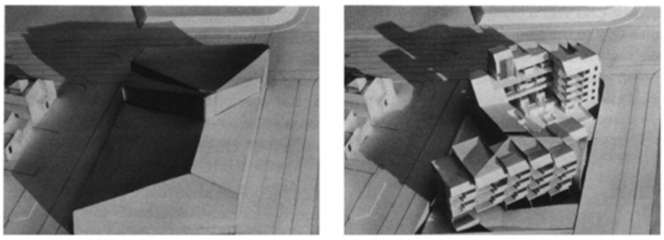


Figure 3.16. View from south 9 A.M. winter, envelope, Gehring, proposal (Knowles 1981, p.243)

Different proposals on the sites are applied under the same envelopes. In Table3.7 their performances are compared under 4 titles; dwelling unit densities achieved, average size of dwelling units, on-site parking and open space characteristics.

Table 3.7. Building and development data for prototype design studies of multifamily condominium housing on six land parcels (Knowles 1981, p.251)

Development Parcels			**a- Dwelling Unit Densities Achieved**				**b- Average Size of Dwelling Units**		**c- On-Site Parking**	**d- Open Space Characteristics**	
Site No.	Area (sq.ft.)	Area (acres)	Designer's name	Total no. of DUs	Land coverage (as % of site)	DUs (per net acre)	Enclosed space (sp. ft.)	Outside space (sq. ft.)	Average stalls per DU	Total open space (sp. ft.)	Total space (as % of site)
A	22,430	.51	Alonzo	25	54	49	1,540	380	1.9	17,700	69
			Myers	30	62	58	1,270	250	1.6	16,300	67
			Pica	26	48	50	1,270	250	1.6	20,200	89
B	23,970	.55	Gehring	32	43	58	1,180	145	1.9	18,000	75
C	26,000	.60	Aguilar	27	55	45	1,200	240	2.3	14,600	56
			Gutierrez	29	50	48	1,080	370	1.9	18,400	70
			Quon	25	52	42	1,350	330	1.8	19,700	75
D	23,700	.54	Liu	22	55	44	1,310	320	2.4	18,100	76
			Stockus	27	65	49	1,360	300	2.1	13,700	56
			Sullivan	26	70	50	1,280	360	2.2	13,600	57
E	20,000	.46	Marquez	25	65	54	1,240	330	1.8	10,800	54
			Stockwell	25	59	54	1,180	180	2.4	10,400	52
F	23,960	.55	Kearns	30	50	55	1,160	270	1.8	17,000	71
			Lisiwicz	40	55	73	1,200	130	2.0	17,200	72
			Wallace	27	65	49	1,280	230	2.3	15,100	68
Averages for all sites	**23,340**	**.535**		**28**	**56**	**52**	**1,260**	**272**	**2.0**	**16,000**	**67**

a. Land coverage is based on building bulk above grade and excludes subterranean parking and building overhangs above the first floor.

b. Program requirements specified a mix of unit sizes, ranging from efficiency to 3-bedroom units, and all units were specified to have some private outside space: decks, balconies, or patios.

c. All parking was placed below grade and conformed to current Los Angeles zoning requirements for on-site parking.

d. Total open space includes private outdoor spaces as well as courts, walkways, and setbacks.

3.C.2. The Bunker Hill Project:

This is an urban project developed under the supervision of USC in a denser district of Los Angeles. Data, photos, and figures are taken from “Sun, Rhythm, Form” of Knowles (Knowles 1981, p.234-244). Bunker Hill is connected to the older, established parts of Los Angeles, as well as to the more recent commercial burgeoning of the area. Large hotels, office, and commercial complexes are turning the area from an underdeveloped district into the most vital part of the city.

Program: A preliminary program for the nine-acre site was made available to the University of Southern California by the CRA (Community Redevelopment Agency) in the fall of 1979. A similar program later became the basis for a competition among five invited developer-architect teams.

1- The mixed-use program called for a total developed area of 3.0-3.9 million sq. ft. (not counting parking, which needed to be on site) on a land area of 393,000 sq. ft., or nine acres. Of the total developed area, the CRA called for 70 percent in commercial and retail (2.1-2.7 million sq. ft.) and 30 percent in housing (0.9-1.2 million sq. ft.), or about 800 to 1,000 dwelling units. In addition, there was to be a museum of about 100,000 sq. ft.

2- Land coverage was not to exceed 60 percent of the site, or 5.4 acres. Of the remaining 3.6 acres, 1.5 acres was designated a public park.

3- The competition program also called for energy-conscious design; and, as an aspect of that concern, the CRA became interested in the studio results of the Bunker Hill Project at USC and consequently included solar access as a factor in the evaluation of final entries.

Properties of the site are:

1- The Bunker Hill site is in a key location, with major downtown shopping to the south, the music center to the north, and the civic center to the northeast. All of these are within a few blocks of the site and thus within walking distance.

2- The slope of the site is pronounced. The grade falls generally from high on the north to about 35 ft. lower on the south.

3- The properties immediately surrounding the site vary in two ways. First, buildings occupy not all of them; therefore, a degree of uncertainty exists about future development along the perimeter. Second, adjacent land uses are varied. Some existing and proposed buildings are major commercial structures. Some housing in the 12-story range is already under construction. And the CRA has proposed additional housing ranging from 3 to 30 stories.

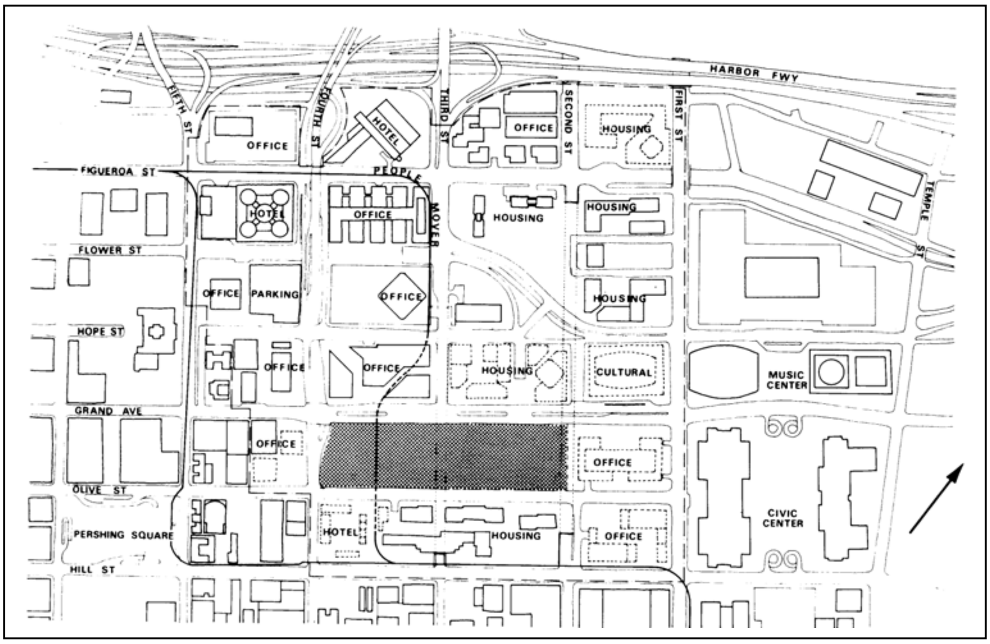


Figure 3.17. Redevelopment area map (Knowles 1981, p.259)

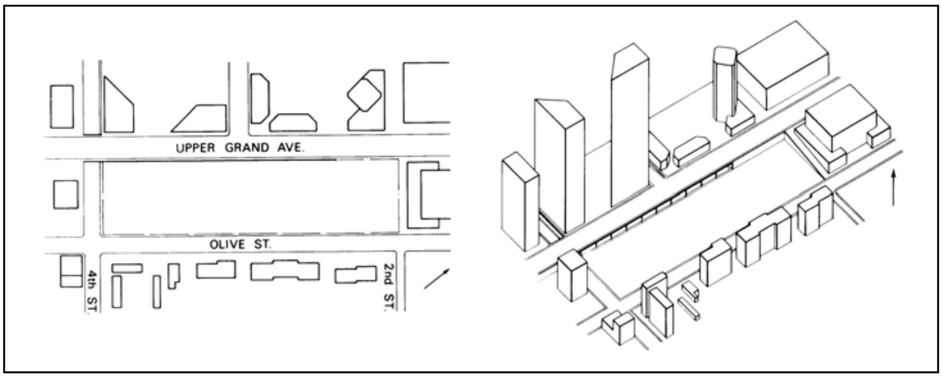


Figure 3.18. Site and immediate surrounding (left), View from south (right) (Knowles 1981, p.260)

Envelope generation rules:

Following the rule of least shadow on housing and most on commercial office buildings, a general picture of acceptable shadows emerges. Thus, the rules for envelope generation make distinctions in the magnitude of acceptable shadowing of surrounding properties.

So the applied rules are:

1- Whole site access, above 20 ft at the property line, is required to protect the housing on the southeast.

2- Only roof top access is required for the most other buildings.

3- Commercial office buildings may be shadowed to 33% of their window wall areas; buildings with less than 10% window area are assured only roof-top-access (Hotel is commercial building; commercial and government buildings have less than %10 window area).

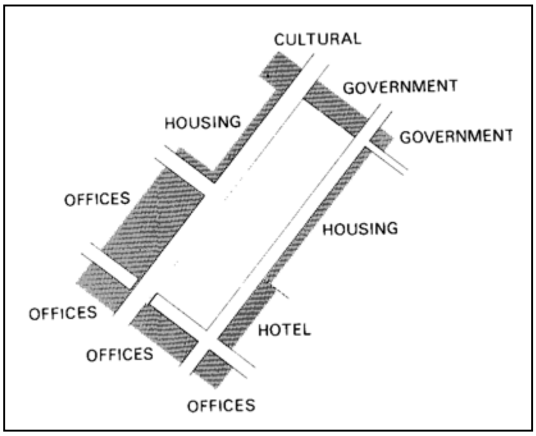


Figure 3.19. Diagram of acceptable shadows (Knowles 1981, p.262)

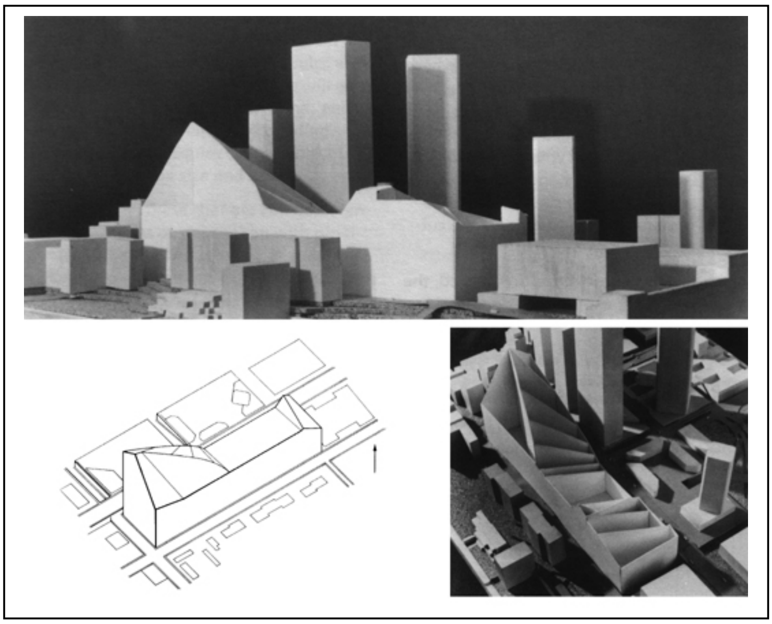


Figure 3.20. View from east; 9 A.M., winter (top), view from east; 12 noon winter, envelope showing the generation planes (down right) (Knowles 1981, p.263-265)

Building designs:

To satisfy the public policy constraint, the envelope shape must match the surrounding scale. To satisfy the option of solar energy and environmental quality, the designer must work within the envelope. The designer's option, rather than the policy constraint, inflicts the greatest development price on Bunker Hill. Three of the proposals are shown in the Figure 3.21.

Figure 3.21. Views from south; 9 A.M., winter, proposals of Robert Tyler, James House, Randall Hong (Knowles, 1981; p.276-280)

3.C.3. Florianopolis Project:

The main purpose of the study is to systematize the application of the solar envelope. Approach is analyzing the existing urban context with principles of solar zoning, rather than applying them to developing area, as it is done in previous examples. Method consists of evaluating the results of conventional zoning policies by superimposing them with the results of solar zoning principles. Data and figures are supplied from an article entitled “A Methodology for Sunlight Urban Planning: A Computer Based Solar and Sky Vault Obstruction Analysis” (Pereira, Silva and Turkienikz 2001, p.217-226).

The objectives of the study are; to allow the evaluation of the impact on insolation conditions of buildings that go beyond the envelope limits and to apply the solar envelope in areas subjected to development.

The drawings from Figure 3.22 present the current situation. The plot subdivisions were defined as each building had its own plot and had been located by the adoption of equal set backs between buildings.

The Solar Envelope application follows the recommendation suggested in the present study it consists of plot-by-plot application, based on a horizontal plane

2m above the ground level. In the cases where the buildings face a street, the adopted envelope limit is the plot in the other side of the street. In this way, the example in Figure 3.22 is simulated with Module 1 (figure 3.23).

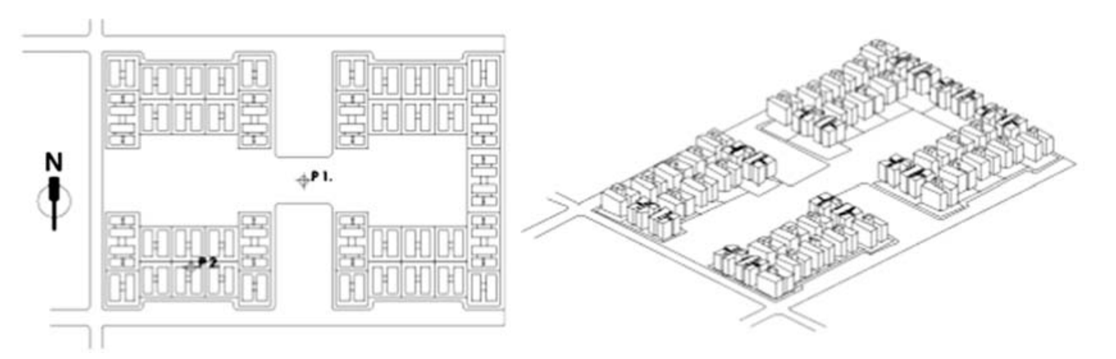


Figure 3.22. Drawings showing the existing situation (Pereira, Silva, and Turkienikz 1998, p.223)

The volumetric difference between the current situation and the one allowed by the Solar Envelope becomes clear when the 3D models are superimposed. The building volumes go beyond the envelope limits, which mean an inadequate condition in terms of insolation and sky vault obstruction (Figure 3.23).

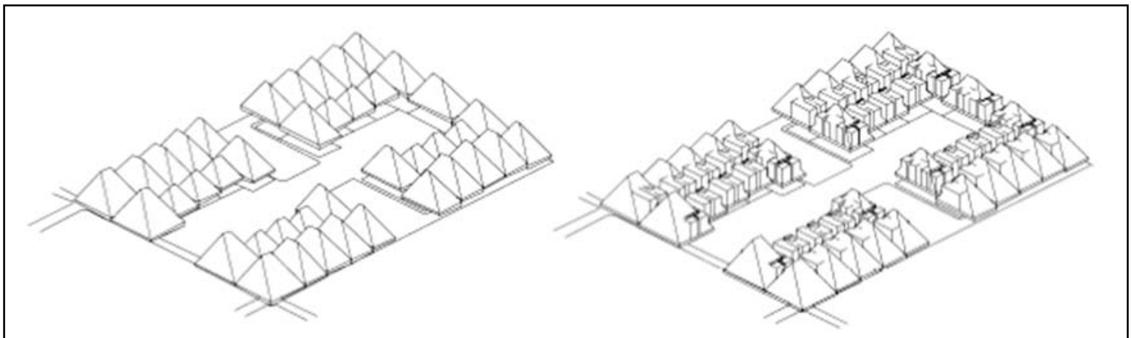


Figure 3.23. Drawings showing the solar envelopes and the superimposition of them with existing blocks (Pereira, Silva and Turkienikz 2001, p.223)

For the exemplifying an analysis through the Obstruction Masks method, a reference point between buildings was adopted (Figure 3.24). A computational code called MascaraW, which is compatible with other softwares on the basis of DXF files, is used to simulate the obstruction masks. The result from the computer simulation confirm the analysis done in Figure 3.23, besides showing the efficiency of the Solar Envelope as an insolation regulation tool. The application of the Solar Envelope produces important gains in terms of insolation and sky view, mainly during winter months, where solar heat gain is desirable (Figure 3.24).

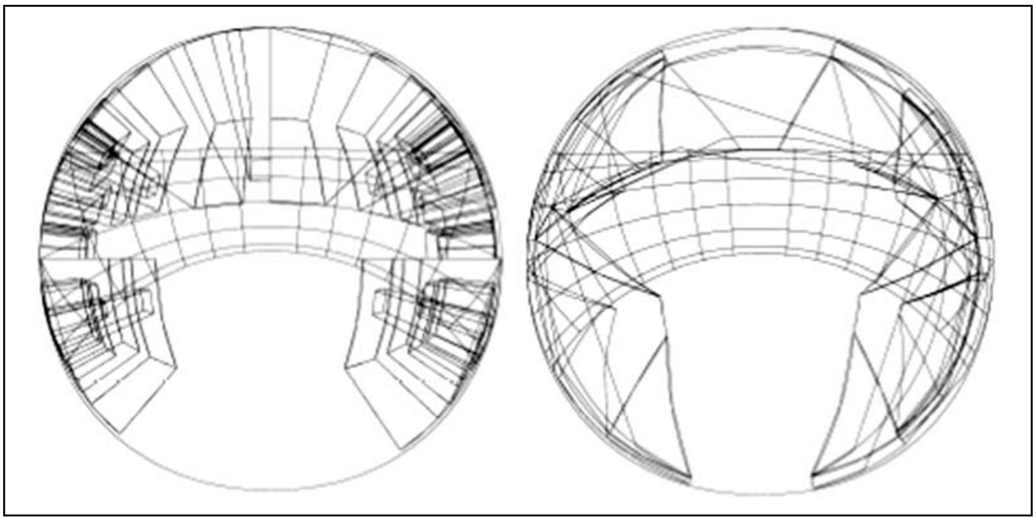


Figure 3.24. Building obstruction mask (left) and envelope obstruction mask (right) are seen by the façade P2 (Pereira, Silva, and Turkienikz 2001, p.224-225).

CHAPTER 4

CASE STUDY ON ODTÜKENT RESIDENCES AT METU CAMPUS

Considering Solar Envelope as a technique, which gives assistance to creation of architectural and urban form, with the help of solar rights consciousness we can define two separate fields of applications. One of them is to use solar envelope to guide the development as we observed in sections 3.C.1 and 3.C.2. In such applications solar envelope becomes a concretization of environmental effects, which directly influence the design process. Another application is to use solar envelope as a parameter to evaluate the performance of a design in its context. Such an approach is exemplified in chapter 3.C.3.

In this chapter an analytical study will be developed on Odtükent dwelling units at METU campus. An evaluation on the results of the former development principles with the help of proposed solar rights considerations will be beneficial to the future development attempts. As being a negotiable issue with the market constraints, land uses and environmental concerns in one frame, solar rights considerations can be tested with this key study.

Three-dimensional models of the existing context and the results of the solar envelope studies will be constructed during this study. The super imposition of these two will give us the chance of making comments on solar rights performance of the site.

4.A. ODTÜKENT:

Odtükent, which consists of residences for academic staff, is a part of the development project of METU campus that is found in 1956 and serves for 18.000 students recently. It is on the west of the overall campus site (Figure 4.1).

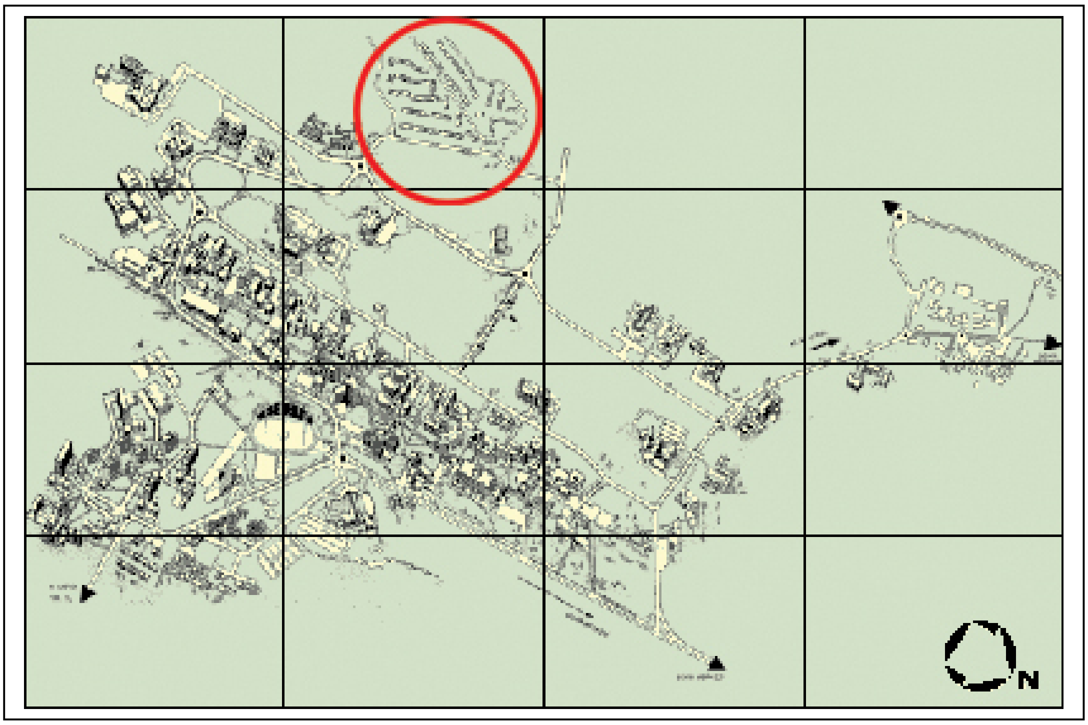


Figure 4.1. Schematic map of existing METU Campus (http://www.metu.edu.tr)

Project aimed to answer the increasing dwelling needs of academic staff with a satisfying level of spatial quality and comfort both in the levels of architectural and urban design. Baykan Günay realized urban design of the first stage of project, which was changed depending on the changes in production model (Figure 4.2 – 4.3). Gönül Evyapan and Erhan Acar developed primary steps of the architectural design. Erhan Acar completed application stage designs. At this stage Kadri Atabaş supported the project. ODTÜ-Kent is a project, realized with the contributions of members and students of METU Faculty of Architecture (Güzer 2001, p.53).

Site is placed in a loop and situated on a north-facing slope, which creates a height difference of roughly 22m in 380m (%5,8). Generally north slopes are not ideal sites in the means of energy conversion.

There are two different dwelling types that are 2 or 3 stories of row houses and 3 or 4 stories of apartment blocks. There are 130 row houses, which contains 1 or 2 dwelling units, where as there are 12 apartment blocks that roughly contains 132 dwelling units. These blocks are arranged on two different grid orientations deflecting with 60º and 15º from north-south line (Figure 4.4).

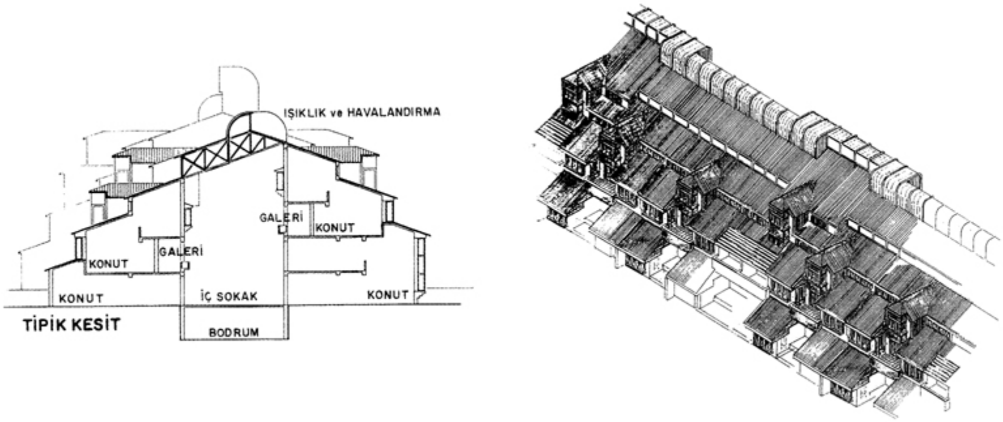


Figure 4.2. Typical section and axonometric projection of the unrealized inner street, proposed in the early stages of the project (Güzer 2001, p.52)

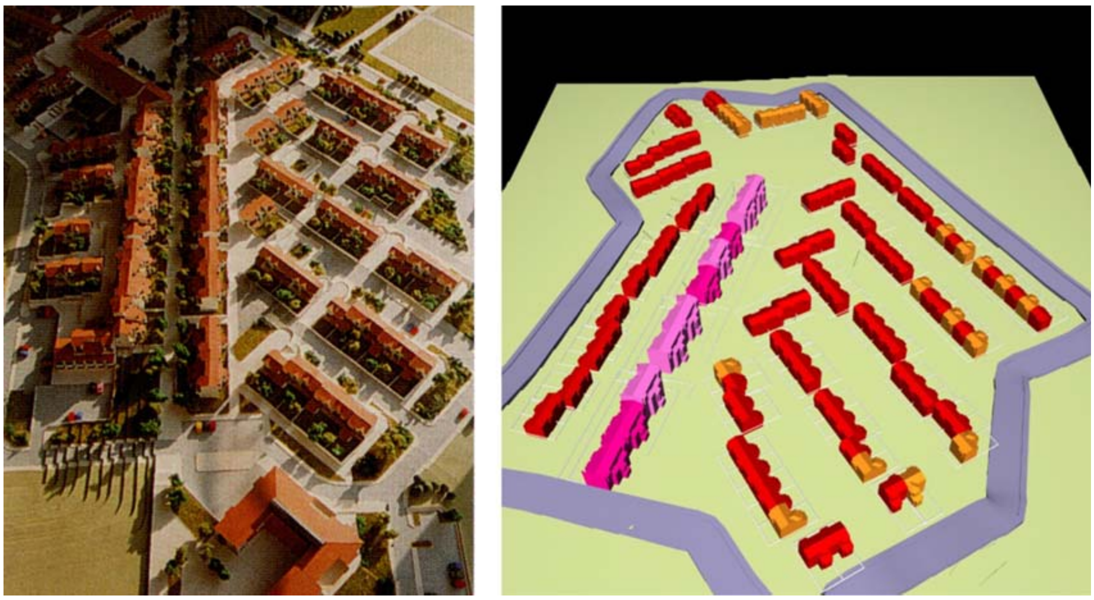


Figure 4.3. Unrealized model for the first stage of the project is shown on the left (Güzer 2001, p.52). Abstract computer model on the right shows the existing situation

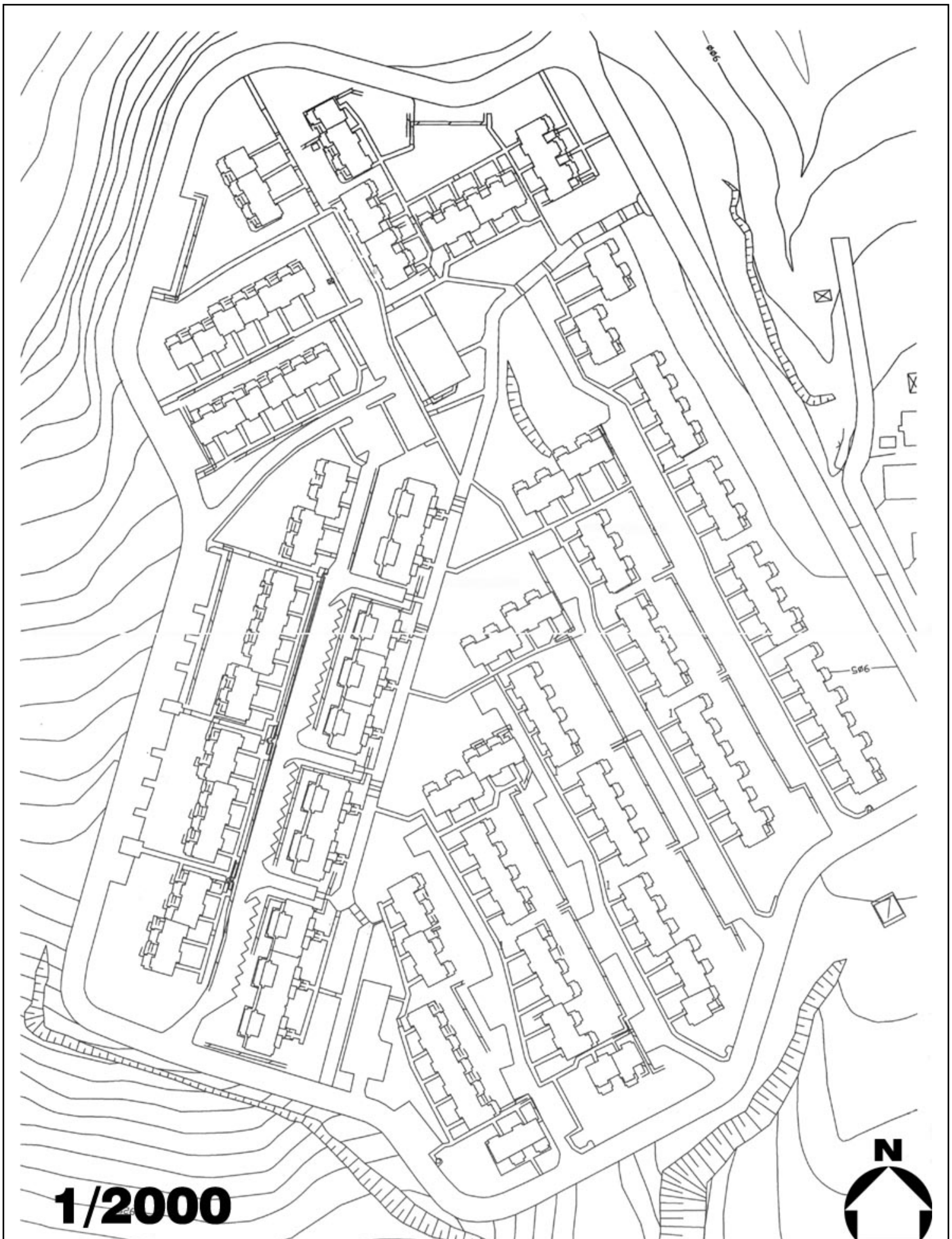


Figure 4.4. Plan of the overall site (by METU department of construction works)

During the study, three-dimensional models are used to represent the proposed solar volumes to satisfy the proposed insolation needs. Every building unit is modeled in abstract three-dimensional form where as the envelopes are in two-dimensional frames (Figure 4.5). Terrain is assumed to be in its natural form because of the still developing landscape applications. Other landscape elements, such as trees, perimeter walls and supporting walls are considered neither in modeling nor in solar envelope generation. Row houses are placed on ground levels that are proposed in design stage and solar envelopes of them are modeled according to the slope. Apartment blocks' sites are considered to be flat on ground levels specified in projects.

Figure 4.5. Picture on the left is the existing situation (Güzer 2001, p.54) and the abstract models produced by the author are in the middle and on the right

4.B. RULES FOR ENVELOPE GENERATION:

Because of the low-density character of the site the rules for generating the envelope are very close to the ideal conditions. FAR's (floor-area ratio) are between 1-1.3 for row houses and 1.4-1.5 for apartment blocks. If we consider the density of urban districts of Ankara as 4-5, these ratios are relatively low. That's why the solar rights principles are set under two titles:

1. Spatial rules: The most decisive property that should be mentioned is the latitude as a spatial character of the site. Ankara is on 40º northern latitude.

As we mentioned before any landscape elements, privacy walls are neglected because of being under construction. Buildings are allowed to shade the roads defining their territory. For this reason the short sides of the row houses that are not designated by a road are decided to limit the solar envelope. But on the other hand the long sides that are not attached to another, are allowed to cast shadow till 5m, which is the distance that is used to separate the groups of row houses. Different than the row house villas, the parcels of the apartment blocks are defined by the environing pedestrian and motorways. So the envelopes of these 4 parcels are permitted to exceed till 4m on northwest, 7.5m on southeast and northeast, 15m on southwest, and 5m on the pedestrian roads separating these parcels.

A very important spatial constraint that affected the envelope volume is the attached character of the row houses. That's why for every site the longer sides assumed to be occupied by 6.6m of walls, which is equal to the height from the ground level to the slab under the roof structure. The height of the ridge is not preferred because of the possibility of being variable. This height is very decisive for the envelope to be constructed and most generally created the image that it satisfies the needs of solar rights but if we think that sidewalls suppositions and they guarantee some amount of shade, we understand price of poor insolation.

In case of apartment blocks that are also seemed to be in the row character this is perceived as the trial of standardization. So the envelopes are structured as one envelope for every single parcel. Assumptions of walls constructed between these taller buildings may cause bigger envelopes, which may be charming in first glance. But the increasing volume will cause a decrease in surface volume ratio, which is preferable for energy conversion principles but not so good for spatial quality (www-rcf.usc.edu).

2. Time rules: These are composed of daily and yearly limits of desired solar insolation. In other words to make an evaluation on solar rights performance we should decide which insolation is a right for the inhabitants of the site. This is at the same time may be called the finding the useful insolation for this specific site.

As we clearly know, the annual limits of the northern hemisphere are 21st of December and 21st of June (equinoxes). On the other hand to define the daily limits we should check the hourly insolation values of Ankara according to months (Table4.1.). Specifying the solar azimuth and solar altitude angles gathered by matching the cut-off times supplied from hourly insolation values with the equinox dates will be completion of the necessary data to construct the solar envelopes of the site.

Cut-off times: is the time interval that is specified as useful insolation. According to the hourly insolation values table of Ankara 7 months are under-heated (October-April) and 5 months are over-heated (May-September). So considering under-heated period as winter times and over-heated period as summer, we can make some comments to decide the cut-off times.

To optimize the solar energy supplied, the symmetric intervals according to noontime are preferred like 9-15 or 10-14. For 9-15 interval a vertical façade facing to south gains 92% of the energy available in winter and 67% in summer. Winter energy gain seems magnificent but in summer the shading necessity occurs in a serious level. Another interval 10-14 performs as gaining 70% of the available energy in winter and 53% in summer.

Table 4.1. The total radiation on a south facing vertical façade at 40º N Latitude (Watt/m²) (Demirbilek 1982, p.40)

MONTH	HOUR	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	U	O	TOTAL
JAN	**U**				230	550	750	850	890	850	750	550	230				5650		5650
	O																		
FEB	**U**			40	350	580	740	840	860	840	740	580	390	40			6000		6000
	O																		
MAR	**U**			120	340	515	660	750	780	750	660	515	340	120			5550		5550
	O																		
APR	**U**		15	60	230	390	520	600	640	600	520	390	230	60	15		4270		4270
	O																		
MAY	**U**	5	30	65	150	290	400									5	945		3540
	O							480	500	480	600	290	150	65	30			2595	
JUN	**U**	10	35	70	95	250											460		2970
	O						350	430	450	430	390	250	95	70	35	10		2510	
JUL	**U**	5	30	65													100		3540
	O				150	290	400	480	500	480	600	290	150	65	30	5		3440	
AUG	**U**		15	60													75		4270
	O				230	390	520	600	640	600	520	390	230	60	15			4195	
SEP	**U**			120	340	515	660										1635		5550
	O							750	780	750	660	515	340	120				3915	
OCT	**U**			40	350	580	740	840	860	840	740	580	350	40			5960		5960
	O																		
NOV	**U**				230	550	750	850	890	850	750	550	230				5650		5650
	O																		
DEC	**U**				150	510	730	830	870	830	730	510	100				5260		5260
	O																		
																TOTAL	41555	16655	58210

U Denotes Underheated period and O Denotes Overheated Period

In comparison, R. Knowles advices 9-15 intervals for the city of Los Angeles, which is on 34° northern latitude. This interval supplies 77% of winter insolation and 45% of summer in Los Angeles (Knowles 1981, p.248). Because of the latitude difference we naturally cannot reach similar insolation values in Ankara but with a tolerable amount of shading necessity and considerable amount of winter insolation 10-14 intervals is suitable for Ankara. 70% winter insolation promises 4 hours of unobstructed solar access in the coldest days of the winter during when the average direct insolation period is 4 hours and 57 minutes in winter months (Meteoroloji Bülteni 1974, p.665).

Finally the solar azimuth and altitude angles results as follows:

Table 4.2. Angular data of Odtükent

SEASON	APARTURE	SOLAR ALTITUDE	SOLAR AZIMUTH
WINTER 21st of December	10:00	20°	30°
	14:00	20°	330°
SUMMER 21st of June	10:00	60°	66°
	14:00	60°	294°

4.C. GENERATION OF ENVELOPES:

Even though we have specified the rules of envelope generation, there still is an ambiguity about this site. The question is; do we have to construct a single envelope for a single block or envelope for separate group of blocks including 2 to 6 attached blocks. Deciding this will affect the shape and size of the parcel, which will affect the final volume as we mentioned in previous chapters.

When we start constructing the solar envelopes, two different approaches will be shown, which will be called as approach A and approach B. Approach A will try to construct one envelope for one parcel, which belongs to one block of row houses. Second one will construct the envelopes once for every group of row houses that are attached each other, but separated from others with 5m wide pedestrian roads. First approach is dominated by being attached and resulted with almost uniform envelopes for every block staying side to side, whereas in the second the generated volume will be divided according to the planimetric divisions of the parcels, which means that every parcel will have different volumes.

4.C.1. Generation of Envelopes with Approach A:

Mainly Odtükent site is organised on two different grid orientations. These are 60º and 15º deflected from south grids (Figure 4.4). Dwelling units are organised in mainly two types of buildings; 2-3 story row houses and 3-4 story row apartments. On the 60º grids there are only row houses having very similar dimensions, but according to their orientation there are two types of sites in the means of resulting with different totally different solar envelopes. On the 15º grids there are similarly oriented row houses and apartment blocks. So finally we can say that the primary work to be done is to construct mainly three different envelopes (Figure 4.6).

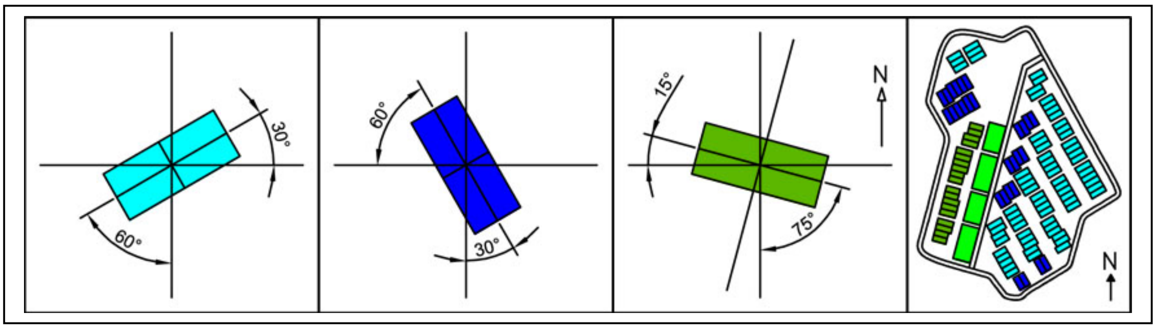


Figure 4.6. Characteristic sites according to their orientations

It should be mentioned that solar envelope couldn't easily be standardised for a number of parcels especially for a site showing different slope characteristics. Indeed almost every single parcel has its own envelope. But technically it is not possible to make detailed comments on every single parcel although it is necessary to reach a convincing level of adaptation to environment. For this purpose all the parameters are taken into consideration to reach the envelopes to model the site with proposed envelopes. But in this stage only four of the envelopes are going to be constructed with the vertical plane method (Descriptive method) of Knowles.

4.C.1.1. 60º west of south: This site is the one having south facade deflected with 60º to west. As a method descriptive vertical planes will be used and later on the effects of being attached will be added. Dimensions are 8.3m to 20m.

Step 1: Use Winter Cut-off Times:

The winter morning rays (10:00 winter; α = 20°, θ = 30°) (Figure 4.9) approach the site across its southeast boundary. Planes located at those boundaries and cut to precisely intersect the sun's rays as they enter over the site cast shadows to the opposing northwest boundary. The winter afternoon rays (14:00 winter; α = 20°, θ = 330°) (Figure 4.9) approach the site from the southeast and southwest. Planes located at those boundaries are shaped to cast shadows to the opposing northeast and northwest boundaries.

Step 2: Use Summer Cut-off Times:

The summer morning rays (10:00 summer; α = 60°, θ = 66°) (Figure 4.9) approach the site across its northeast and southeast boundaries. Vertical planes at those boundaries are shaped to cast shadows to the opposing southwest and northwest boundaries. The summer afternoon rays (14:00 winter α = 60° θ = 294°) (Figure 4.9) approach the site across its southwest and northwest boundaries. Vertical planes at those boundaries are shaped to cast shadows to the opposing northeast and southeast boundaries.

Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

The combination of summer rays slopes across the site to strike the northwest and southwest boundaries in the morning, the northeast and southwest boundaries in the afternoon. The combination of winter rays slopes across the site to strike the northwest boundary in the morning, the northwest and northeast boundaries in the afternoon. The planes intersect at different heights across the site.

Step 4: Combine Effects of the Summer and Winter Cut-off Times:

In order to satisfy both summer and winter insolation needs in one volume, we will take the minimum angles for each façade. Northeast and northwest planes and the ridge between these facades will be constructed according to the winter envelope. Southwest and southeast facades and the ridge between them will be taken from summer envelope. The envelope constructed will not be carrying the effects of being attached.

Step 5: Combine Effect of Walls on Long Sides:

These walls, which are shown in blue colour in the chart above, are abstract and used to construct the final envelope. They are on 6.6m height. These walls are added to the envelope but the bottom lines on the northeast and southwest facades will be protected as they are constructed previously. The planes on these facades will be extended until they reach the 6.6m height adjacent walls. As we see on the figure 4.7 these planes reach each other over the 6.6m walls. From that point we can start protecting the rights of the adjacent sites. For this purpose we carry the planes on the northwest and southeast sides of the site that are drawn during the construction of the original envelope. These planes will be placed over the adjacency walls. Intersecting the four planes the effects of the sidewalls will be added to the envelope.

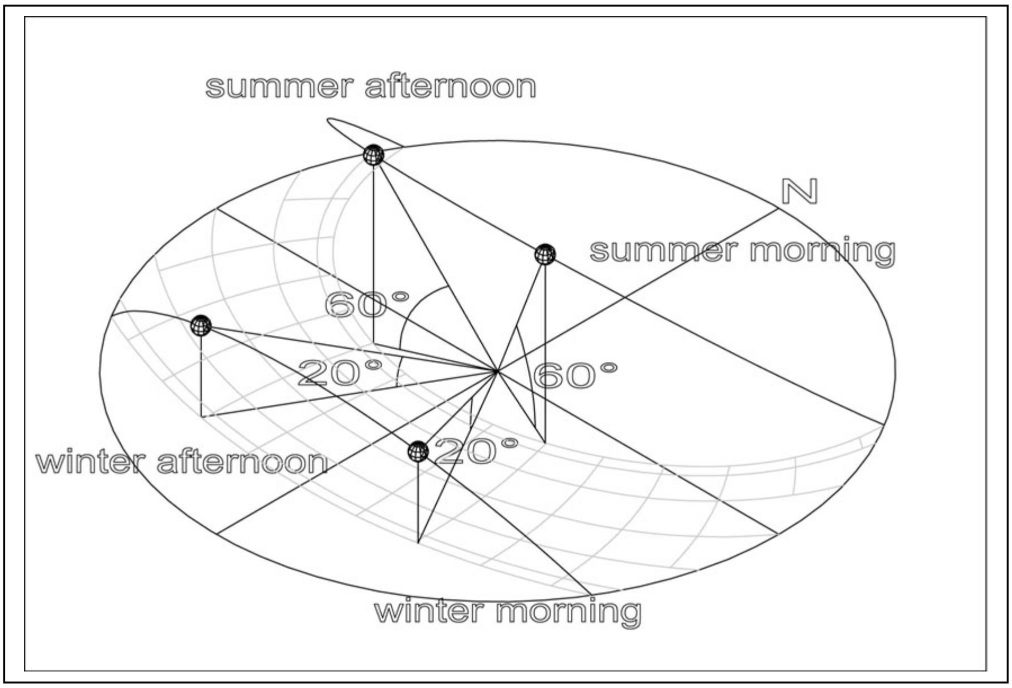


Figure 4.7. Planes of sunrays in winter and summer cut-off times

Step 6: Additional Comments on the Effect of the Cut-off times:

Before finalising the process of solar envelope generation, we should mention one more effect, which aims to make use of the sites attached ness to reach the optimum solar envelope. While we were defining the effects of the cut-off times we said that the winter afternoon rays approach the site from southeast and southwest, and they strike on the northwest and northeast sides of the parcel. As we remember the shades and shadows created after 2:00 PM are allowed according to our time rules. Similarly and specifically to this parcel we see that adjacency wall also creates shadows for the same part of the site. So we can enlarge our envelope placing the plane showing the rays striking the north corner of the site at 2:00 PM in

21st of December. This plane is shown in red colours in the Table 4.3. This plane is extended vertically till it intersects with the plane that limits the northwest border of parcel over the 6.6m walls. Consequently all the planes covering the envelope will be extended till they reach to the other. Finally we will trim the envelope on the north corner, in order not to exceed the shadow conditions proposed by the summer cut-off times which may cause shadows in specified times on the protected areas around.

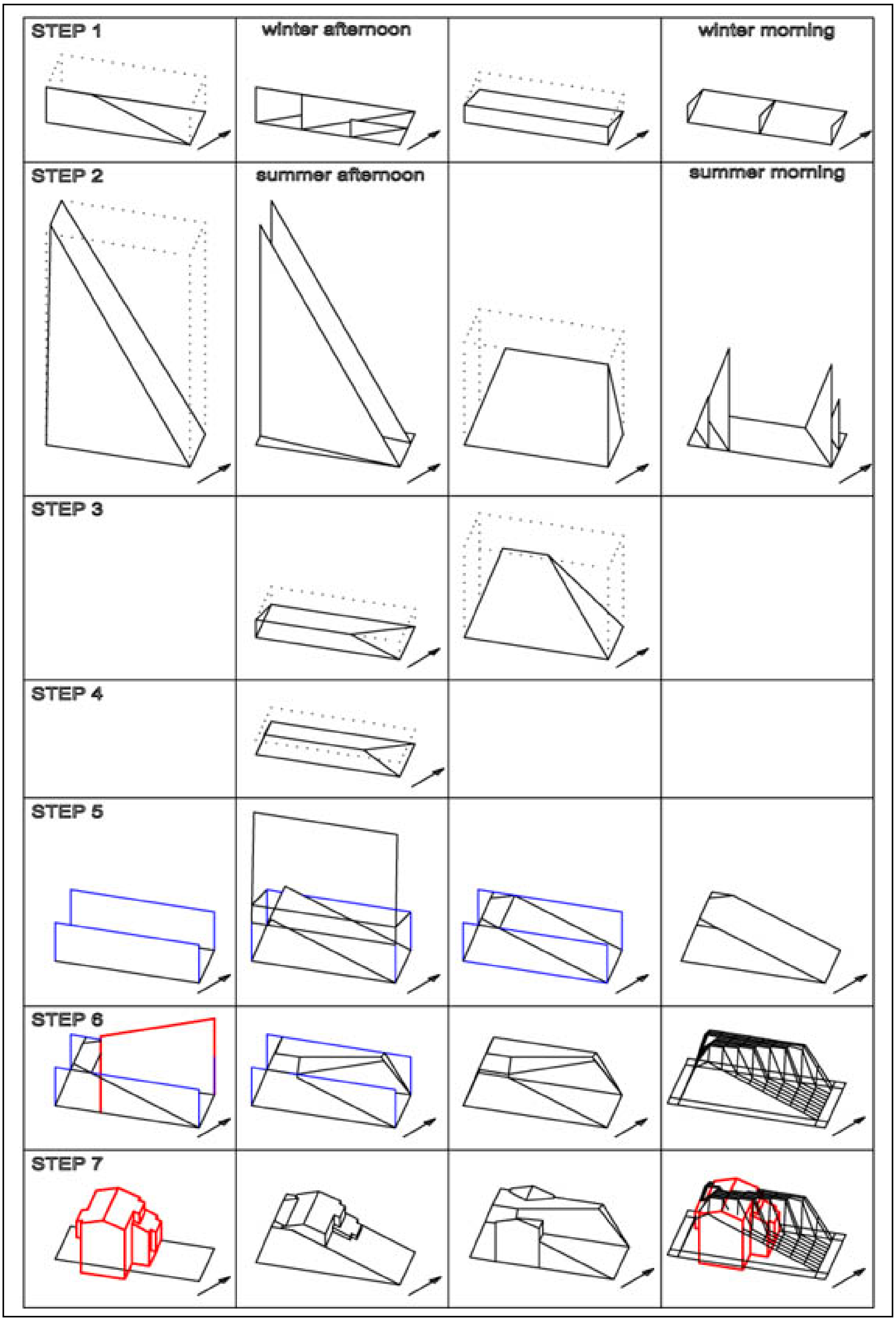
Step 7: Superimpose the Row Houses and Their Envelopes:

Envelopes constructed in step 5, step 6, and Solvelope are shown with the row house block. As we mentioned above envelope of step 6 and Solvelope are the same and the difference of the step 5 between them results from a difference of adjacency perception. The overall site results and shadow analysis are shown on the Figure 4.10 and 4.17-18 respectively.

To make a comparison we shall look the envelopes produced by Solvelope and the result of descriptive method at once. The difference is because of the difference of the visualisation methods of solvelope and autocad 2002, which is used to produce the drawings. Solvelope defines the volume by the lines that intersect with each other in points, whose vertical positions are mathematically calculated according to the specified variables (time and space). Dividing the parcel according to a certain grid specifies these points. In this method higher the number of points more accurate the envelope is drawn. But number of the vertices is not user's preference so the accuracy of the surfaces defined by the Solvelope is not sufficient as Autocad 2002 application. It should be added that in this study Autocad 2002 is used only as a drafting tool, where as it has more potential to render solar envelops. As it is mentioned before Calcsolar is an Autolisp application converting graphic and numeric data in to solar envelopes.

At this point it should be underlined that addition of every new effect to the method, changes the formation of the planes creating the envelope but their slopes stay constant. If we remember chapter 3, we calculated these planes' slopes with profile angle method. It was much simpler and time saving but without examining the planes showing the sunray planes, there is a risk of missing some occasions created by other effects like attached buildings. The comment made on step 6 of the last solar envelope we examined is a result of such an occasion.

Table 4.3. Envelope for the site 60º deflected to west of south with approach A



4.C.1.2. 30º east of south: Second envelope that will be explained is the one deflected 30º east of south (Table4.4.). Dimensions are 8.3m to 20m. In fact this site is on the same grid with the previous site but the difference is the orientation of the façade suitable for solar access.

Step 1: Use Winter Cut-off Times:

The winter morning rays (10:00 winter; α = 20°, θ = 30°) (Figure 4.9) approach the site across its southeast boundary and cast shadows to the opposing northwest boundary. The winter afternoon rays (14:00 winter; α = 20°, θ = 330°) approach the site from the southeast and southwest. Planes located at those boundaries are shaped to cast shadows to the opposing northeast and northwest boundaries.

Step 2: Use Summer Cut-off Times:

The summer morning rays (10:00 summer α = 60°, θ = 66°) (Figure 4.9) approach the site across its northeast and southeast boundaries. Vertical planes at those boundaries are shaped to cast shadows to the opposing southwest and northwest boundaries. The summer afternoon rays (14:00 winter α = 60° θ = 294°) approach the site across its southwest and northwest boundaries and cast shadows to the opposing northeast and southeast boundaries.

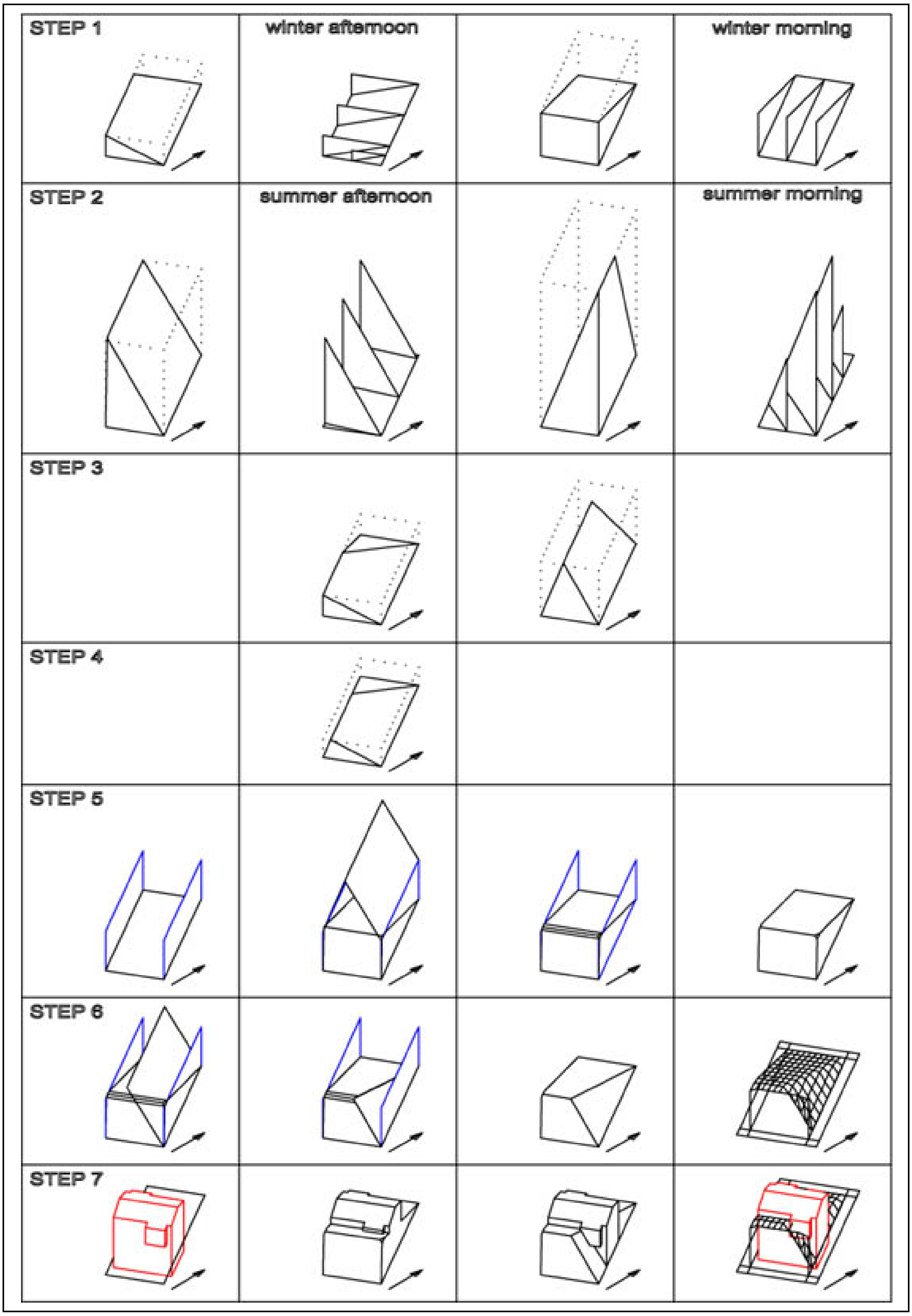
Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

The combination of summer rays slopes across the site to strike the northwest and southwest boundaries in the morning, the northeast and southeast boundaries in the afternoon. The combination of winter rays slopes across the site to strike the northwest boundary in the morning, the northwest and northeast boundaries in the afternoon. The planes intersect at different heights across the site.

Step 4: Combine Effects of the Summer and Winter Cut-off Times:

To combine the summer and winter envelopes we will take the planes having the minimum angle with ground. So the northeast and northwest boundaries will be defined with the planes taken from winter envelope. On the other hand the summer envelope contributes the final envelope with southeast and southwest boundaries.

Table 4.4. Envelope for the site 30º deflected to east of south with approach A



Step 5: Combine Effect of Walls on Long Sides:

The planes starting from southeast and northwest sides will be protected and they will be extended to reach each other. The southwest and northeast planes will be carried over the 6.6m walls and by using them the corners created by the intersection of the southeast and northwest planes will be trimmed. Result is the final envelope for this orientation.

Step 6: Additional Comments of Solvelope:

Solvelope defines this envelope differently. The reason is that solvelope tries to protect the site or the area that is placed on the northeast of our site. This may be because the difference in the perception of adjacency but the resulting envelope is not coinciding with the result of descriptive method. However we will be using the results of the solvelope in overall site models and evaluations because of the descriptive methods time-consuming character. Additionally the southeast façade of the solvelope's result looks to be taller than the descriptive methods result. This difference is negligibly minor and the reason is the rendering incapability of the Solvelope.

Step 7: Superimpose the Row Houses and Their Envelopes:

4.C.1.3. 75º east of south: Third envelope to be constructed is the one deflected 75º east of south (Chart 4.5.). Dimensions are 8.3m to 20m.

Step 1: Use Winter Cut-off Times:

The winter morning rays (10:00 winter; α = 20°, θ = 30°) (Figure 4.9.) approach the site across its southeast and southwest boundaries and cast shadows to the opposing northwest and northeast boundaries. The winter afternoon rays (14:00 winter; α = 20°, θ = 330°) approach the site from the northwest and southwest and cast shadows to the opposing southeast and northeast boundaries.

Step 2: Use Summer Cut-off Times:

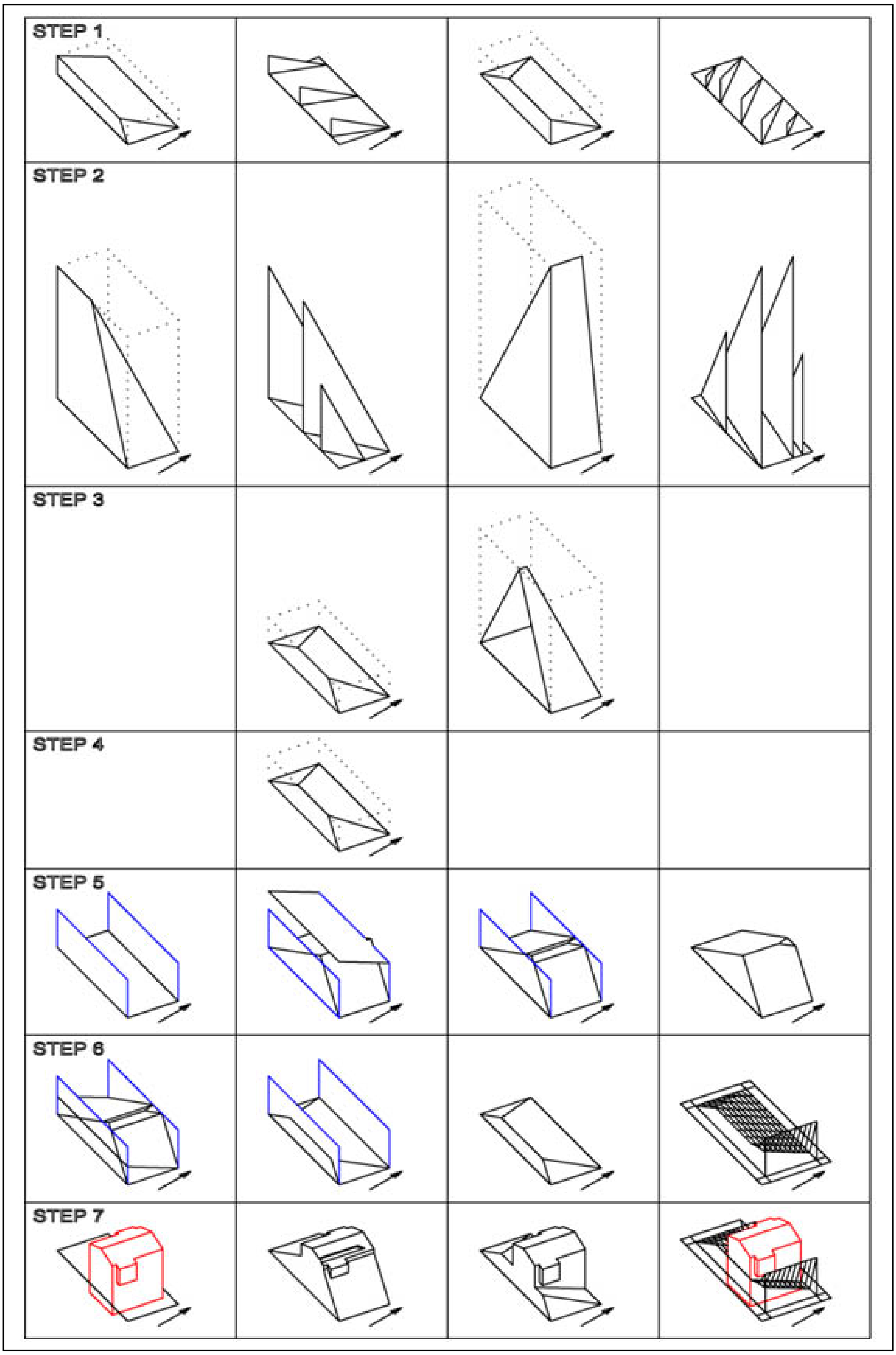
The summer morning rays (10:00 summer α = 60°, θ = 66°) (Figure 4.9) approach the site across its southeast and southwest boundaries and cast shadows to the opposing northwest and northeast boundaries. The summer afternoon rays (14:00 winter α = 60° θ = 294°) approach the site from the northwest and southwest and cast shadows to the opposing southeast and northeast boundaries.

Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

Step 4: Combine Effects of the Summer and Winter Cut-off Times:

Step 5: Combine Effect of Walls on Long Sides:

Table 4.5. Envelope for the site 75º deflected to east of south with approach A



Step 6: Additional Comments of Solvelope:

As in the previous example solvelope protects the site on the northeast and defines a lower envelope than the descriptive method. The formation of the southeast façade is also varying because of the rendering incapability. These changes does not mean that Solvelope gives false results because the angles of the defined planes are checked and approved that they are correct and exactly the same as the planes defined by descriptive method. However it can be claimed that with some amount of software modification Solvelope will perform better in such an application.

Step 7: Superimpose the Row Houses and Their Envelopes:

4.C.1.4. Other parameters affecting the envelope generation in approach A:

With a closer observation we can realize that the similar row houses placed in similar parcels but behaving different in the envelope in means of exceeding different amounts of volumes. Fundamentally this is because of the close relation of the solar envelope and the environment. Such an attitude will result with great variety in forms to supply necessary adaptation. On the other hand the existing formation of Odtükent is a consequence of an attitude of mass housing promising standard comfort for every dwelling by the repetition of the same or very similar housing blocks. Because of this, a reasonable explanation of this difference in solar rights performance should be done. The main parameters that effect the formation of the solar envelopes are slope, orientation and streets.

<u>Slope:</u> Being a north facing slope site is negatively affected in general. Every individual parcel has its own slope conditions but despite the trials of modeling with the slope, making comments about the effect of slope will not be healthy because of the insensitivity of the modeling tools used (Solvelope). We can see the difference of the envelopes between the two parcels on same orientation but on different slopes (Figure 4.8). Example site is 8.3m to 20m and it is south façade is deflected 60º to east. To make a comparison second parcel is assumed to have 2m drop on north edge, which is a general case in the overall site. Heights of the envelopes result as 9.4m, 7.3m respectively.

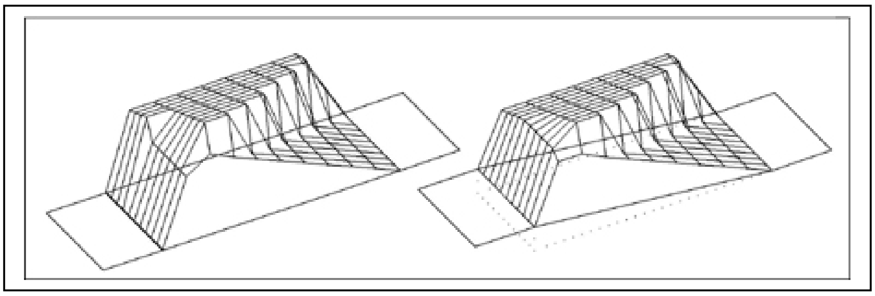


Figure 4.8. Effect of slope

Streets: The other parameter affecting the envelopes is the street formation. As it is mentioned before shorter sides of the parcels are used to limit the envelope. In other words envelopes are not allowed to extend short sides as they are, from the longer sides in the means of shadow casting. In the figure below the change of the envelopes when they are allowed to cast shadows on the neighbouring streets, is observed. Heights of the envelopes are 5 m, 9.4 m, and 9.7 m respectively.

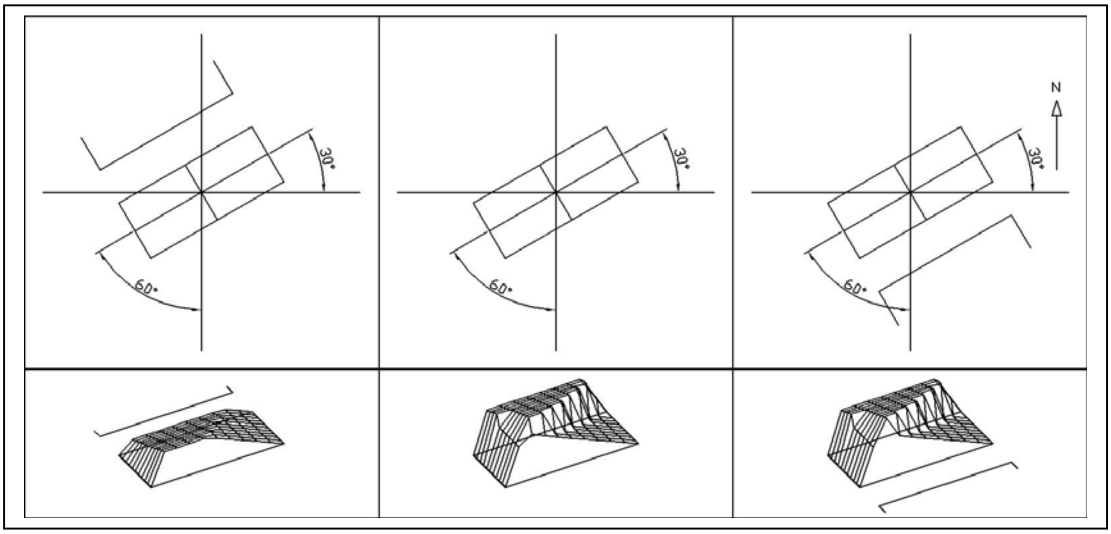


Figure 4.9. Effect of the streets on the envelope

4.C.1.5. Results of Approach A:

Overall results of the approach A for the site are shown on the Figure 4.10. Pictures on the left show the constructed envelopes. The one on top is the result of the data gathered from the Solvelope, which is consisting of volumes defined by lines, not constructed as solid objects. To be able to make healthy shading analysis these volumes converted in to solids by using Autocad and 3DS Max applications that are shown in the picture below. Pictures on the right are the super imposed images of the existing situation and the envelopes. Exceeding parts of the buildings from the envelopes will be the reason of the exceeding shadows from the limits set in the stage of rules of envelope generation.

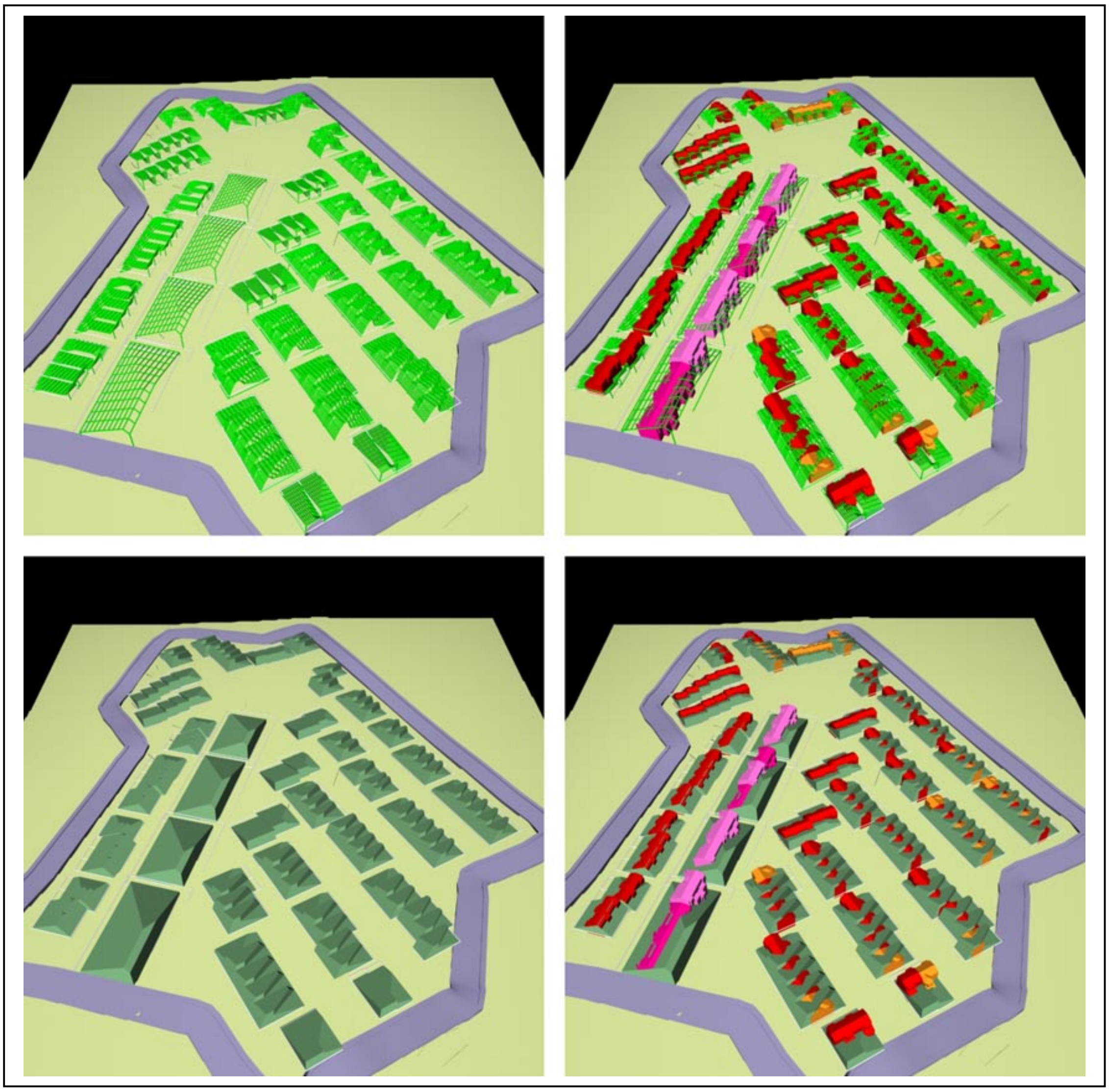


Figure 4.10. Results of approach A

4.C.2. Generation of Envelopes with Approach B:

To exemplify the results of changing attitude, the envelopes of the groups of blocks that involve 4 adjacent blocks on two different grids and 3 different orientations will be designated. In addition to these the appropriate envelopes will be constructed for an example parcel occupied by apartment blocks. The plans of these sites are shown in the figure below.

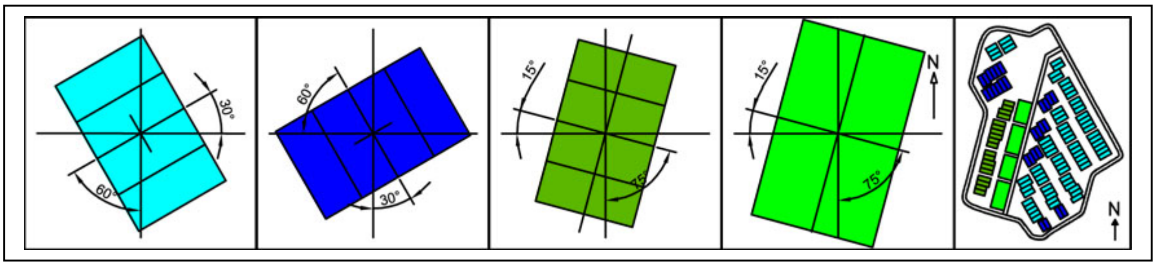


Figure 4.11. Characteristic sites according to their orientations

During the application of this approach the slope is neglected. Group of row houses is assumed to be resting on the same level. The reason of this is to avoid causing more ambiguity.

4.C.2.1. 60º west of south: This site is the one having south facade deflected with 60º to west. As a method descriptive vertical planes will be used. Additionally the streets on the northwest and southeast that are 5m wide will be considered. The envelope constructed will be enclosing the four sites and this envelope will be sliced in to four according to the planimetric divisions of the parcels. Dimensions are 33.2m to 20m.

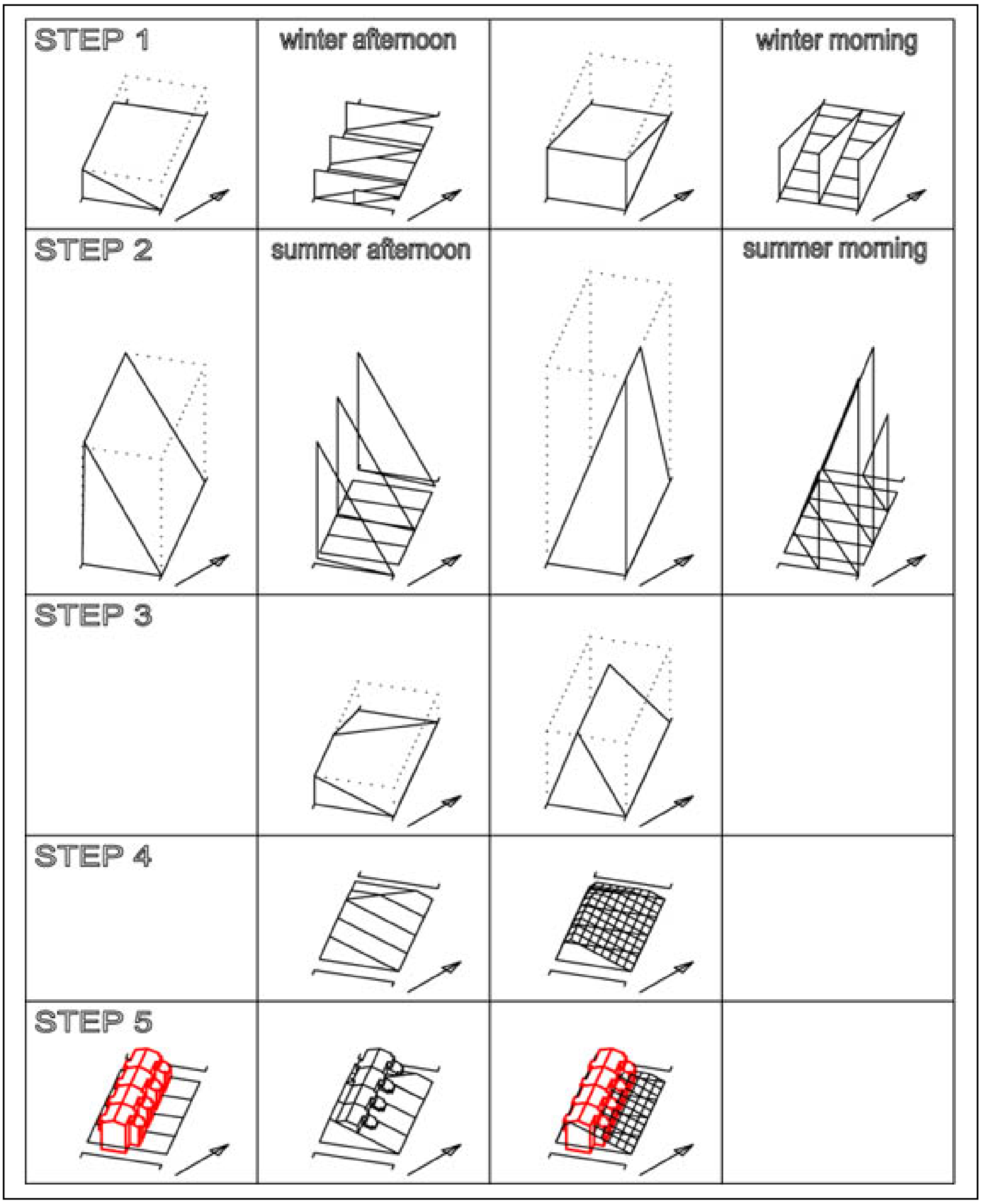
Step 1: Use Winter Cut-off Times: (10:00; α = 20°, θ = 30°, 14:00; α = 20°, θ = 330°)

Step 2: Use Summer Cut-off Times: (10:00; α = 60°, θ = 66°, 14:00; α = 20°, θ = 330°)

Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

The combination of summer rays slopes across the site to strike the northwest and southwest boundaries in the morning, the northeast and southwest boundaries in the afternoon. The combination of winter rays slopes across the site to strike the northwest boundary in the morning, the northwest and northeast boundaries in the afternoon. The planes intersect at different heights across the site.

Table 4.6. Envelope for the site 60º deflected to west of south with approach B



Step 4: Combine Effects of the Summer and Winter Cut-off Times:

In order to satisfy both summer and winter insolation needs in one volume; we will take the minimum angles for each façade. Northeast and northwest planes and the ridge between these facades will be constructed according to the winter envelope. Southwest and southeast facades and the ridge between them will be taken from summer envelope. Designated envelope will be sliced in to four to see the every individual envelope of the parcels. At this stage the envelope defined by the solvelope is shown in the figure (Table 4.6.). Very significantly we can see that the results of two applications are more harmonious with each other, compared with the results gathered in approach A. The reason is the difference of attitude towards the adjacency.

Step 5: Superimpose the Row Houses and Their Envelopes:

4.C.2.2. 30º east of south: Second envelope that will be explained is the one deflected 30º east of south (Table 4.7.). Dimensions are 33.2m to 20m.

Step 1: Use Winter Cut-off Times: (10:00; α = 20°, θ = 30°, 14:00; α = 20°, θ = 330°)

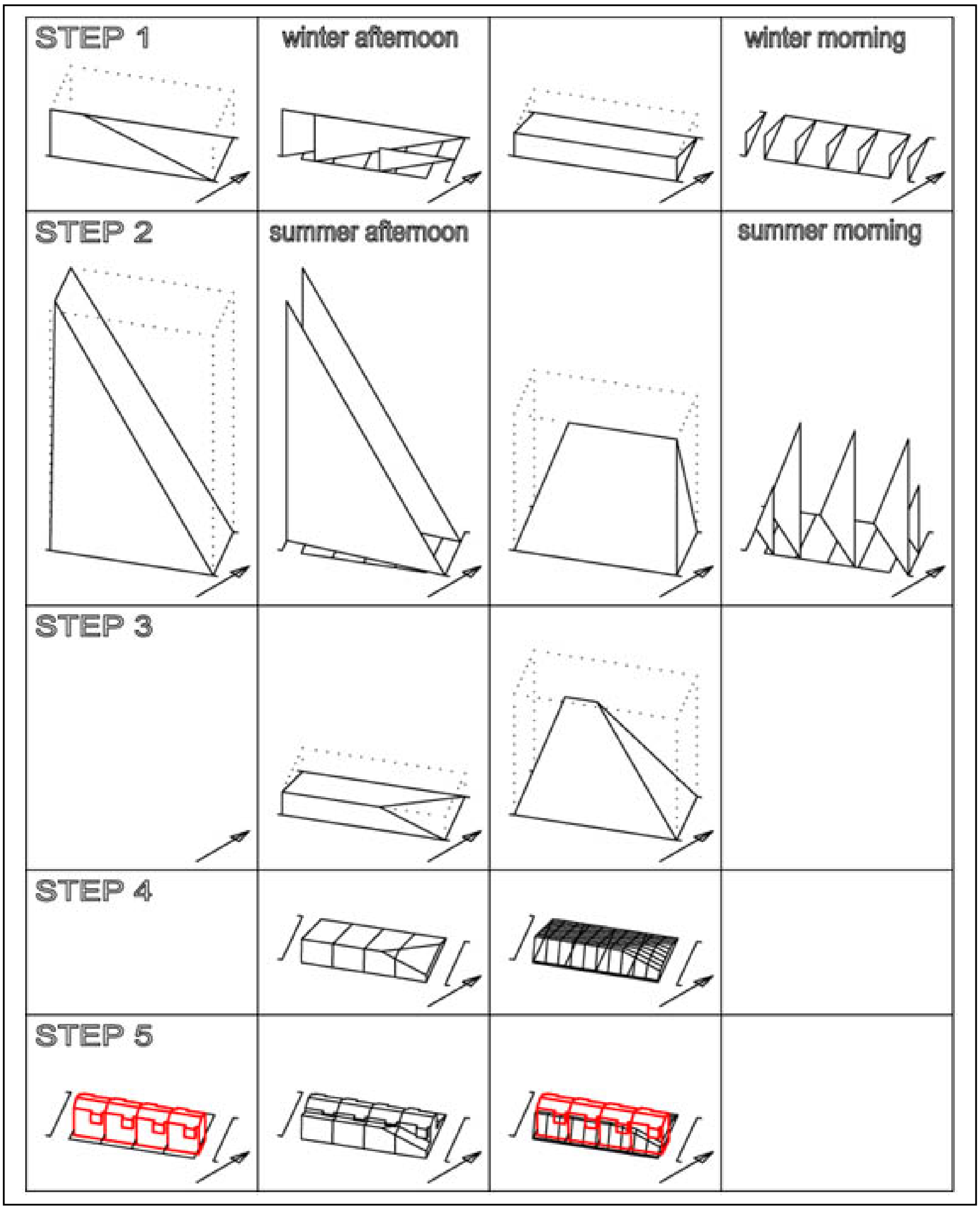
Step 2: Use Summer Cut-off Times: (10:00; α = 60°, θ = 66°, 14:00; α = 20°, θ = 330°)

Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

Step 4: Combine Effects of the Summer and Winter Cut-off Times:

Step 5: Superimpose the Row Houses and Their Envelopes:

Table 4.7. Envelope for the site 30º deflected to east of south with approach B



4.C.2.3. 75º east of south: Third envelope to be constructed is the one deflected 75º east of south (Table 4.8.). Dimensions are 8.3m to 20m.

Step 1: Use Winter Cut-off Times: (10:00; α = 20°, θ = 30°, 14:00; α = 20°, θ = 330°)

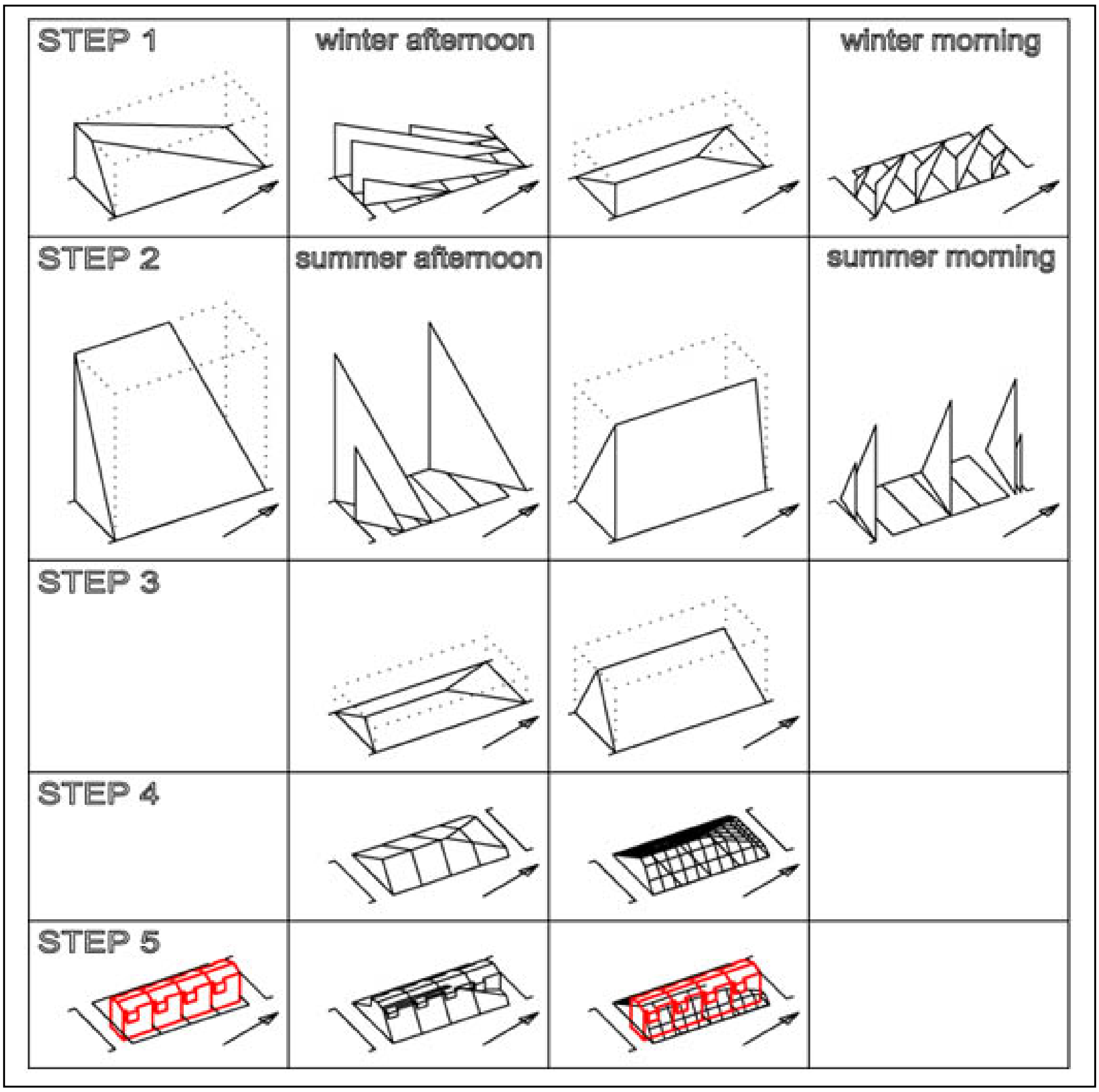
Step 2: Use Summer Cut-off Times: (10:00; α = 60°, θ = 66°, 14:00; α = 20°, θ = 330°)

Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

Step 4: Combine Effects of the Summer and Winter Cut-off Times:

Step 5: Superimpose the Row Houses and Their Envelopes:

Table 4.8. Envelope for the site 75º deflected to east of south with approach B



4.C.2.4. 75º east of south (apartments): Fourth envelope to be constructed is the one deflected 75º east of south (Table 4.9.) as the third one. But this site has a difference in dimensions because it is one of the sites that the apartment blocks are placed on. Dimensions are 25m to 40m and the envelopes of this parcel is permitted to exceed till 4m on northwest, 7.5m on southeast and northeast, 15m on southwest, and 5m on the pedestrian road separating this parcel from it's neighbour. As we mentioned before these blocks are also row apartments like row houses. However we will not use the same attitude with row houses when we are constructing the envelopes. Because apartments type dwelling development, aims to reach a higher density. Trying to judge such a development with strict insolation standards would be unfair.

Step 1: Use Winter Cut-off Times:

The winter morning rays (10:00 winter; $\alpha = 20°$, $\theta = 30°$) (Figure 4.9) approach the site across its southeast and southwest boundaries and cast shadows to the opposing northwest and northeast boundaries. The winter afternoon rays (14:00 winter; $\alpha = 20°$, $\theta = 330°$) approach the site from the northwest and southwest and cast shadows to the opposing southeast and northeast boundaries.

Step 2: Use Summer Cut-off Times:

The summer morning rays (10:00 summer $\alpha = 60°$, $\theta = 66°$) (Figure 4.9) approach the site across its southeast and southwest boundaries and cast shadows to the opposing northwest and northeast boundaries. The summer afternoon rays (14:00 winter $\alpha = 60°$ $\theta = 294°$) approach the site from the northwest and southwest and cast shadows to the opposing southeast and northeast boundaries.

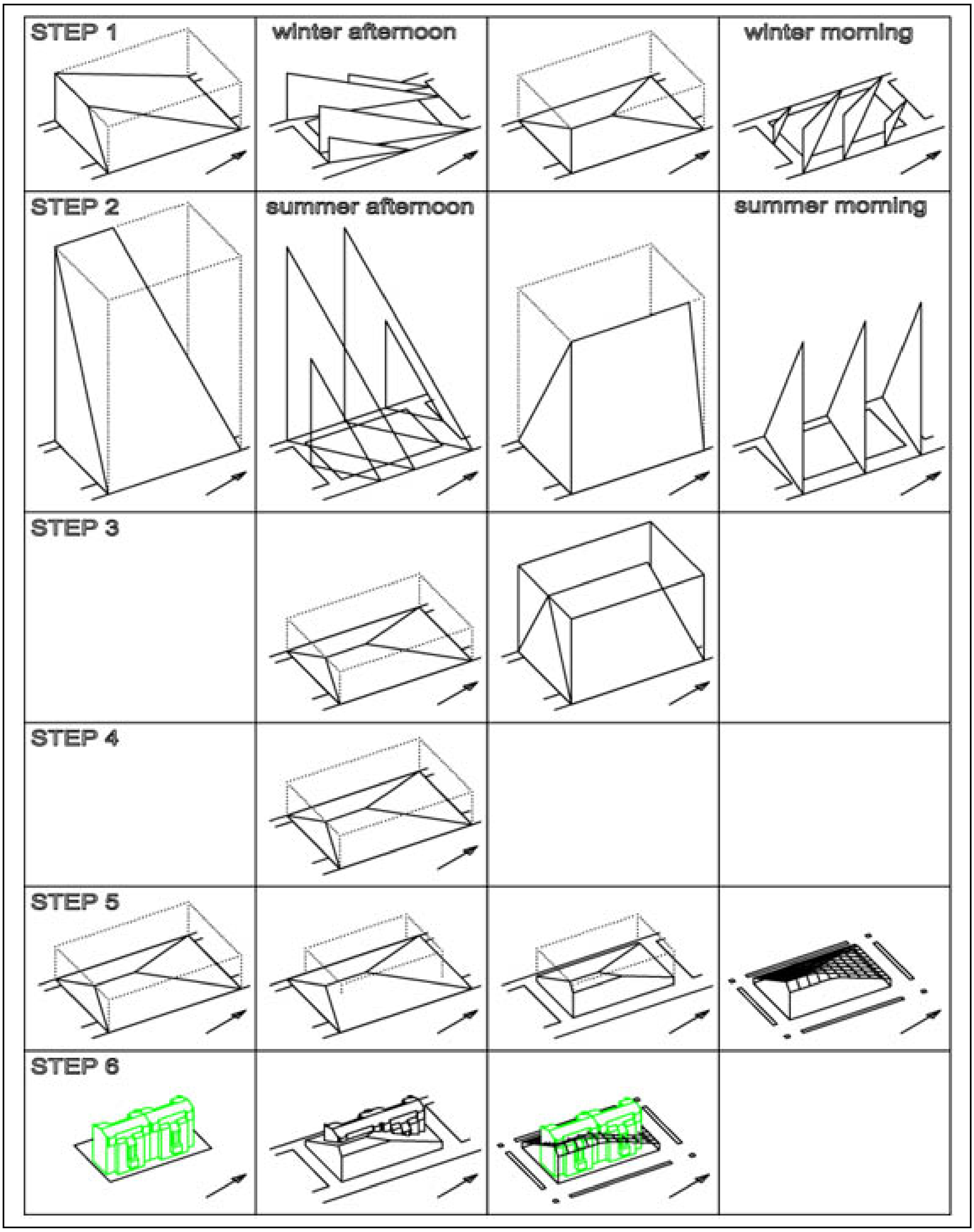
Step 3: Combine Effects of the Morning and Afternoon Cut-off Times:

Step 4: Combine Effects of the Summer and Winter Cut-off Times:

Step 5: Trim the Envelope According to Site Boundaries:

Step 6: Superimpose the Apartment Blocks and Their Envelope:

Table 4.9. Envelope for the apartment blocks 75º deflected to east of south with approach B



4.C.2.5. Results of the approach B:

First of all it should be mentioned that in the pictures showing the results of both approaches, the envelopes of the apartment block are gathered with approach B. The reason is that the envelopes gathered from previous approach are not reasonable. Second approach's poor sensitivity to slope, which is understood from the buried pieces of some of the envelopes (Figure 4.12), can be declared as an additional comment. Approach B is in sufficient in case of excessive slope conditions which is seen on the north-east of the site.

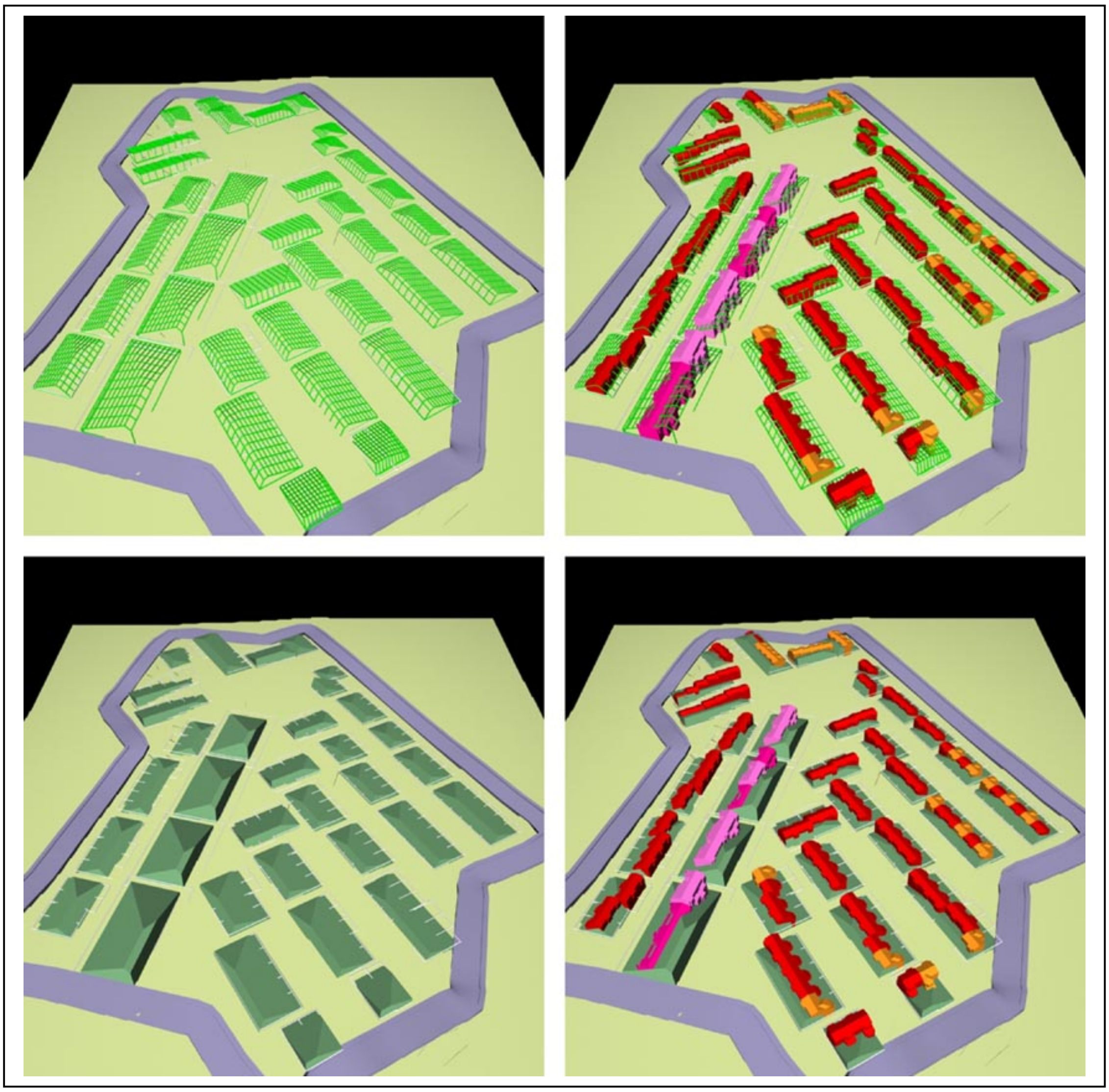


Figure 4.12. Results of approach B

4.D. RESULTS

In this section the constructed envelopes are going to be tested with shading models. According to our presuppositions, by the help of with we set our rules of envelope generation, these volumes should not cast shadows beyond the limits we let them to. During the evaluation of these result it should be memorized that this is an experimental study and the result were not presumed from the beginning. Additionally as it is stated in previous section Odtükent site is not such a high-density residence compared with the other mass housing examples in our cities. It is obvious that in a high density urban context the method of solar envelope would give more efficient results in the means of, making use of shading analysis for building design.

4.D.1. Shadow Maps of the Site:

In this section the performance of the envelopes generated are going to be tested with the help of three-dimensional models. First of all the existing situation will be modeled (Figure 4.3). Hourly shadows will be animated according to winter extremes. As we mentioned before the winter shadows will be tested for the angles of 21st of December. The performance evaluations will be made according to the spatial and time constraints defined to set the rules of envelope generation. These are the solar zoning principles defined for this parcel.

According to these principles row houses are proposed not to cast shadows exceeding the parcel boundaries, except the ones on the street side which are permitted to cast shadows for 5m, that is the depth of the roads separating the group of houses. Apartment blocks are permitted to exceed 4m on northwest, 7.5m on southeast and northeast, 15m on southwest, and 5m on the pedestrian road separating this parcel from it’s neighbour. These limits are shown in the figures.

The following figures 4.13 to 4.20 are the shadowing plans of the existing buildings and the envelopes defined in the previous sections. In case that the limits of permitted shadows are the boundaries of the parcels that are shown with black lines in the plans, looking at the shadows on the plan is the best way to make an evaluation.

4.D.1.1. Shadows of Existing Situation:

Figure 4.13 is the reproduction of the 1/2000 plan shown in the figure 4.4. Black lines are the parcel boundaries and at the same time the maximum limits of the permitted shadows. Figure 4.14 shows the shadows in the morning cutoff time in the 21st of December, when the shadows are the longest in the northern hemisphere. We observe serious shadows produced by the apartment blocks, falling on the villas on the west boundary. From the figure we see that these shadows are spoiling the parcel boundaries of the villas on the west and casting shadows on their façade (Figure 4.21). Such extensions are not tolerable if we set our rules to limit the shadows with our own boundaries. Additionally we observe that the shadows are elongated when the slope is increased. Figure 4.14 shows the case that is over shadowing at noontime, when the sun has the highest angle during day. Next figure represents the shadows of the afternoon cutoff time. These shadows are not causing severe problems but they don't satisfy the rules we set.

Before going into the shadow analysis of the solar envelopes some overall comments may be set related to the site organization according to the shadow maps of the figures 4.14, 4.15, and 4.16. Olgyay advised south-southeast as an ideal façade orientation for the northern hemisphere in the means of energy efficiency (Olgyay 1963, p.57). For similar reasons but with more detailed calculations Nur Demirbilek stated that 30º east of south is best for winter and 60º west of south is worst for summer in Ankara (Demirbilek 1882, p.34). The sun facing facades of the buildings in the site has angles of 60º west of south, 30º east of south and 75º east of south. We see that second group of blocks seems to have ideal orientation, but because of the view direction, which is on the north side of the side related with being a northern slope, the living rooms having greatest window openings are placed as the northeast and northwest facades. Most of the dwellings have warm bedrooms yearlong, but cool and gloomy living rooms in winter. Depending on the shadow maps we see that only 6 blocks on the south end and 4 blocks' living rooms on the east end can have direct sunlight during specified time intervals in the 21st of December.

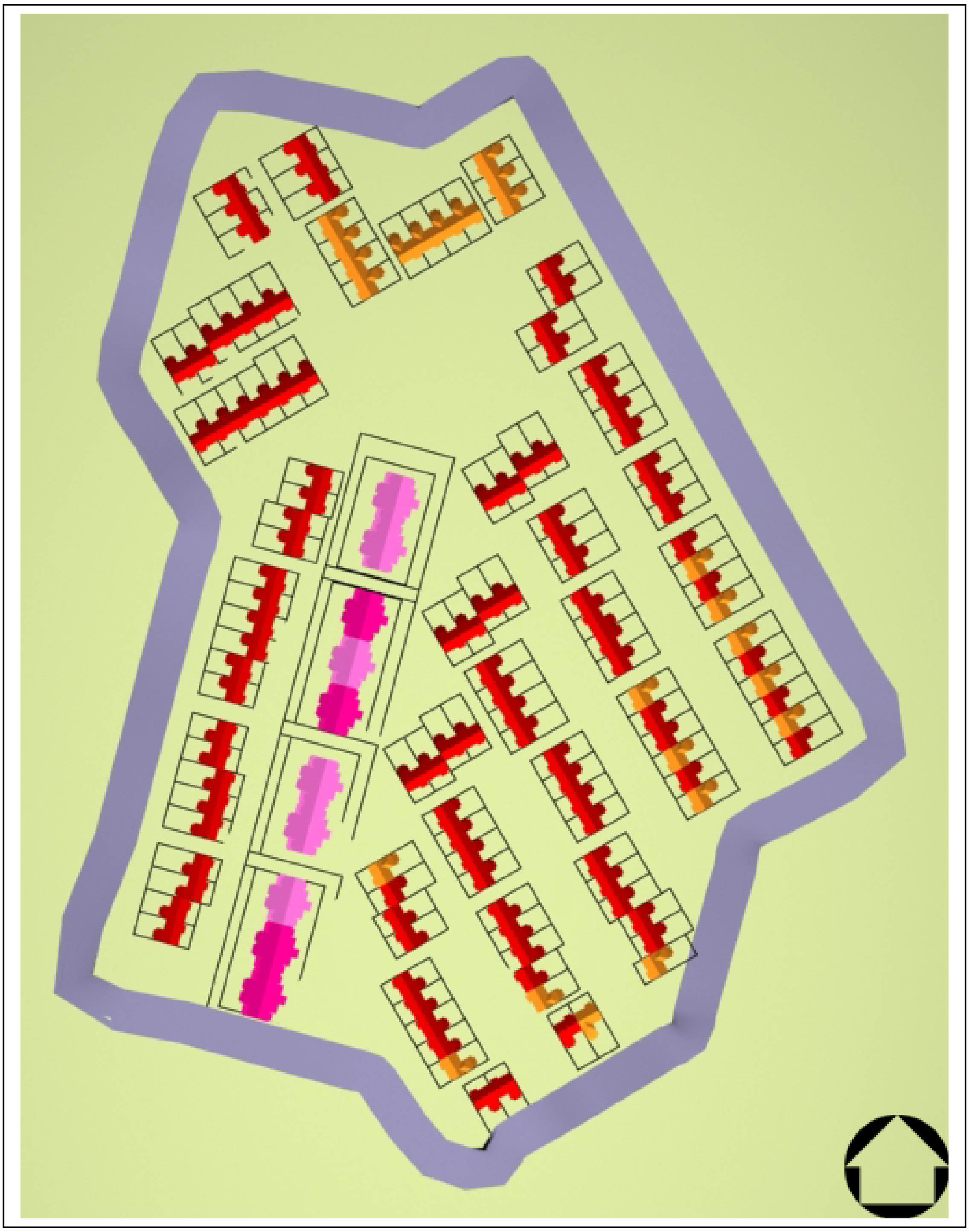


Figure 4.13. Plan View of the site without any shading

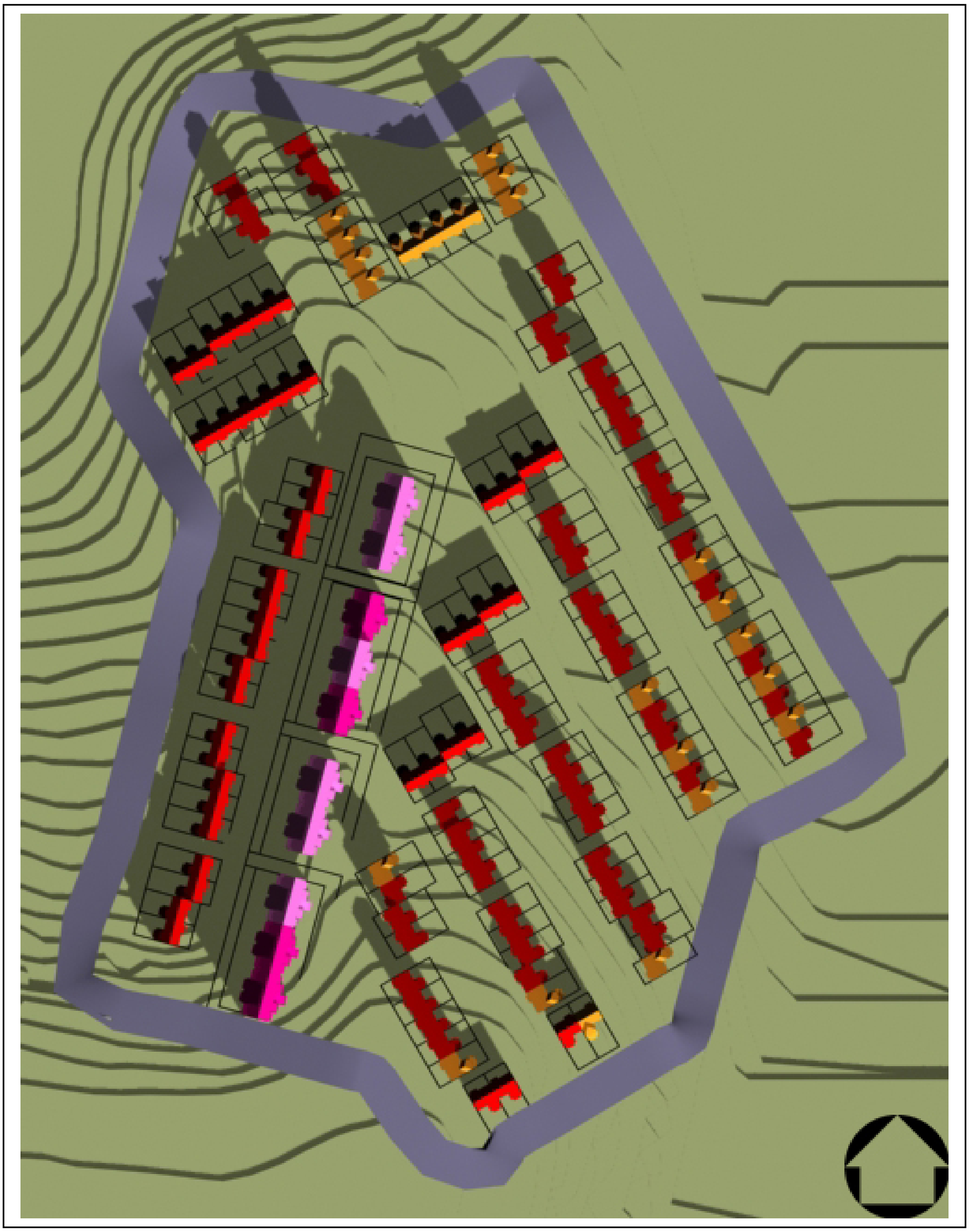


Figure 4.14. Plan View of the existing situation with the shadows of 21st of Dec. at 10:00 -morning cutoff time-

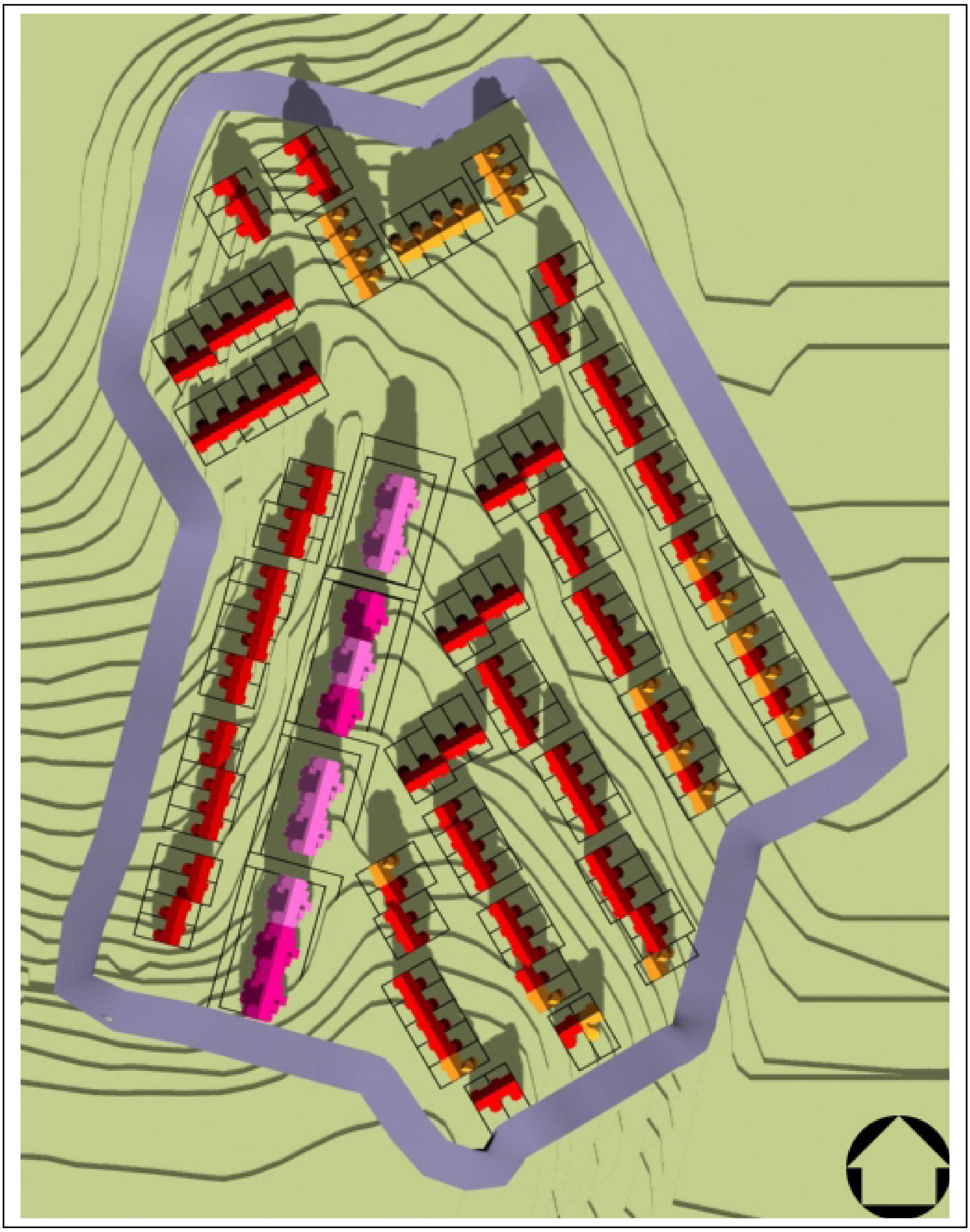


Figure 4.15. Plan View of the existing situation with the shadows of 21st of Dec. at 12:00 -noontime-

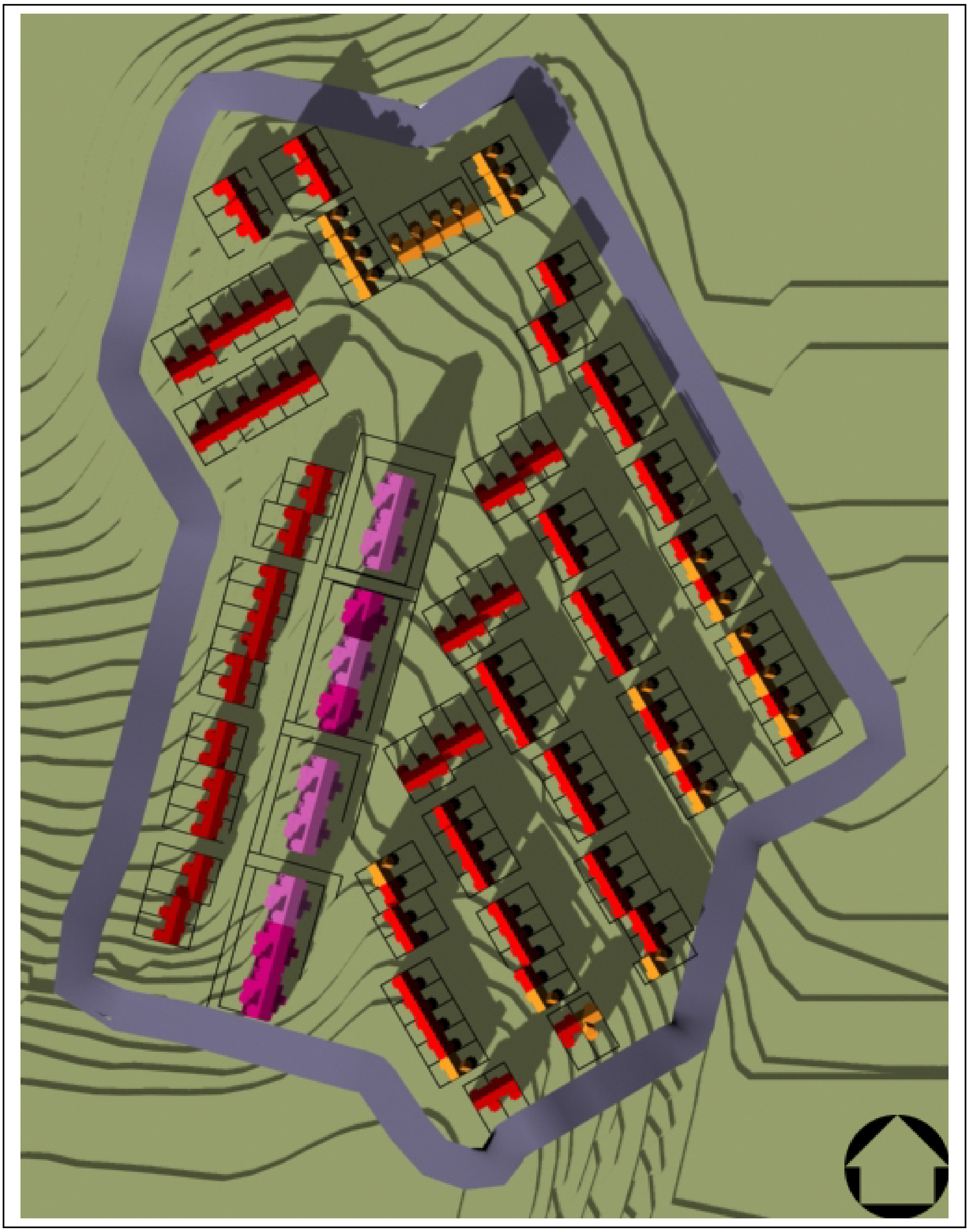


Figure 4.16. Plan View of the existing situation with the shadows of 21st of Dec. at 14:00 -afternoon cutoff time-

4.D.1.2. Shadows of the Envelopes:

In Figures 4.17 and 4.18 we see the shadows of morning cutoff time and afternoon cutoff time for the results of approach A respectively. In approach A shadows are much smaller compared with the existing situation, but still they exceed beyond the limits we set. The reason is that we neglected the slope during the construction of the envelopes. Most of the shadows may be explained with this except the shadows of the blocks having 60º west of south orientation (on the east boundary). These blocks cast shadows on each other, which is meaningless for row houses. These shadows are cast by the extension of the envelope, which comes from the extra comment developed by Solvelope. This comment is stated with the explanations of Table 4.3 above.

Envelops of approach B casts less shadows than approach A. results are almost satisfying the limits we set in the beginning. The disadvantage of this method is that group of parcels are assumed to be one parcel during the envelope generation. That's why the group of blocks being placed on different ground levels such as the ones on the north boundary of the site, give ambiguous results. If we place the envelope to a lower level, some part of the envelope is buried in the ground (30º east of south oriented blocks on north west). Otherwise we place the envelope to a higher level, which means shadow casting (60º west of south oriented blocks on north end). So according to shadow maps approach B is more successful than approach A.

Figure 4.17. Plan View of the envelopes of approach A with the shadows of 21st of Dec. at 10:00 -morning cutoff time-

Figure 4.18. Plan View of the envelopes of approach A with the shadows of 21st of Dec. at 14:00 -afternoon cutoff time-

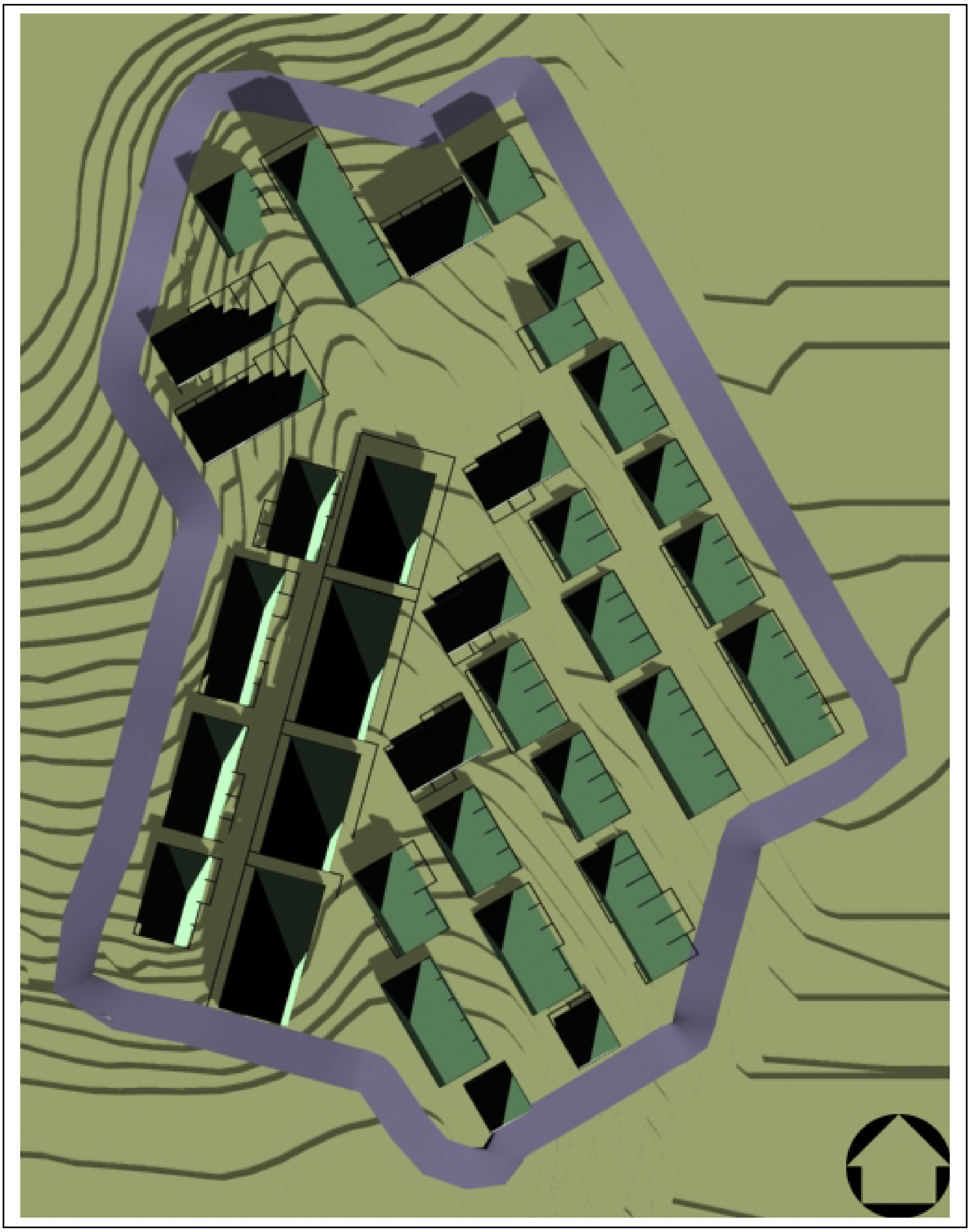


Figure 4.19. Plan View of the envelopes of approach B with the shadows of 21st of Dec. at 10:00 -morning cutoff time-

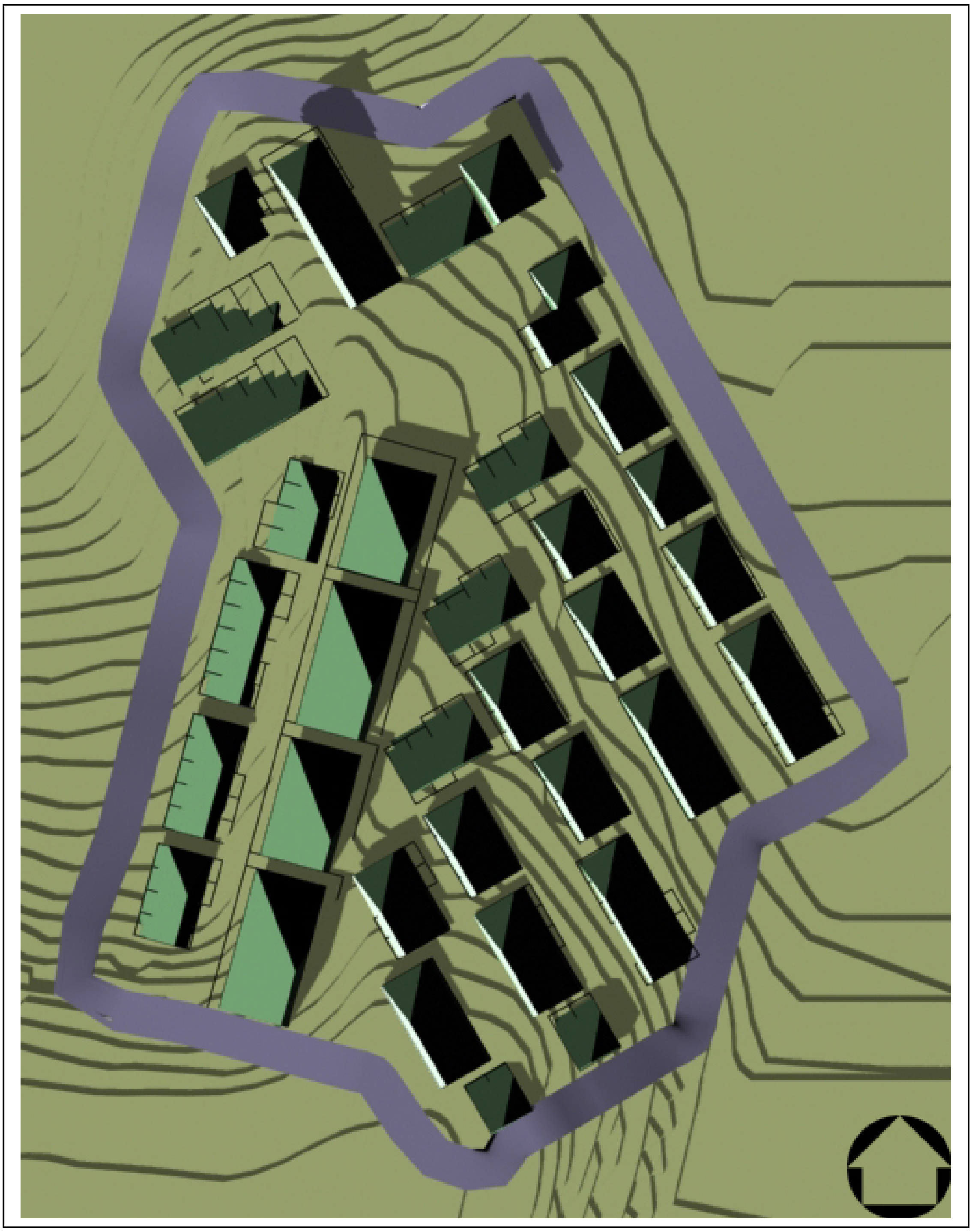


Figure 4.20. Plan View of the envelopes of approach B with the shadows of 21st of Dec. at 14:00 -afternoon cutoff time-

Following figures consist of detailed view of shadows cast by the apartment buildings, which cause the most problematic shadows in the site as we mentioned before. Figure 4.21 is perspective view from south showing the superimposition of the proposed envelope and the apartment building. The exceeded pieces of the building from the envelope will cause the shadows exceeding the horizontal limits of the site. We can clearly see the shadows falling on the façade of row houses on the west (Figure 4.22). These shadows are observed only at 10:00 in the morning. The rest of the day shadows seems not to be irritating including the afternoon cutoff time. In the next figure we see that these shadows are faded back till the boundary of west blocks (Figure 4.23). This is not sufficient indeed. The shadows beyond the apartments limits are the results of the slope as we mentioned formerly. From the designer's point of view, knowing the envelope limits in early stages will let him/her to choose different block organization. From Table 4.10 we know that these 4 story blocks may easily be developed under this volume, which means no loss of density. The outcomes of this sensitivity are equal share in terms of solar rights and better energy conversion.

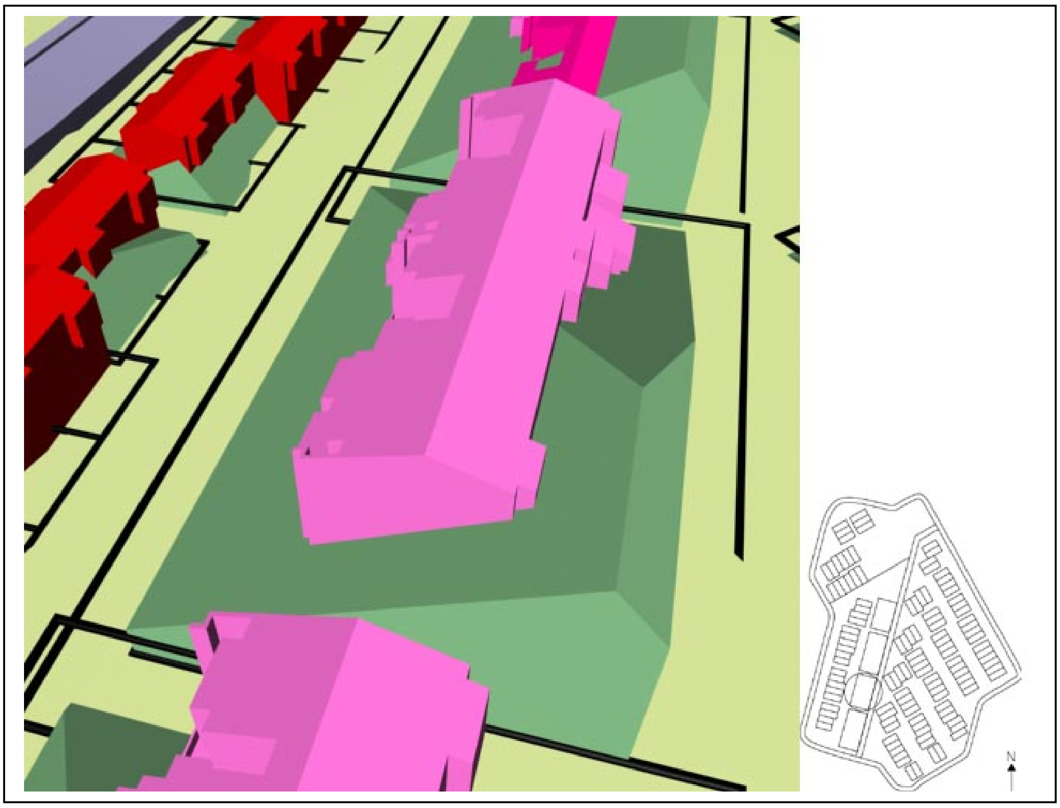


Figure 4.21. Superimposition of the attached apartment blocks with their envelopes

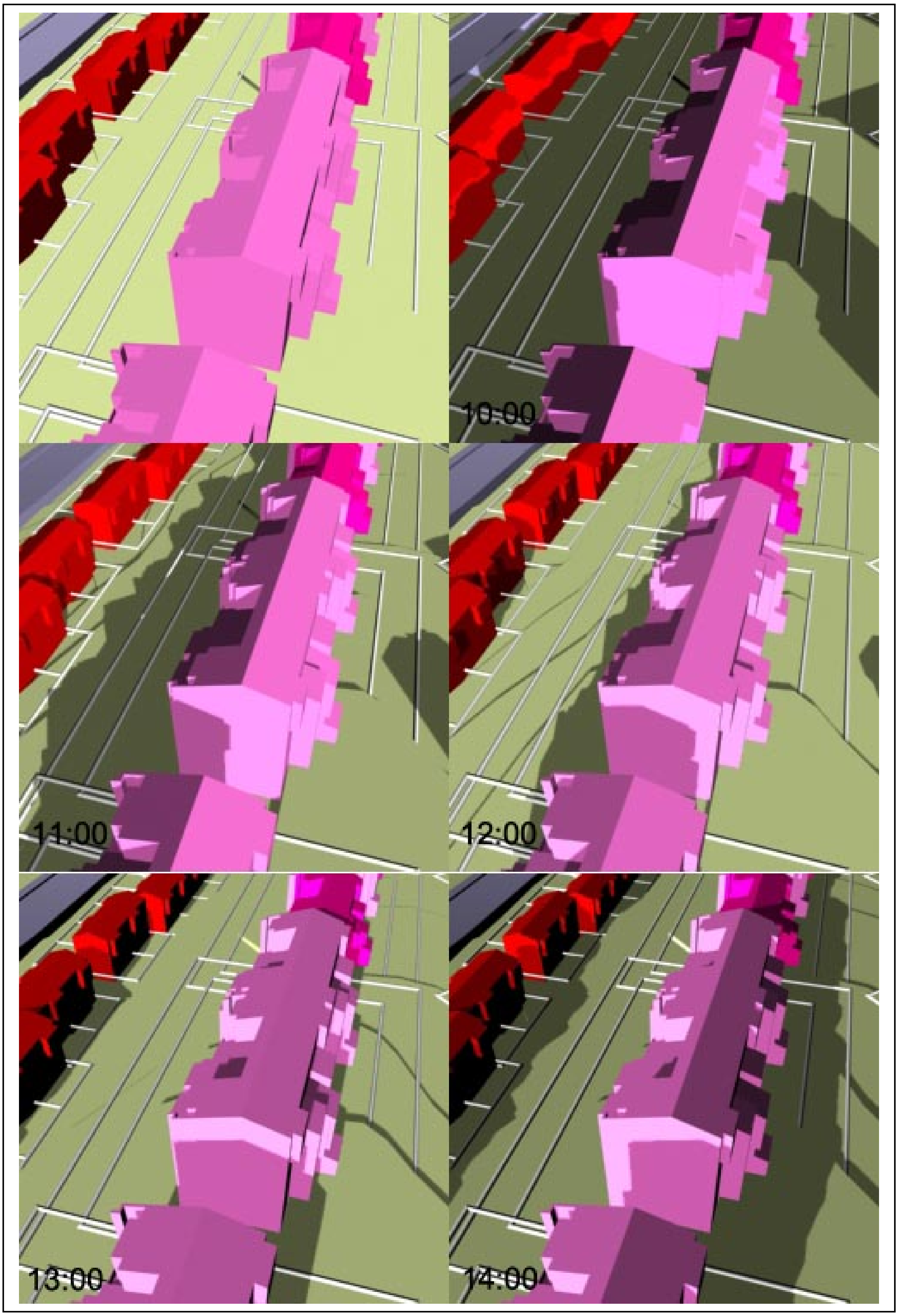


Figure 4.22. Hourly shadows of the apartment blocks in 21st of Dec.

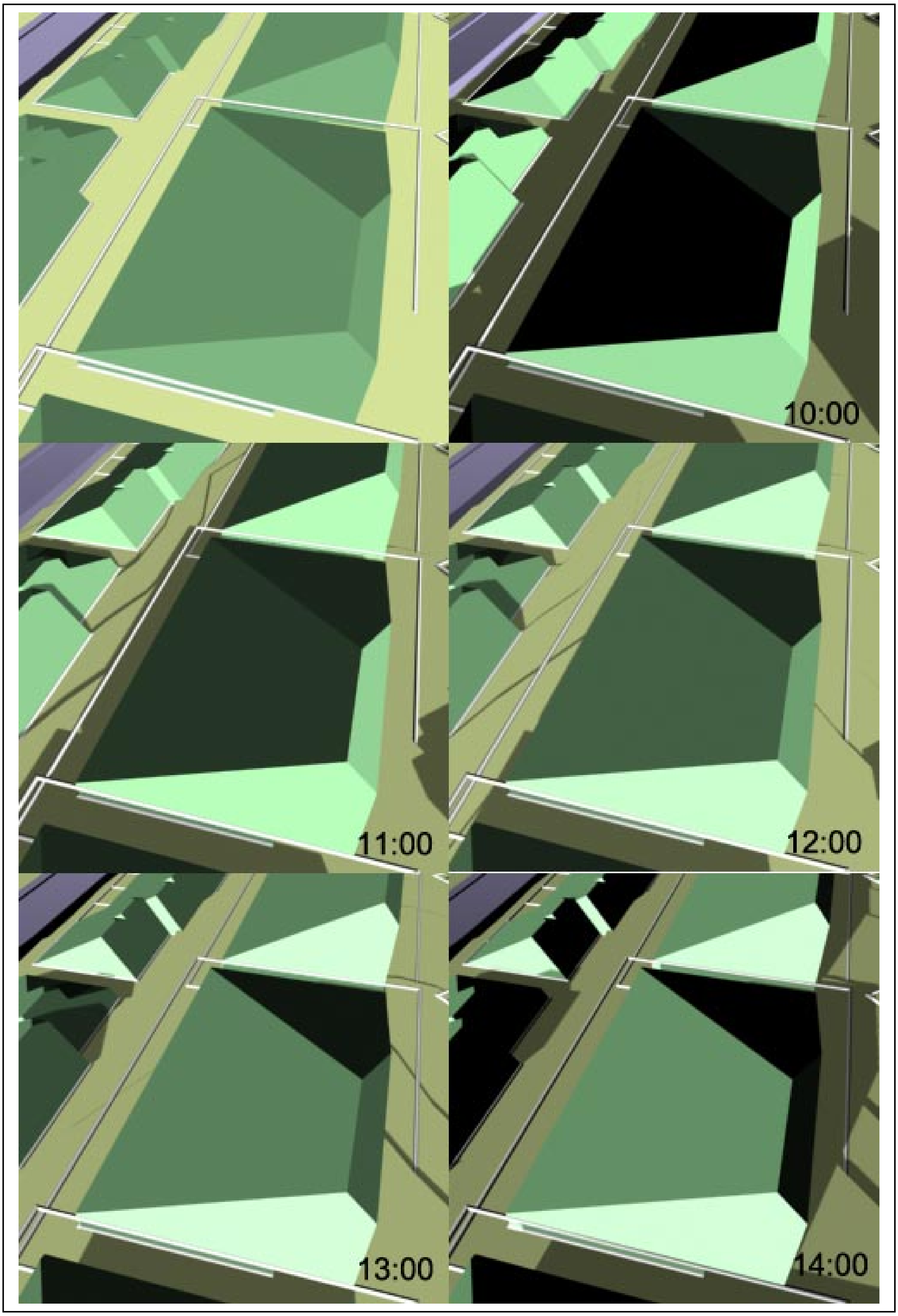


Figure 4.23. Hourly shadows of the envelopes in 21st of Dec.

4.D.2. Comparative Results of Approach A and B:

At this section the results of the envelopes supplied by different applications of the solar envelope method will be compared. The comparison will be developed between three different results in terms of height and volume. Two of these three results are the outputs of Approach A. First one is the envelope supplied in step 5 of the Tables showing the envelope generation. Second, is the result of Solvelope that is reached in the step 6 with some additional comments. Their superimposed images with existing situation are shown in step 7. The third one is the results supplied with Approach B. Another part of the data is related with the apartment blocks, which will be compared with the existing situation. The collection of the overall results is shown in the following section with three-dimensional, rendered images. Additionally the shadow and shading performances of the existing situation and compared envelopes are animated on these models.

- Differences between descriptive method's and Solvelope's results: The heights and the volumes of the envelopes supplied by both methods are same for all orientations if we consider the parcel in the neighbourhood of the street on its east, but in case of the mid parcels and the parcel on the west street, the numeric data shows dramatic differences (Table 4.10.). The reason is the ambiguity of the results of Solvelope. Envelopes of Solvelope define taller and bigger envelopes for 60º oriented sites whereas shorter and smaller envelopes for 30º and 75º oriented sites. In the previous section, while we are defining the envelopes step by step, we have explained the extra comments developed by the Solvelope and noted these on the step 6 of every table. This difference of comments is because of the Solvelopes perception of adjacency walls.

Table 4.10. Numeric results of the envelopes constructed (by Birol Topaloğlu)

		Orientation	Parcel Type	Height (max)	Volume
Approach A	Step 5 (Descriptive method)	60°	East Street	4.84 m	446 m^h
			Mid	7.72 m	671 m^h
			West Street	7.72 m	671 m^h
		30°	East Street	5.59 m	454 m^h
			Mid	7.12 m	590 m^h
			West Street	7.12 m	591 m^h
		75°	East Street	5.01 m	432 m^h
			Mid	7.53 m	624 m^h
			West Street	7.53 m	624 m^h
	Solvelope	60°	East Street	4.84 m	446 m^h
			Mid	9.55 m	916 m^h
			West Street	9.55 m	917 m^h
		30°	East Street	5.59 m	454 m^h
			Mid	7.12 m	494 m^h
			West Street	7.12 m	494 m^h
		75°	East Street	5.01 m	432 m^h
			Mid	3.12 m	223 m^h
			West Street	3.12 m	223 m^h
Approach B	Row Houses (Descriptive method)	60°	East Street	4.84 m	446 m^h
			Mid	7.72 m	643-673 m^h
			West Street	7.72 m	673 m^h
		30°	East Street	5.59 m	454 m^h
			Mid	7.12 m	587-591 m^h
			West Street	7.12 m	591 m^h
		75°	East Street	5.01 m	432 m^h
			Mid	7.53 m	606-625 m^h
			West Street	7.53 m	625 m^h
	Apartment Parcels	(4 stories x 2) (north)		14.03 m	7207 m^h
		(3 stories x 2)+(4 stories)		14.03 m	9315 m^h
		(4 stories x 2)		14.03 m	7412 m^h
		(3 stories x 2)+(4 stories)		14.03 m	8445 m^h
Existing row houses		60°,30°,75°		7.8 m	460 m^h
		60°,30°,75°		7.8 m	498 m^h
Existing apartment blocks		75°	4 stories	14.32 m	1767 m^h
		75°	3 stories	11.37 m	1383 m^h

- Differences between approach A and approach B: According to both approaches the height and the volume are same for the parcels on the streets. But the difference is encountered in the mid site parcels' volumes. In the case of approach B mid site parcel adjacent to the parcel on the east street, defines itself smaller to protect the other. In the case of the approach A, we do not have the chance to use this unexpected effect as a variable. So in the approach A, the adjacent parcels will be casting shadows on each other (Figure 4.24). In conclusion it can be stated that Approach B performs better in the means of solar zoning principles.

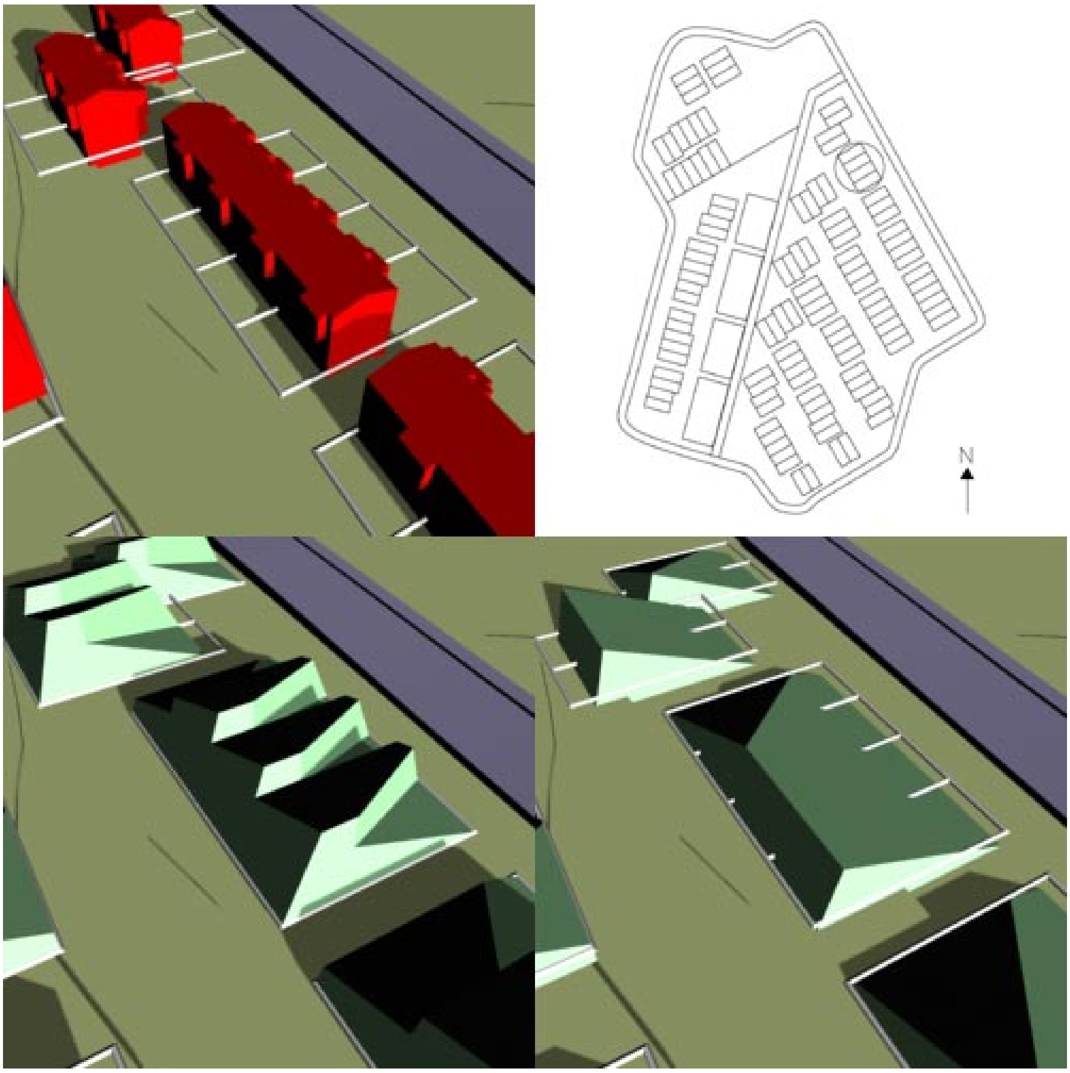


Figure 4.24. Figure shows the shadows cast by existing buildings (upper left), envelope of approach A (down left), and envelope of approach B (down right) in the 21st of December at 10:00 in the morning

- Effect of orientation: In chapter 3, section 3.A.2.e the effect of orientation on solar envelope is briefly explained. In the same section this effect is graphically shown in Figure 3.10, which shows that envelope increases both in volume and height if the longer side of a rectangular site faces to south. According to the graph in Figure 3.10 the smallest volume is constructed for the site when the long site is deflected with 60º, which is the same with 30º deflected east of south parcels of Odtükent, which is the smallest envelope in the table 4.10. Similarly the parcels deflected with 75º east of south parcels are the ones having the minimum deflection from south (for the long side), which results with the greatest envelopes in three different orientations.

- A further comparison for every single envelope may be developed according to the existing situations. Solar envelope does not claimed to be the only variable to create architectural form but it can give three-dimensional guidelines to the designer. This volume may be called as one step processed, semi-raw, or ready to be sculpted bulk. Considering the maximum heights of the envelopes and the existing row houses, we see that approach B cannot satisfy the existing situation. If we consider the volumes of the parcels on the east street, we realize that they can hardly define same amount of volume with the existing situation, which means that these parcels cannot be developed with the same density with the existing situation. In site and west street parcels perform better in terms of volume. The reason for the parcels that are side to side but does not behave similar in terms of volume is the orientation. Principally the adjacent building blocks situated on cardinal dimensions and elongated as they face longer facades to south will define same volumes on east and west ends.

- For the case of the apartment blocks, the criterion of maximum height is not satisfied especially for the blocks of 4 stories. But the values about the volume are much hopeful which means that the solar zoning principles may satisfy similar density with a lower block organisation.

4.D.3. Overview for the potentials of solar envelope in architectural design:

- Formal potential of solar envelope: It can be evaluated that designers can get benefit in many ways from the above techniques during their design process. The application of envelope technique on Odtükent residences helps us to perceive some improper adaptations on site plan and some proximity problems (which could have been easily eliminated with slight shifts in orientations in the site plan stage of design) as mentioned in the analysis. It must be noted, however, that the whole residential area of Odtükent has not serious design problems in a general sense. The residential area has a low density and the settlement area has a big opportunity to use open spaces between the buildings. This situation is not always true for the urban with high-density areas. The envelope technique will be more helpful for such areas in the decision making stage of designs. For example, more incremental attitude, which is applied by Knowles and presented in chapter 3, would result with higher variety of designs. Figure 4.25 shows the collection of results for different parcels by different designer for Wilshire Housing project (Section 3.C.1). It is obvious that the buildings have similar attitudes towards the query of reaching higher spatial quality without rejecting market needs in the means of density. They all have cascading terraces, elaborate use of courtyards and sensitivity to orientation. Building profiles rise and fall with each site's envelope; change are attractive, with sudden changes in scale from one new project to another, or between old and new projects. Within this overall, unifying order, there is a diversity resulting from the self-expression of individual designers (Knowles 1981, p.242). Consequence is a coherent urban atmosphere resulted from environmental sensitivity, which is necessary for a sustainable development regardless of any fashionable design attitudes.

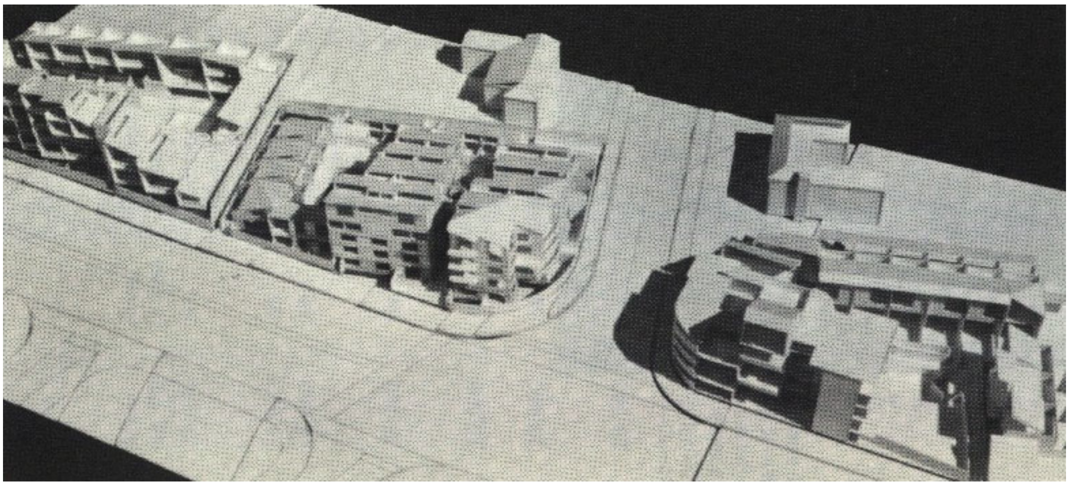


Figure 4.25 Model showing three parcels developed by different architects (Knowles 1981, p.242)

- Eliminating try and error: Sensitivity to the environmental effects and solar rights during the design process is not a new concept. Shade and shadows may be tested both for urban and architectural forms with contemporary devices of modeling and animation tools. An application of such an attitude may be the one followed in section 4.C.3.a.1 when we have tested the shadows of the existing situation of Odtükent. According to the results gathered from this analysis a designer may modify the design to supply more success in the means of solar rights and energy conversion. This feed back may be repeated for a few more times. Applying solar envelope method will inevitably eliminate the time consumption caused by try and error. Solar envelope represents the maximum developable volume not to cast shadows around the site. This three dimensional limit is a result of space and time constraints that are specific to a particular site. Spatial constraints are, latitude, parcel shape and size, slope and orientation, which are all considered by a designer in design process. Relative motion of the sun according to the earth is examined in coherence with spatial constraints by solar envelope method. Consequently solar rights and energy conversion performances of the building turns in to a design input rather than a feedback.

- Density decision of urban plans: In the early stages of an urban development, urban planners evolve judgments of site selection, orientation and zoning principles. Such judgments are closed relation with the environing constraints that are main concerns of solar envelope. Considering that the urban plans giving vertical limits for development, solar envelope does the same thing with a different attitude. In addition to the market constraints, solar envelope shows awareness to, solar rights performance to supply advanced level of life quality and energy conversion performance to fulfill sustainable development. According to Knowles' (www-rcf.usc.edu), and Capeluto and Shaviv's (2001, p.275-280) works solar envelope does not prevent density in urban development, but organizes it. Knowles reached 5-7 stories of housing blocks, which means a satisfying density even for Ankara, in urban environment of Los Angeles (www-rcf.usc.edu). In some cases solar envelope may give way to a high-rise development as Knowles presented in the Bunker Hill Project (Knowles 1981, p.257-282), which is presented in section 3.C.2.

CHAPTER 5

CONCLUSION

The complexity of production process of architecture, in the means of changeability of concerns of designers and users, resulted with numerous manifestations of form generation. Solar envelope, as a technical method does not manifest an overall design method. It bears on the necessity of adaptation of man-made world to the environment. This adaptive behavior is the underlying reason of the desire of maximum comfort that people seek for. Exclusive behavior during this search caused lack of interaction between artificial environment and natural environment. Further loses are the expiration of limited sources of earth and lack of quality of life. In this thesis the significance of solar access, is underlined to reach resource conservation and a higher average of life quality. For this purpose the role of solar access is examined under with its roles in improving life quality, in energy conversion, in solar rights concept and in form generation. As a result the method of solar envelope is presented as a design assistant.

- <u>Software Applications:</u> Solar envelope method is complete with the definitions and processes presented by R. Knowles for more than twenty years. But further studies require computational approaches. In fact we have mentioned some of the studies accomplished in USC under the supervision of R. Knowles but the speed of the developments are just as fast as the developments in computer engineering. Increased the capacity to process information of computers, people had chance to make more analysis that is digitally supported on solar envelope. Making observations on wider urban sites or a whole district may give us to evaluate the solar rights of every individual. Additionally as it is mentioned before effect of slope on solar envelope couldn't be efficiently observed with the tools (Solvelope, CalcSolar) available now.

- <u>Mobile Solar Envelopes:</u> A very challenging concept is expressed by R. Knowles giving perspectives for the future urban environments (www-rcf.usc.edu). In his paper "Interstitium", with P. F. Koening they proposed changing envelopes depending on the season. They construct an analogy with the adaptive behavior of the deciduous trees, which are in full leaves in summer to reach maximum solar access and lose their leaves in winter to provide passive solar gain. They exemplified this behaviour in traditional architecture with Spanish toldo, which is a textile covered the courtyard in summer and taken off in winter to get winter insolation. Considering that designing mobile architectural elements for the purpose of solar control and creating selective environments, with contemporary technology, they reinterpreted the Spanish toldo with solar and wind considerations. Consequently they said that interstitium of solar envelope may raise and decay with seasons, accommodating modern flexible structures. Such an attitude allows architecture to explore a rhythmic design strategy with implications for energy and life quality. (www-rcf.usc.edu).

Instead of a fixed image of the city, people see a transforming picture that, as in the Spanish courtyard, corresponds with the tradition. The result can be a connection to nature that has been missing in our era. Space and form are no longer static concepts.

- Solar Envelope for Ankara: Another challenge of study is the starting the arguments about quality for human life and benefits of solar rights in the context of Turkey. If Turkey wants to be involved in the trials of escaping from the dependence to the fossil fuels, energy efficiency and maximisation of the alternative energy use should be primer concepts. Necessity of the access for any kind of utilisation of solar energy that is available all over the globe becomes a concern for Turkey.

Unfortunately in the improvement regulations of Ankara there are only two direct references related to solar access. First is about the sun breakers. In the 5th section, item 46-4-b lets the owners to construct sun breakers for 0.40m horizontally exceeding from the closed projections of a façade (ABBİY 1999, p.39). Second is in the same sections 54-1st item about the day lighting and ventilation of the flats. It is said that living rooms, bedrooms, kitchens, bathrooms, WC's, and staircases should be day lit and naturally ventilated, and added that day lighting and naturally ventilating one bedroom and one living room, is enough for every separate unit (ABBİY 1999, p.52).

If we make a closer look, we realize that regulations use similar tools to arrange privacy rights that are used to provide solar rights. These are setbacks, height limitations, and projection limitations. These are elements that directly affect the form generation process of architecture just as the solar envelope but the difference is in their motivations. In comparison it is obvious that it does not have preciseness as solar zoning principles. It is so hard to realize that these regulations are set for Ankara. Claiming that special quality desired for the city of Ankara can be found in the regulatory improvement plans, will not prove itself that it is hard to say that Ankara gives a satisfying quality of life to the settlers. Thus we should add that the attitudes of improvement plans should be supported with solar zoning concerns, at least to a certain extend. A counter evaluation may be done on solar zoning principles in relation to the market needs and urban density performance. Without falling in to fallacies of neglecting, solar zoning seeks for a synthesis of solutions.

- Solar Envelope in Design Studios: In addition to these fields of studies, education is an additional aspect that environmental sensitivity and consciousness about solar access are to be promoted. Being equipped with the solar access consciousness and assistant methods like solar envelope, a student may feel confident about trials on creating spaces manifesting high quality of life for the occupants. Such equipment will ease to understand and realize the potentials of the context that is unique for every design problematique. We clearly know that solar access consciousness and solar envelope has already been issues of either elective or must courses. Moreover being supported by the digital media, which is probable for solar envelope by various channels, during education process, is inevitable for the contemporary member of the architectural faculties.

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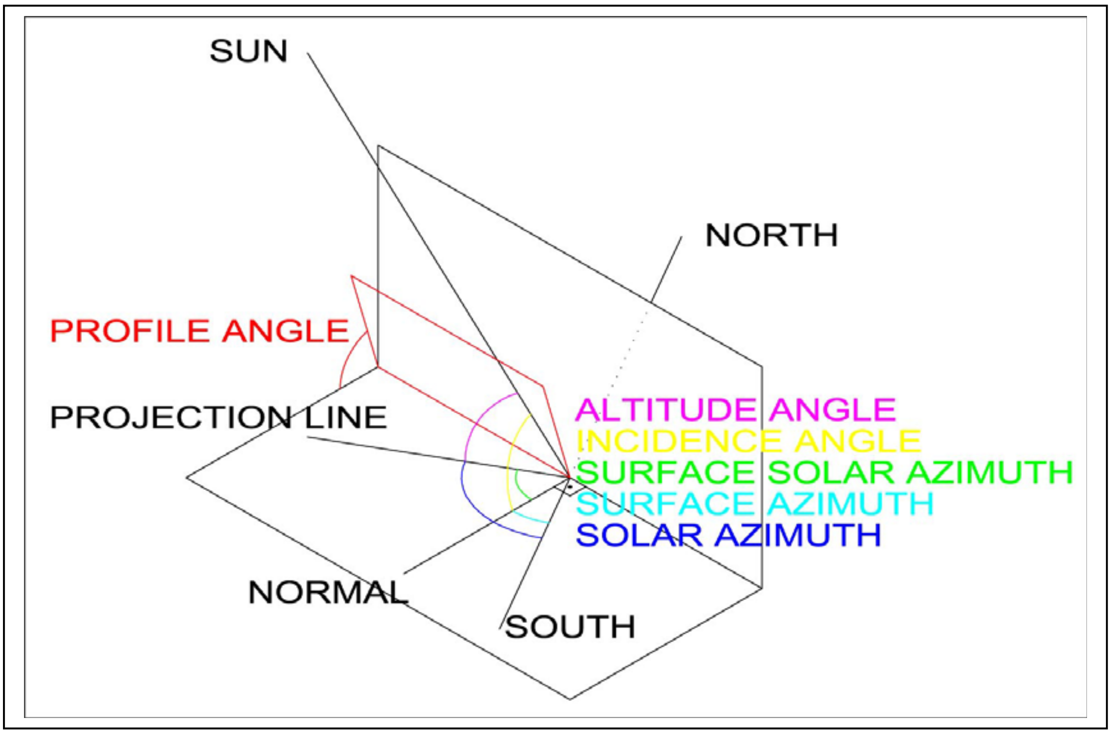
APPENDIX A



Solar Altitude in degrees is the angle between the earth-sun line and its projection on the horizontal.

Solar Azimuth in degrees is the angle between the projection on the horizontal plane of the earth-sun line and north-south line in that same plane. The azimuth line is eastward in the mornings and westward in the afternoons.

Incidence Angle is the angle between the direct rays of the sun and line normal to the surface.

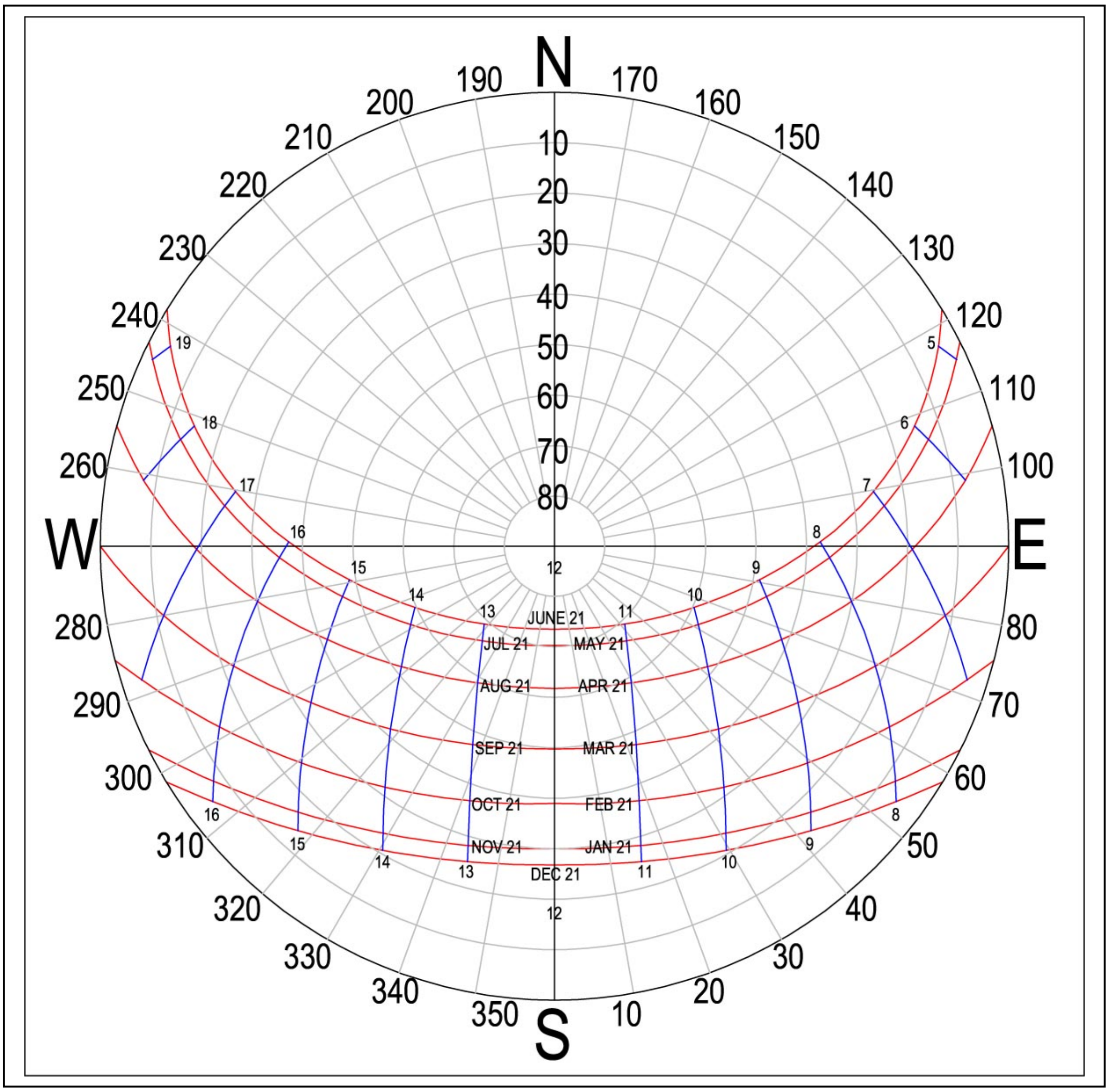
Profile Angle (Vertical Shadow Angle) is the angle between a line normal to the surface and a plane tilted about a horizontal axis in the plane of the vertical surface until it includes the sun.

Surface Azimuth is the angle between the line normal to the surface and south line.

Surface Solar Azimuth (Horizontal Shadow Angle) is the angle between the projection on the horizontal plane of the earth-sun line and the line normal to the surface.

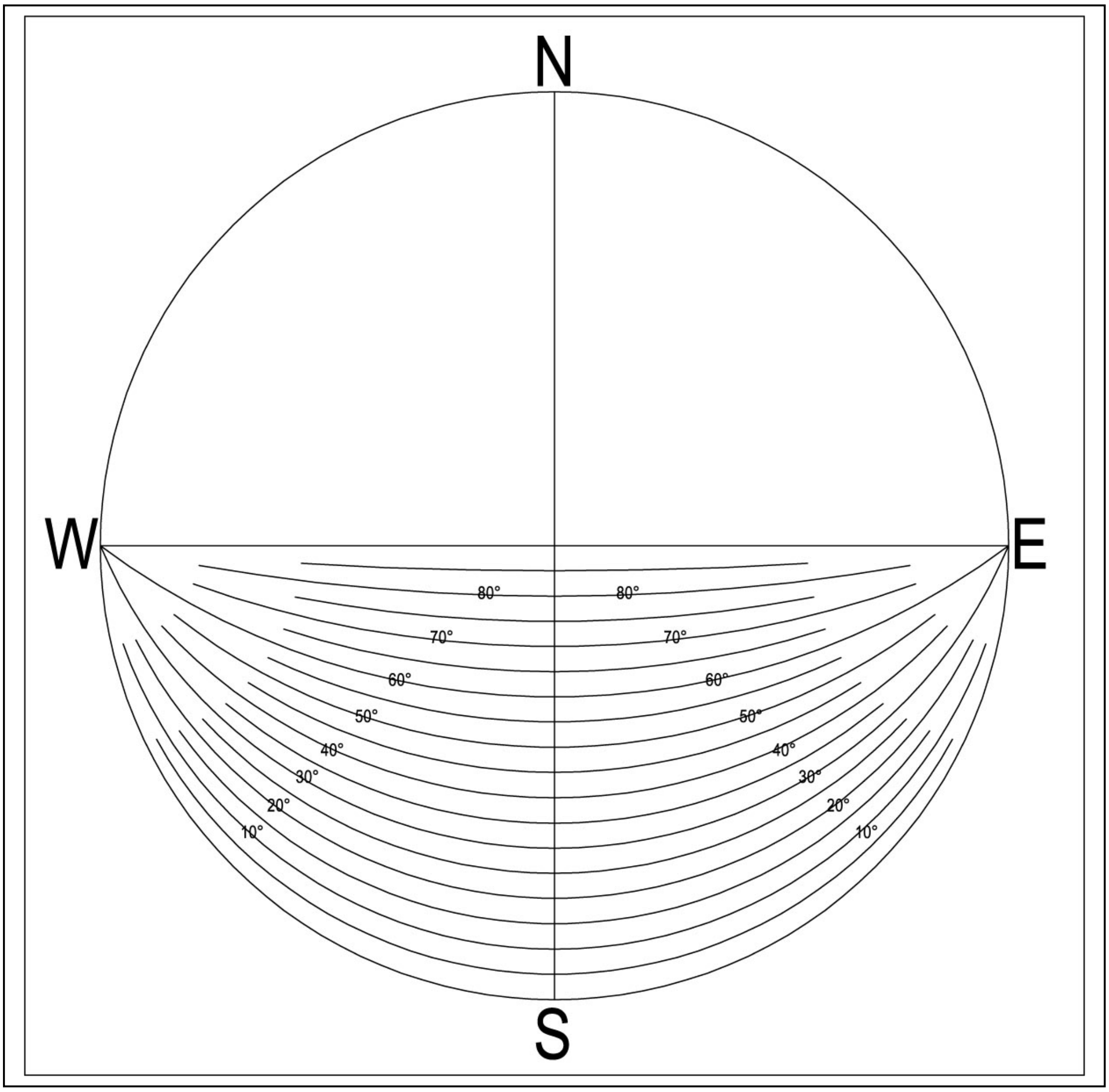
Appendix A: Definitions for solar angles (Demirbilek, 1984; p.7-8)

APPENDIX B



Sun chart for 40º N Lat., is drawn in Sun Path Diagram Plotter

Source: http://www.usc.edu/dept/architecture/mbs/tools/ecsdnld.html



Profile Angle protractor supplied form course notes of ARCH 282 ‘Design of Energy Efficient Buildings’ (METU)