INTEGRATION OF NATURAL VENTILATION TO OFFICE BUILDING TYPOLOGY IN THE ANKARA CONTEXT: A CASE STUDY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

AHMET UĞURSAL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF ARCHITECTURE

AUGUST 2003

Approval of the Graduate School of Natural and Applied Sciences

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ABSTRACT

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August 2003, 112 pages

Together with a global concern for the reduction and conservation of energy, the oil crisis of 1973 brought about a turning point in the design of buildings. Responses in this vein were mostly concentrated on the simplistic one of sealing the building against outdoor conditions. This approach towards energy consumption, associated with the introduction of air-conditioning systems, led to different problems such as Sick Building Syndrome. Lack of user satisfaction also appeared to be a common complaint in such sealed, air-conditioned buildings, leading to a marked drop in employee efficiency and, hence, return on capital investments.

In this study, Emek İşhanı, a sealed office building located in Ankara, whose curtain wall system was renovated in 2001, was investigated in terms of its natural ventilation potential under two sub-topics. With a survey conducted, user perception towards environmental conditions, and health problems they suffered were investigated. With a computer simulation, natural ventilation potential of the building in terms of energy consumption was examined.

It was resulted from the survey that building occupants have serious health problems. They are also not satisfied with the way the ventilation system functions and most of the occupants liked to have a window opening to outside in order to adjust the inner conditions. It was resulted from the computer simulation that integration of natural ventilation did not make any significant difference in the annual energy consumption of the building. On the other hand, cooling loads of the building were eliminated in summer months. As a result, introduction of natural ventilation appeared to be an appropriate tool for more user satisfaction and energy conservation.

Keywords: Office Building, Natural Ventilation, Sick Building Syndrome, Energy Consumption, Computer Simulation

ÖZ

DOĞAL HAVALANDIRMA'NIN OFİS BİNASI TİPOLOJİSİNE ANKARA BAĞLAMINDA ENTEGRASYONU

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Ağustos 2003, 112 sayfa

1973 yılında ortaya çıkan petrol krizi, kullanılan enerjinin azaltılması ve korunması yönündeki küresel yaklaşımla birlikte, bina tasarımlarında bir dönüm noktası olmuştur. Bu konudaki yaklaşım, daha çok binanin dış hava şartlarından yalıtılması şeklinde gerçekleşmiştir. Enerji tasarrufunu amaçlayan bu tutum, klima sistemlerinin de kullanılmasıyla beraber Hasta Bina Sendromu gibi ciddi problemlerin oluşmasına sebep olmuştur. Ayrıca kullanıcı memnuniyetsizliğinin bu tür dış hava şartlarına kapalı binalarda genel bir şikayet olarak ortaya çıkması, çalışanların verimliliğinin düşmesiyle beraber uzun vadede daha büyük maddi kayıplara yol açabilmektedir.

Bu duruma karşılık, bu çalışmada Ankara'da yer alan ve 2001 yılında giydirme cephe sistemi değiştirilen Emek İşhanı'nın doğal havalandırma potansiyeli iki açıdan incelenmiştir. Bina kullanıcıları ile yapılan bir ankette, çalışanların iç ortamla ilgili görüşleri ve sağlık problemleri araştırılmıştır. Yapılan ikinci çalışmada binanın doğal havalandırma potansiyeli enerji kullanımı açısından incelenmiştir.

Yapılan anket çalışmasına göre bina kullanıcılarının ciddi sağlık problemleri vardır. Ayrıca kullanıcılar havalandırma sisteminin işleyisinden memnun olmamakla beraber, pek çoğu iç ortam şartlarını ayarlamak için dışarıya pencere açma isteğini

belirtmiştir. Yapılan bilgisayar simülasyonuna göre, doğal havalandırmanın entegrasyonuyla, binanın yıllık enerji kullanımında önemli bir değişiklik olmamaktadır. Diğer taraftan, yaz ayları için binayı soğutmada kullanılan enerji giderleri ortadan kaldırılabilmektedir. Sonuç olarak, doğal havalandırma daha fazla kullanıcı memnuniyeti ve enerji tasarrufu icin uygun bir araç olarak ortaya çıkmıştır.

Anahtar Kelimeler: Doğal Havalandırma, Hasta Bina Sendromu, Enerji Tüketimi, Bilgisayar Simülasyonu

To the Earth

ACKNOWLEDGEMENTS

First of all, I am thankful to my supervisor Mr. Arda Düzgüneş for his critical viewpoint on the subject and the study, and to Mrs. Soofia Tahira Elias-Özkan, for her support to the study and belief in me. I am also thankful to all jury members for their invaluable ideas.

I would like to thank to Ms. Elif Sönmez, for her guidance on the survey of Emek İşhanı, and to Mr. Erol Kalelioğlu for providing information on the HVAC system of the building.

Finally, I am grateful to Elif for everything beyond the words and to my family for supporting me for the last twenty-six years to realize this study, and of course to all my friends, especially Aydın.

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INTRODUCTION

In this chapter is presented first, the initial idea and framework of the study. Arguments are explained in relation to scholars who worked on similar subjects. Objectives are mentioned as primary and secondary objectives. The procedure of the study is explained in the next part, and finally the contents of the study were briefly explained under disposition.

1.1 Argument

At the beginning of the 21st century, people were spending most of their time inside the buildings. There is a complex network of buildings that people move about in during a typical day. As may be predicted, the condition of those buildings is directly related to the well-being of their occupants. Among many other building types, offices have greater importance, because people spend most of the typical day in such offices. These office spaces are generally densely occupied areas where occupants cannot behave without considering the occupants of the same space. In other words, office spaces support certain behavioral patterns while restricting certain others and minimize realization of individual preferences. This is mainly because offices are places for production and efficiency is the key element in such production. There are some other reasons such as security, maintenance *etc*. which are not the concern of this study.

Norms were introduced to office environments to provide a certain amount and quality of activity. The problem was that those norms were determined in laboratory environments, which generally do not meet the actual needs of the occupants; and consciously or not human well-being is ignored for the benefits of the corporations. Moleski and Lang (1986, pp.4-5) refer to Katz and Kahn who formulated the office environment as follows:

> A corporation is a complex social organization consisting of a system of structural, functional and social components. Within this system, people behave in an interrelated fashion according to the norms, values and roles that are formed by the goals of the organization and accepted by its members. A social organization reduces the variability of human behavior by three types of pressures: task requirements in relation to satisfying an individual's needs; demands arising from shared values and expectations; and reinforcement of accepted rules.

As explained above, in the complex environment of offices, many problems occur. Hartkopf, Loftness, Drake, Dubin, Mill & Ziga (1993) pointed out that the Architectural and Building Sciences Directorate of Public Works of Canada identified the following serious problems, after extensive commercial building performance evaluations:

- Spatial problems for cabling, storage, privacy, and way-finding;
- Acoustic problems of people and equipment, untempered (if not amplified) by building interiors;
- Thermal problems of excessive heat, of unbalanced mean radiant temperatures, of local controls not adjusted for the occupancy, and of local sensors not corresponding with local controls (due to frequent spatial/layout changes);
- Air quality problems due to low air changes per hour for energy conservation, outgassing from materials and equipment, and short-circuiting from air supply to air return above poorly designed interior systems; and
- Visual problems of glare, brightness contrast, and flicker from overpowering arrays of light fixtures and unmanaged windows.

The two issues, which are thermal comfort and air quality, have become problems after the energy crisis of 1973. After this energy crisis, decreasing the global energy consumption became the major goal. The solution used for the reduction of energy use was formulated mainly around the increase of insulation levels of building envelopes, which reduces air infiltration by sealing the building. By this method while the inner environments became more controlled, they also became more uniform according to the norms.

Today the situation is that a solution to a problem has created another set of problems that are more important and severe than the previous ones. Occupants of office buildings are now suffering from diseases due to humidity condensation or bacteria and fungi that grow inside. Productivity decreases due to poor indoor air quality determined by low-air change rates. This situation was created to consume less energy in buildings. However, there are two points that energy conscious design should find a balance between:

> The thermal performance of the building envelope and the appropriate selection of techniques for heating, cooling and daylighting; and an acceptable quality of indoor climate in terms of thermal comfort, ventilation effectiveness or indoor air quality (Allard, 1998, p.1).

In this study, employment of natural ventilation techniques has been proposed as a solution to the problems of office environment. It was accepted that natural ventilation with a good design is logical and applicable to many types of buildings from low-rise dwellings to high-tech office buildings in many climates. Employment of natural ventilation in office environment, with appropriate integration, seems to provide answers to many complaints, associated with Heating, Ventilating and Air Conditioning (HVAC) systems, such as noise, health problems (eg. Sick Building Syndrome), requirement for routine maintenance and energy consumption. Moreover, natural ventilation of an environment is preferred by the occupants, because it provides a healthier and more comfortable indoor. This approach of integrating natural ventilation to office buildings will be mainly the introduction of an old knowledge in the 21st Century once more with the help of modern technologies. Design of the naturally ventilated office environment requires more work than the design of a usual sealed office building. However, reduction of maintenance costs of the mechanical equipment and increased worker efficiency compensate initial expenses of the building design process. More importantly, as buildings are the main elements of life that serve the well-being of their occupants, and providing healthier and more pleasant environments should, in any event, be the main objective of architecture.

1.2 Objectives

Objectives of this study were formulated under the purpose of achieving more energy efficient and healthy office buildings in the Turkish context. There are two sets of objectives defined, one being the primary and the other being the secondary set.

One primary objective of the study is to bring up the problems that originating from the ventilation design of a typical office environment and to establish awareness among researchers and professionals for healthier and friendly working environment. Another one was to introduce natural ventilation to the design process as one of the main considerations for more energy-efficient buildings. The last primary objective was to provide a guide for future researchers and professionals.

Secondary objectives of the study can be grouped under three topics of which the first is to determine the problems of HVAC system in the Emek İşhanı and develop an approach for similar studies. The second one was to determine the type of diseases that the occupants suffer in the building under study and make the building management be aware of the complaints. The last secondary objective was to raise an awareness among the occupants of office environments towards their working conditions.

1.3 Procedure

In the first phase of the study an interview is conducted with the mechanical engineers of the building to get the information of the system of ventilation and energy consumption before and after the façade of the building was changed. Issues that were considered for the design of the new façade system were also given importance, since they are highly related to occupant satisfaction.

In the second phase of the study building related sickness of occupants in general were compiled from similar studies conducted on this subject. A survey for the occupants of the Emek İşhanı was prepared to determine the occupants' perception and problems associated to that specific working environment.

In the third phase, occupants from sample rooms on different storeys and on different façades of the high-rise building were selected to apply the questionnaire prepared. The results of the questionnaire were evaluated with appropriate statistical applications to determine the overall satisfaction level, and ventilation effectiveness and related factors.

Fourth phase covered the simulation of the building's energy performance with the Energy-10 software application. In this part, two simulations were run simultaneously. First one was based on the actual condition of the building, the second one was formulated on the assumption that building has a different ventilation system which integrates fresh air from outside without any intervention and a different kind of HVAC system which works only for heating purposes. The results were compared on day-by-day basis to determine the optimum conditions for different times of the year.

1.4 Disposition

This report is composed of five chapters, of which the first one is the 'Introduction.' In this chapter aspects of a working environment is covered first and then problems related to that environment are explained briefly. Finally, natural ventilation is proposed as solution to those problems. In the second chapter, which is the 'Literature Survey,' general aspects of office buildings were clarified at first hand, including their historical development. Then, importance of 'Indoor Air Quality' is emphasized. Following this are given the characteristics of airflow and natural ventilation design. In the next part, principles of energy-conscious design was detailed. Finally is explained the human comfort in relation to air movement and bioclimatic chart. In the third chapter, user satisfaction and ventilation effectiveness survey is explained. Firstly, the survey material and secondly the survey methodology were described. Then, results of the analysis are explained in 'Results and Discussions' under two categories one of which is the 'overall satisfaction' and the other is 'ventilation effectiveness'. In the forth chapter, computer simulation of Emek İşhanı is explained. First was explained the simulation material. Then was described the simulation methodology. Finally is presented the results and discussion of the simulation. Annual energy use, gas emissions, cost breakdown, indoor temperature investigations are explained for existing and hypothetical situations. Since two different studies wee conducted on Emek İşhanı, materials and methodology of each study, presented in chapter 3 and 4, are given seperately in order to make the subject clearer. In the last chapter, namely the 'Conclusion,' is presented the concluding remarks of survey and simulation; and wider issues are also discussed.

CHAPTER 2

LITERATURE SURVEY

In this chapter, first are explained the office buildings and related concepts. Development of office buildings is clarified under the guidance of energy consciousness and HVAC systems development. Then, effects of environmental conditions over humans were explained. This is followed by issues related to indoor air quality. Those issues are indoor pollutants, Sick Building Syndrome (SBS), HVAC systems and individual control. Following this, concept of energy conscious design was further detailed. Then, natural ventilation was explained under the subjects of characteristics, levels of design, types and uses, and relation to high-rise buildings. Finally, the effect of air movement on human comfort is elucidated together with bioclimatic chart.

2.1 Office Buildings

Arnold (1999a), referring to Pevsner's book titled 'History of Building Types' states that the first office building in history is the Uffizi in Italy. This building was designed by Vasari and built in the city center of Florence between 1560 and 1581 to accommodate governmental offices of the State of Tuscany. However it was not until the 19th Century that large office buildings in modern terms did appear.

At the end of the 19th Century, one of the major constraints in designing an office building was the provision of adequate lighting. As Arnold (1999a, p.42) states "Although electricity was common by the 1890s, the cost and output of the lamps meant that office work was still largely carried out by daylight". This meant that the planimetric depth of the floor had to be limited between the outside wall and internal corridor wall. On the other hand, this situation gave the opportunity to ventilate the building by means of operable windows. Major obstacle was providing adequate daylight but keeping cool was not a major concern. Ventilation was necessary mainly for sanitary purposes and for the elimination of excessive humidity (Arnold, 1999a).

2.1.1 Development of Office Buildings

In this section, is first explained the development of office buildings under the guidance of advances in technology. The effect of oil crisis of 1970's on building technologies, and the effect of HVAC systems on build designs are detailed. Then the understanding of office environment from a more theoretical standpoint is clarified and finally the impact of environment on workers is further explained.

(i) Emergence of Sealed Office Buildings

As it is noted earlier, oil crisis of 1973 was the turning point in the development of contemporary office buildings. Energy policies of western countries were regulated to reduce global energy consumption mainly used for heating and air conditioning. This development of a sealed office-building concept is detailed in this section.

O'Sullivan (1988) indicates that buildings used to be naturally ventilated through opening windows and there was sufficient amount of fresh air to breathe. Same author identifies 1973 oil crisis as the time that everyone began to seal the gaps and cracks in their houses and places of work, to thus reduce the volume of occupied space, hence, the volume of heated air provided to each person. The main objective was to reduce the fuel bill by reducing heat loss through ventilation.

Nielsen points out that the idea of unsatisfactory air quality being a present-day problem of buildings is widely subscribed to. According to him, people who adhere to this view think that

> The difference between good, old buildings and poor, modern buildings- in terms of indoor climate- is that modern buildings are tighter. To save energy, buildings are being made increasingly tight, and sophisticated mechanical ventilating systems must cope alone with what used to be taken care of leaks and simple ventilating systems (Nielsen, 1988, p.128).

Holdsworth & Sealey (1992) taking a position like Nielsen, indicate that reducing the infiltration of air resulted in sealed buildings. According to the authors, sealed buildings create, moreover, unforeseen problems of pollution of the internal microclimate, and people show a desire towards fresh air.

According to O'Sullivan (1988), introduction of sealed office building concept creates more general problems other than the decreased level of indoor air quality. O'Sullivan states that approaching to the problem of energy consumption from the point of reducing the amount of fresh air available to each person changes the norms; so, instead of traditional levels, minimums become those norms. This situation is highly associated with the use of mechanical ventilation and air conditioning. The result of this changing of norms is that margins of safety for acceptable indoor environments are reduced, which means that acceptable risks tend to become problems. This is a problem that will be repeated by the designers and practitioners who are to use those norms in their future designs.

(ii) Office Building-HVAC Development

Ventilation and daylighting were the two major constraints for every office building at the beginning of the 20th Century. Arnold (1999a) gives the example of New York of 1900, where buildings were reaching heights of 120 meters, though floor plans and sizes were constrained by daylighting needs for clerical work. As result of the preoccupation with ventilation in that era, mechanical ventilation was introduced to many new large and tall buildings.

According to Arnold (1999a), the Larkin Building was probably the first building that was designed to accommodate all the aspects of modern air conditioning. This building was designed by Frank Lloyd Wright and completed in 1906. The owner required a sealed building with mechanical ventilation. Although it was not specified, Wright also designed a refrigeration plant for cooling this building.

Although the Larkin building was widely reported and known at the beginning of the 20th Century, development of air conditioning in offices did not gain much popularity for the next 20 years. By the mid-1920s theatres, hotels and department stores and very rarely offices were the building types in which air conditioning was installed (Arnold, 1999a). To quote him verbatim "In fact, the skyscraper 'as we know it' evolved without the benefit of air conditioning. Classic buildings such as the Woolworth and Chrysler reached unprecedented heights by relying on nature to provide lighting and ventilation" (Arnold, 1999a, p.45).

Arnold (1999a) states that the Johnson's Wax Company Administration Building again designed by F. L. Wright and completed in 1939, was the first building that really took the advantage of the air conditioning system. Apart from air conditioning, Wright included innovative features such as "hydronic underfloor heating and clerestory windows constructed from bundles of glass tubes to produce diffuse light" (Arnold, 1999a, p.53). However, there was a problem for tall buildings of that era associated with air conditioning. Mechanical plants placed at intermediate levels to reduce vertical duct sizes, were creating the major drawback, because of the very limited space remained (Arnold, 1999a).

Another change occurred in the 1930s, when the United States recovered from the great depression. Air conditioning sales doubled in one year and major manufacturers produced room air conditioners, which were mostly applied to offices. However, although this new terminal system was known and published, applications did not changed from the earliest installations of centralized air conditioning (Arnold, 1999b).

Willis Carrier, who is the inventor of modern air conditioning, recognized the problems of air conditioning systems in the 1920s and proposed high velocity air as a solution. In the 1930s, he further developed the idea into an 'air and water' terminal. The first installations of this kind of system were completed in 1940, just before the United States entered the war and all building activity was suspended (Arnold, 1999b).

According to Arnold (1999b) the air and water induction unit air-conditioning system had some advantages over the all-air systems used at the time:

- Most heat gain and loss from the building is through the window and the under-sill location of the units compensates with minimal effect on the room condition.
- Heating and cooling energy is transported around the building by water, a much more efficient medium than earlier systems that used air.
- Considerably less vertical duct space is required, as the main supply ducts operate at high velocity and only handle enough air to meet the minimum fresh air ventilation requirements.

Arnold (1999b) indicates that, during the 1950s and the 1960s, light, and transparent buildings, achieved by curtain walling became very popular. Moreover air conditioning in this type of buildings was so integrated that it was impossible for buildings to operate without it.

The concept of a new all-air system (VAV-Variable Air Volume) was introduced in the late 1960s. This system was intended "to provide air conditioning from the window wall to the core, independent of depth and only supplemented by heating at the perimeter" (Arnold, 1999b, p.38).

Arnold (1999b) also states the advantages of VAV system over the constant flow systems used previously. In VAV system, airflow rate varies with the rate of cooling; therefore, less energy is consumed to deliver the decreased rate of airflow. Also the maximum duty of air handling plants could be kept less because, the maximum demand for cooling never coincides simultaneously in all spaces. Also outside air was incorporated to provide cooling when outside conditions were appropriate.

Arnold (1999b) points out the disadvantages of VAV systems, one of which is the size of the air-handling plants and ducts. They were occupying twice the floor space and VAV needed ceiling voids 30% deeper. This was creating undesirable situations especially for high-rise buildings. Solution to the problem was installing air-handling plants at each floor supplied with only the minimum rate of fresh air by other means.

Beginning from the mid-1970s, air conditioning systems gained a vast popularity with energy crisis and VAV was the dominant system employed during the building boom of the 1980s. But during this period alternative solutions to cooling by passive means, namely natural ventilation, were produced by some designers (Arnold, 1999b).

As a conclusion, Arnold (1999b) claims that air conditioning had two major effects on office buildings. First one is that, offices were designed without considering the passive means of providing comfort conditions. Second one is the introduction of new materials and building techniques based on the idea that air conditioning is the element to provide comfort conditions.

(iii) Contemporary Office Case

Davis & Szigeti (1986) argue that large proportion of office buildings were constructed in the last two decades 'to accommodate large number of white-collar workers,' but authors further argue that occupants of those buildings are often dissatisfied with the way those spaces function and it is thought that office spaces fail to meet the needs of the workers.

To clarify the notion of 'working space,' Goodrich (1986) defines six different subsystems or dimensions in a sociophysical system of work environment:

1. People: the kind of people who work in the office, their psychological characteristics, and their needs, perceptions and expectations.
2. Work: the work system, its organization and requirements, and the tasks these people perform.

3. Social Processes: communication, relationships, group processes, and what is usually described as the informal organization.
4. Organization: the organization itself, including its culture, resources, business plan, and competitive environment.
5. Technology: the technology that is used by people to perform their work activities.
6. Environment: the designed environment (including various building and interior systems) itself.

The scope of this study falls into the subsystem of ‘Environment.’ Moleski & Lang (1986, p.8) argue that physical setting functions to support the behavior in three different ways, one of which is the “physical elements required to sustain the physical states necessary for an individual to satisfy his or her needs.” Those physical elements are light, heat, sound, sanitation, firmness of surface and smell. This concept of ‘physical elements’ is very much related to the understanding of Goodrich’s notion of ‘Environment.’ The other two functions are “to provide physical facilities and spatial arrangements that aid specific activity patterns and hinder others” and generating and maintaining “mental and emotional states necessary for need satisfaction by fulfilling symbolic, aesthetic, and ambient functions” (Moleski & Lang, 1986, p.8).

It is mentioned by many authors that the mentality of designing an office space should be adapted to the needs of the contemporary working understanding. Moleski & Lang (1986, p.3) refer to Ackoff, who argued that “In today’s dynamic world, corporate organizations are faced with massive changes, affecting their nature, the work they perform, and their members.” Moleski & Lang (1986, p.3) also refer to Pava on this subject who indicated that there is a necessity to make “innovations in the design of corporate workspace, including the restructuring of the environmental-planning process.” Same authors also argue that “because of complexity and diversity of needs, office design must go beyond solutions for the so-called physiological and task needs and provide for more complex, social and psychological needs” (Moleski & Lang, 1986, p.15).

Goodrich's six sub-systems of an office environment, namely, people, work, social process, organization, technology and environment were mentioned earlier. Moleski & Lang (1986) take this position to a more specific level and they categorize the physical environment into four parts. They are spatial organization, environmental components, environmental attributes and perceptual qualities. The part, related to the subject of this study is environmental attributes. Environmental attributes are the elements that give the activity site its character and mode; those attributes include lighting, temperature, color, materials and acoustics.

The relation of these environmental attributes to the well being of the workers is very critical in today's working environment, because they directly affect the efficiency of the worker, thus of the organization. Goodrich (1986), referring to Building Programs International, states that 90% of the costs are salaries and benefits and the other 10% is for creation, construction and operation costs over the life of a typical office building Moleski & Lang (1986, p.15) add to the subject such that "the inconspicuous cost of a building not conforming the human values of the user is much more greater than the conspicuous cost of the building construction."

From the brief information given above it can be inferred that changing the design approach of office buildings to a human base is highly essential not only for the well being of workers but also for corporations.

2.1.2 Effect of Environmental Conditions on Humans

Moleski & Lang (1986, p.8) call the physical setting as the "[…] man-made container of behavior, which acts as a filter between people and the natural environment." The sixth sub-system defined by Goodrich, which is environment, is one of the main elements of the so-called 'man-made container of behavior' that effects the condition of humans in office spaces. Boutet (1987) states that climatic conditions affect the individual performance and the capacity of the body. With the capacity of the body, Boutet means the capacity of physical and mental work, sleep, rest and overall enjoyment of life. Boutet (1987, p.33) further argues that "A suitable cimate will produce feelings of vigor; an unsuitable climate will stimulate depression; and a lack of climatic conditions destroys vigor and hapiness of, and brings about the atrophy of disuse in men."

Davis & Szigeti (1986) formulate the problems affecting the users in the working environment under three categories. The first includes those causing physical health hazards; the second, those affecting peoples' relations to each other and to their environment; and the third, those that impede the work effectiveness of individuals and/or groups. However, Hartkopf, Loftness, Drake, Dubin, Mill & Ziga (1993) classifies the problems of an office environment as: spatial, visual, thermal, air and acoustic quality problems as well as building integrity problems (Table 2.1).

Finally, Moleski & Lang (1986, p.8) argue that "Before the human context for the solution can be established, there must be a humanistic interpretation of the worker's values and needs."

Table 2.1. Problems in the Office Environment
Source: Hartkopf *et al.* (1993)

Spatial quality problems	• Tripping, ducking cables and cable changes • Pile-ups of print-out and computer peripherals • Work surface now covered by equipment • Neck strain from screens on conventional desk • Tired arms, backache from keyboards on desk • Sitting long hours in "dining room" chairs
Visual quality problems	• Glare from windows without controls • Reflections of light fixtures/windows on screens • Coping with contrast ratios (from black-on-white text, to white-on-black screen) • Headaches, eyestrain from focusing on screen
Thermal quality problems	• Overheating from equipment, hotspots (500-1000 W each) • Radiant heat effect near equipment • No heat, air when high partitioning is introduced
Air quality problems	• Outgassing from some equipment and wiring • No control of fresh air, removed from windows (because of glare) • Need for more environmental change and control owing to reduced mobility
Acoustic quality problems	• Printers without acoustic covers (sold separately) • Annoyance from some keyboards (clicks) and disk drives (whirrs) • Modified mechanical systems with greater noise • Future voice-activated technologies
Building integrity problems	• Unanticipated weight of equipment and paper • Heightened need for dust-free environment

2.2 Indoor Air Quality

In this section the concept of Indoor Air Quality (IAQ), pollutants in an indoor environment, Sick Building Syndrome (SBS), which is an air-quality-related problem, are presented in detail.

As stated earlier, after the energy crisis of 1973, ventilation was appeared to be the easiest target to reduce the energy expenses of a building. Fordham (2000) points out that ventilation equipments were adjusted to reduce the fresh air supply to buildings sacrificing the IAQ. Wineman (1986) cites Hardy (1974) and Wheeler (1969) for their study on office workers, who reached the conclusion that the two most important factors that affect the comfort of an office worker are good air circulation and the temperature in the workspace. Wineman (1986) also argues that these are the factors with which workers are generally dissatisfied. According to Yeang (1999, p.246), there are three major sources of poor IAQ, namely, "hermetically sealed buildings and their synthetic furnishings, reduced ventilation and human bio-effluents." Yeang (1999, p.246) also quotes Robertson who argued that more than 50% of poor indoor quality is due to inadequate ventilation.

2.2.1 Indoor Pollutants

According to Cunningham (1989), pollutants in an indoor environment were classified by ventilation engineers (ASRHAE 1985) under three types according to their source and method of formation:

- Dusts, fumes, and smokes, which are primarily solid particulate matter, although smoke often contains liquid particulates.
- Mists and fogs, which are liquid particulate matter.
- Vapours or gases, which are non-particulate.

Watts (1996) includes nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), radon, formaldehyde, sulphur dioxide (SO_2), ozone (O_3), mineral fibers, tobacco smoke, body odours and other substances into the set of indoor pollutants. Black, Roark & Schwartz (1986) list pollutants, sources and control methods in detail as presented in Table 2.2.

Table 2.2. Indoor Pollutants, Sources and Control Methods
Source: Black *et al.* (1986)

Indoor Pollutants, Sources, and Control Methods.

Pollutant	Sources	Control
Tobacco smoke	Cigarettes and other tobacco products	Smoke-free zones, rooms, and ventilation
Nitrogen dioxide (NO_2)	Gas combustion appliances, e.g., stoves, water heaters, unvented space heaters, furnaces, and kerosene heaters	Modify flame temperature, vent appliance, tandem combustion chambers, and room ventilation
Carbon monoxide (CO)	Same as No_2, plus fireplaces, and wood stoves	Modify combustion parameters, vent appliance, and room ventilation
Radon and radon daughters	Soil, rocks, and building material, such as bricks, concrete, stone	Vented crawl spaces, basements, seal conduits, and sumps; provide vapor barrier below slab
Formaldehyde	Building and insulating materials, furniture, adhesives, consumer products, and combustion	Modify production process, substitute stable adhesives, modify combustion appliances; room ventilation, cooling, and dehumidification
Carbon dioxide CO_2	Kerosene heaters, gas heaters, and people	Modify combustion parameters; ventilation
Asbestos	Ceiling and floor tiles, pipe insulation, thermal and acoustical insulating materials, concrete, and spackling compound	Removal, encapsulation, enclosure, and sealants; education of exposed individuals; warnings
Organic compounds	Building materials, consumer products, furnishings, polishes, waxes, maintenance materials, pesticides, and room deodorants	Substitute stable, nontoxic materials; room ventilation
Particulate matter	Combustion sources, wood stoves, fireplaces; biological agents, e.g., microorganisms, molds, pollens, and animal dander	Air cleaning, filters, and ventilation; cleaning of ventilation systems

Fanger (1988) in his research on unoccupied office buildings found that there are several pollutants in spaces and ventilation systems; and human bioeffluents comprise only 13% of the total pollutants. The same author also states that this situation was reflected different to the ventilation standards. Those standards accept the human entity as the main pollutant in an environment, thus ventilation standards are being identified according to the number of people in a space. In 15 office spaces that Fanger investigated he reached to the conclusion that materials and ventilation systems, which are ignored in standards, are the major contributors to poor indoor air quality. Those pollutants come from building materials, furnishings, carpets, books, office machines and ventilation system (Fanger 1988). Also Clevenger (1986, p.91) indicates that "smoking, materials and chemicals released from the building materials and equipment maintenance materials, and even ventilating systems themselves are under scrutiny." Fanger (1988) gives the ventilation requirements of offices based on the smoking conditions in Table 2.3.

Table 2.3. Ventilation Requirements in Office Buildings
Source: Fanger (1988)

	$l/s\ m^2$
Comfort equation (Indoor air quality = 1.4 decipol)	
Existing buildings (0.7 olf/m^2) smoking	5
Low-olf buildings (0.2 olf/m^2) non-smoking	1.4
ASHRAE Standard 62-81 (18)	
smoking	1.7
non-smoking	0.25
Nordic Guidelines, NKB (20)	
smoking	1.0
non-smoking	0.4
DIN 1946 Standard, large offices (21)	
smoking	1.9
non-smoking	1.4

*Assuming 0.1 person/m^2 and negligible outdoor air pollution

Robertson lists agents that cause Sick Building Syndrome (SBS) as 74% fungal, and 70 % bacterial contamination (quo. in Cunningham, 1989).

2.2.2 Sick Building Syndrome (SBS)

Reduced ventilation rates to conserve energy after the oil embargo of 1973, increased the contamination of irritating and toxic substances indoors, decreasing the quality of air. This change in the quality of air was accompanied by the economic motivations of building design, planning, construction, furnishing and operation. This situation led to an increase in complaints caused by psychological and health problems associated with indoor pollution. These complaints vary from reports of dizziness, drowsiness, headaches, and weight loss to skin, eye, or throat irritation to pneumonia and cancer (Levin, 1986).

Levin (1986) states that SBS refers to a set of psychological and health problems of office workers. Levin further argues that this is mostly a problem of modern office buildings. To quote the same author "Many investigations of building occupants' complaints in new or remodeled buildings have determined that the occurrence of these symptoms is significantly higher than in 'normal' buildings" (Levin, 1986, p.272).

According to Levin (1986) common symptoms of building sickness are: nasal symptoms such as blocked, itchy, or runny nose; eye symptoms such as itching, irritation or watering of the eyes; mucous membrane symptoms such as dry throat or stuffy nose; work-related asthma symptoms such as chest tightness, difficulty in breathing, and wheezing; and humidifier fever symptoms including fever, joint and muscle pains, tiredness, and headaches. Black *et al.* (1986) presented the results of a research on the SBS symptoms in workspaces as in Table 2.4.

Table 2.4. SBS Symptoms Related to Ventilation System

Source: Black *et al.* (1986)

Prevalence of Symptoms (%) by Type of Ventilation System

	Ventilation System Type (No. of buildings/No. of people interviewed)			
	Natural Ventilation Only (3/328)	Mechanical Only, No Humidification (1/78)	Mechanical, Humidified with no Recirculation (2/411)	Mechanical, Humidified with Recirculation (3/561)
Symptom				
Nasal	5.8	13.7	22.4	17.2
Eye	5.8	8.2	28.3	17.6
Mucous membrane	8.1	17.8	37.9	32.6
Work-related asthma	7.0	1.1	19.0	17.2
Humidifier fever	1.1	—	3.4	2.1

According to WHO (World Health Organization) estimates, 30% of the buildings in the developed world have potential to lead to health problems. Woods (1988) referring to another study where a stratified random sample of 600 U.S. office workers surveyed at home by telephone, indicated that a significant percentage of respondents (24%) were dissatisfied with the air quality at the office. Moreover, 20% of the 600 perceived their performance to be hampered by the air quality. This 20% of the sample also reported "serious" or "very serious" concern with five symptoms associated with Sick Building Syndrome at frequencies more than twice those expected from normal populations (i.e., a tired— sleepy feeling, 56%; a congested nose, 45%; eye irritations, 41%; difficulty in breathing, 40%; and headaches, 39%). From these data the following hypothesis was proposed: "It is possible that 20% of the office workers in the United States are exposed to environmental conditions that are manifested as the Sick Building Syndrome" (Woods, 1988, p.100).

According to Levin (1986) a World Health Organization working group suggested that there are temporarily and permanently sick buildings and affected buildings have the following characteristics:

- They nearly always have forced ventilation systems.
- They are often of relatively light construction.
- The indoor surfaces are often covered with textile, carpets, and other materials with a high surface-to-volume ratio.
- They are energy-efficient, kept relatively warm, and have a homogeneous thermal environment.
- They are characterized by airtight building envelopes

The Sick Building Syndrome seems to be mainly a design problem where physical features of the indoor environment play an important role. This statement is supported by many scholars; on the other hand, there is one more variable which affects the well being of the worker in an office space. This variable is management and maintenance. Watts (1996, p.24) emphasizes this subject in his statement as,

> One factor in increasing occupants' satisfaction is to include an ability on the part of the building, i.e. both the human systems and the physical constructions, to respond quickly to requests for change from its users. An aspect of this is a degree of user control as provided by operable windows, adjustable blinds and manually adjustable thermostats.

The importance of individual control on worker satisfaction and efficiency is covered in the following sections.

HVAC systems together with the sealing of offices were introduced as solution to many problems related to human well-being as well as energy consumption of buildings. However, this approach created other problems related to the same issues. Auliciems (1989) points out that air which is recirculated in the air-conditioning systems cannot be filtered well and that air carries noxious substances. Indoor pollutants such as tobacco smoke accumulates or be distributed away from the source. Also there is the problem of condensation, which creates an appropriate environment for the growing of harmful microorganisms.

Auliciems (1989) indicates some other disadvantages of HVAC systems related to wider issues. He argues that people are not satisfied with the quality of conditioned air and air-conditioning is believed to adversely affect the health. The same author also states that indoor conditions affected by outdoor weather and seasonal conditions maximizes the thermal satisfaction of the occupants. One more point that is covered by Auliciems (1989, p.83) is that "Lack of individual controls, including the sealed windows, are seen as highly undesirable features."

2.2.3 Effects of Individual Control on Workers

Opportunity for individual control is one of the key elements of the personal satisfaction in the office environment not only physically but also psychologically. Hedge (1986) reached to the result in an office environment survey that of the 77% of the staff members reported a desire to be able to open a window. Warren (1988) indicates that incidence of the symptoms of SBS can be related to the level of individual control over the environment. Warren further argues that operable windows can be a form of individual control available to occupants.
In a study conducted by Warren and Parkins, Warren (1988, p.193) concluded that "the incidence of window opening was higher in those buildings which were more thermally responsive and with higher areas of glazing." The same author also argued that window opening was used for additional ventilation by occupants to maintain optimum thermal comfort.

On the other hand, Maldonado (1988) points out that manual control cannot be accepted as the most efficient solution to natural ventilation control. Generally speaking Maldonado (1988, p.189) states, "Manual control can not be used as an effective global control strategy, even if the occupants are knowledgable and able to choose the best possible courses of action demanded by each situation." However, this does not mean that individual control with mechanical support cannot be used in working environment.

2.3 Energy-Conscious Design

It is stated elsewhere that "energy-conscious buildings has to find a balance between two areas: first one is the thermal performance of the building envelope and the appropriate selection of techniques for heating, cooling and daylighting; and the second one is an acceptable quality of indoor climate in terms of thermal comfort, ventilation effectiveness or indoor air quality" (Allard, 1998, p.1).

Aye, Bamford, Charters and Robinson (2000) indicate that environmental movement came into scene out of the concern for energy resources. Authors continue by classifying energy, used in buildings, in three as embodied energy, operating energy and transport energy. Embodied energy includes the production of materials, used in the building structure, services and finishes. Aye *et al.* (2000, p.929) specifically state that

> A new building will have a relatively high embodied energy component whereas a recycled building will have a relatively low embodied energy component, as the energy associated with the existing structure and retained components is not counted. In addition, there will be energy associated with the disposal of the building.

Operating energy is for the operation of the building systems such as heating, ventilating and air-conditioning, lighting, power and transportation in the building. Transport energy is about the location of the building. If the building is easily accessible with public transport, then it means that transport energy is lower, if workers and staff are highly dependent on car, then transport energy will be higher (Aye *et al.*, 2000).

Kolokotroni & Aronis (1999) point out that in the UK and other European Union countries, buildings consume %40 to 50% of the annual energy. According to a survey authors also argue that commercial office buildings use more than 10% of the total energy used. In the same survey, it was concluded that percentage of full air-conditioned floor space has increased to 27% in 1994, which was 7.5 in 1970, 12% in 1980, and 19% in 1990. On the same subject, Ruck (1989) presents graphically that in two different cities located at distant climates, air-conditioning systems comprise the major energy use in office buildings (Figure 2.1).

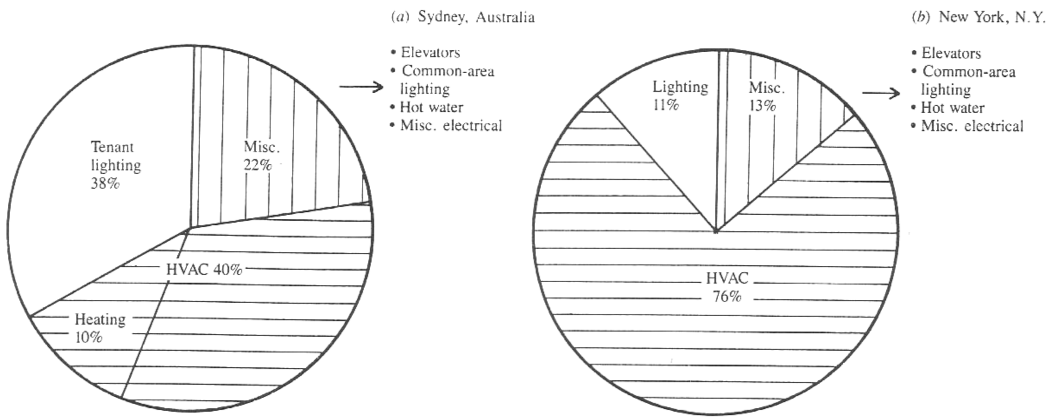

Figure 2.1. Energy Use of Office Buildings in Sydney and N.Y.C.
Source: Ruck (1989)

Allard (1998) points out another concern of energy conscious buildings, which is an acceptable quality of indoor climate. He states that first regulations on energy conservation only addressed to reduction of energy consumption. However, the result was emergence of building related sicknesses. Then another era, energy efficiency, has started when researchers, policymakers and designers recalled that the first function of a building is to protect the occupants from the harsh conditions of the outside environment and present them a healthy and pleasant indoor environment and then conserve energy. To quote Allard (1988, p.2)

> It is now clear that energy conservation cannot be dissociated from the quality of the indoor and outdoor environment. Therefore, the concept of global design of the building is emerging with all environmental aspects taken into account, not only from the performance point of view but also on the basis of many other quality criteria.

One of those quality criteria is the integration of building site characteristics into the design; and this idea leads people to more passive solutions for indoor climate conditioning. Allard (1998) indicate the relation of airflow to pollution level. According to the authors pollution level decreases as the airflow rate increases which helps to provide healthier environments to building occupants (Figure 2.2).

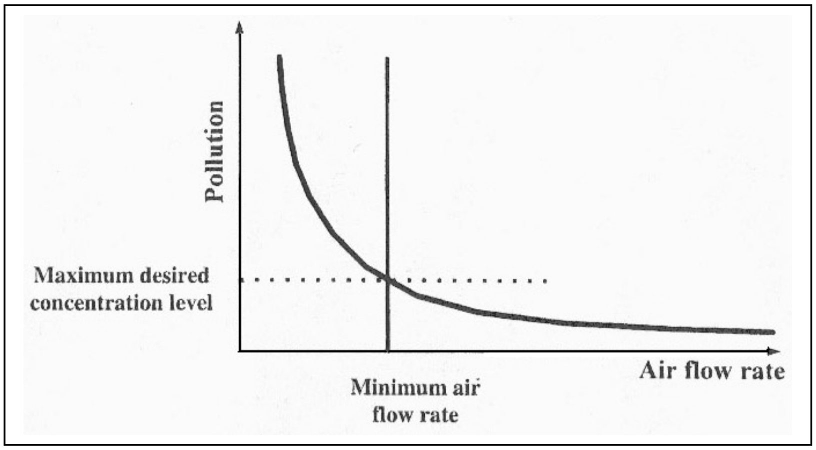

Figure 2.2. Relation of Pollution Level and Rate of Airflow
Source: Allard (1998)

On the same subject Yeang (1999) argues that 'passive devices,' 'appropriate building orientation' or 'climate responsive building configuration' can be solution to user needs, instead of employing buildings' hardware as full-mode strategies. Yeang (1999) further argues that architecture has to understand the building's all features, including the configuration, orientation, external wall design, mechanical and electrical systems and other characteristics, in relation to climatic features of the project site.

As it was stated earlier, the percentage of air-conditioned floor area is increasing significantly for office buildings. Kolokotroni & Aronis (1999) point out that employing passive strategies for cooling demand of buildings will lead to savings on energy consumption of a building. Thus, this will be of great interest to energy generating industries and building investors. According Yeang (1999), who has the same approach to the subject, natural ventilation is a valuable passive strategy and significant amount of non-renewable-fuel-based energy can be saved by lowering the need for mechanical ventilation and air conditioning systems (Table 2.5). He further argues that natural ventilation addresses to basic needs of occupants: the 'removal of foul air and moisture,' and the 'enhancement of personal thermal comfort.'

Table 2.5. Energy Use in Relation to Ventilation System
Source: Yeang (1999)

	Typical air-cond. office (kwh/sq.m.) (kwh/sq.m.)	Good practice open-plan office with nat. vent.
Heating and hot water	222	95
Lighting	67	32
Fans and pumps	61	5
Refrigeration	33	0
Catering	7	4
Total	390	136

It can be concluded that employing passive strategies is not only important from the point of view of capital, but also using renewable energy sources, and providing more pleasant and comfortable indoor environment for occupants.

2.4 Natural Ventilation

Here are introduced the characteristics of airflow and aspects of natural ventilation that contribute to the solutions for the problems of office environment. At the very basic level Yeang (1999, p.244) states that "natural ventilation ensures a fresh air supply to interiors." Allard (1998, p.2) argues that "Natural ventilation appears to be a very attractive solution to ensure both good indoor quality and acceptable comfort conditions in many regions." Allard further states that natural ventilation offers solutions to user complaints originated from mechanical ventilation systems, such as being noisy, creating health problems, requiring routine maintenance and consuming energy. Allard continues by arguing that it is easy to integrate natural ventilation into building design and it provides healthier and more comfortable environment if integrated correctly.

For the integration of natural ventilation design into building activity Priolo (1998, pp.195-96) identifies the design guidelines and criteria for natural ventilation, which are categorized under four major headings:

- *"Site design* aspects regarding the location, orientation and layout of buildings as well as landscaping;"
- *"Design programme* aspects related to the indoor air quality and ventilative cooling requirements;"
- *"Building design* aspects related to the building form, the vertical and plan distribution of spaces, and the location and sizing of the openings;"
- *"Opening design* aspects concerning the selection of the types of opening and the screen, as well as the operational features."

In this chapter, first, characteristics of ventilation and airflow are presented. Then levels of natural ventilation design is explained. Thirdly, types and uses of natural ventilation is clarified, and lastly relation of high-rise buildings to natural ventilation is described.

2.4.1 Characteristics of Ventilation and Airflow

Brown (1985, p.26) explains the way wind interacts with natural and built forms. The same author states that the direction and speed of the wind can be estimated by using three principles governing the air movement. The first principle is that "as a result of friction, air velocity is slower near the surface of the earth than higher in the atmosphere. The reduction in velocity is a function of the ground's roughness, so the wind velocity profiles are quite different for different terrain types" (Figure 2.3).

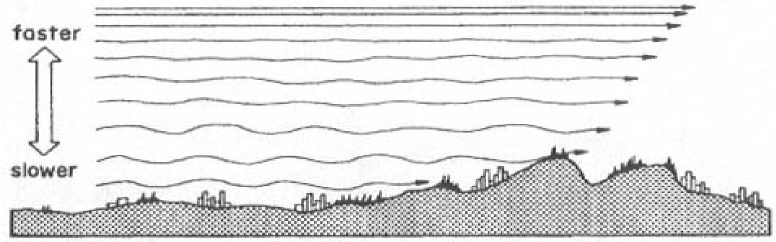

Figure 2.3. Variations in Air Velocity According to the Ground Roughness
Source: Boutet (1987)

The second principle is that “as a result of inertia, air tends to continue moving the same direction when it meets an obstruction. There, it flows around objects, like water flows around a rock in a stream, rather than bouncing of the object in random directions" (Figure 2.4). Third and the last is that “air flows areas of high pressure to areas of low pressure” (Brown, 1985, p.26) (Figure 2.5).

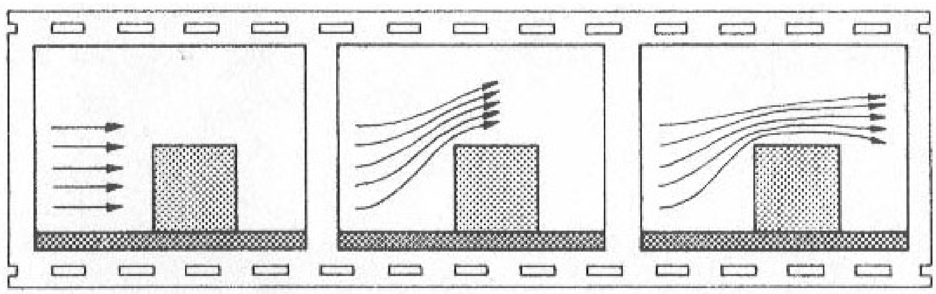

Figure 2.4. Airflow Pattern over An Object
Source: Brown (1985)

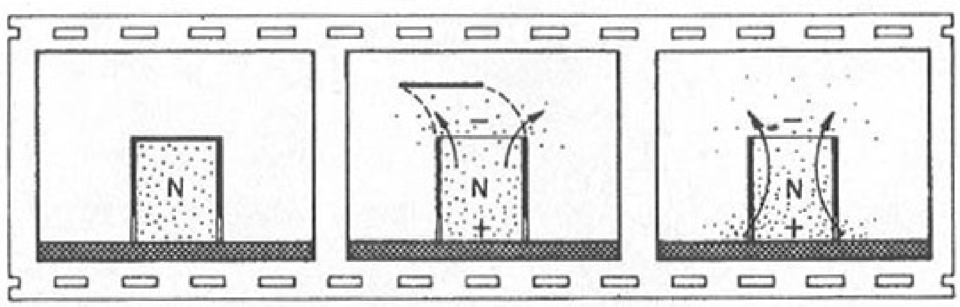

Figure 2.5. Air moves from high to low pressure
Source: Brown (1985)

According to Boutet (1987), air movement is created by buoyancy and pressure differences and modified by inertia and friction. The same author counts landforms, vegetation and buildings as factors that affect the air movement by altering the pattern of the air flow. Boutet (1987) also explains that there are three kinds of flow pattern of air movement: laminar (a), turbulent (b) and separated (c) (Figure 2.6).

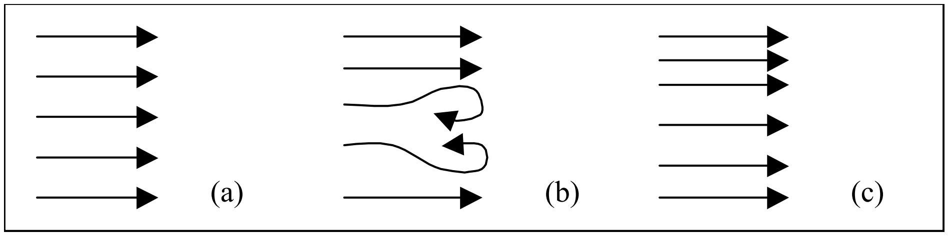

Figure 2.6. Three Types of Air Movement Pattern
Source: Boutet (1987)

Landforms

Boutet (1987, p.47) describes that changes in topography such as hills, valleys, mountains, and ditches alter the velocity of air movement. To quote him "Concave surfaces attract airflow into them; convex surfaces deflect airflow from them" (Figure 2.7 and Figure 2.8). According to the same author this information is applicable to designs in two ways: "a structure may be located to receive or shun airflow, or it may be oriented to capture or reflect airflow."

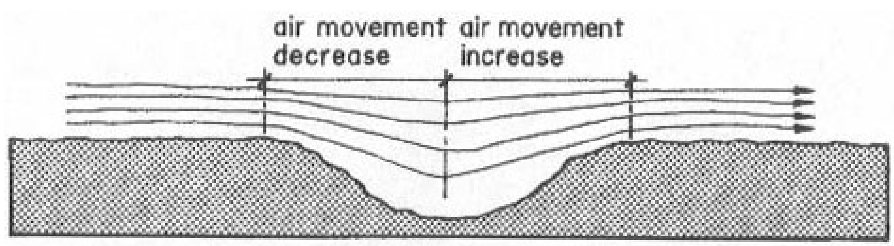

Figure 2.7. Concave surfaces attract airflow into them
Source: Boutet (1987)

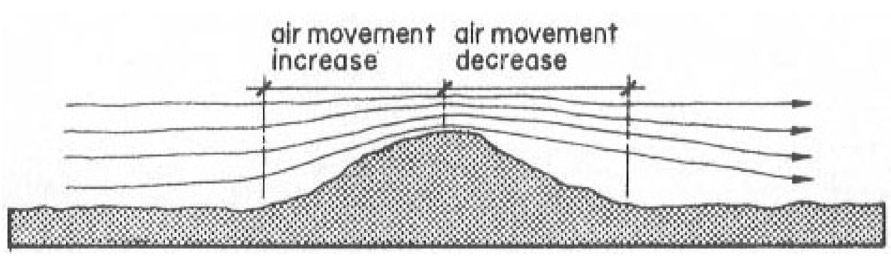

Figure 2.8. Convex surfaces deflect airflow from them
Source: Boutet (1987)

Vegetation

Boutet (1987) explains that vegetation can be used to alter the velocity, pattern, and quality of air movement, through appropriate selection and placement of various species (Figure 2.9). He further continues that vegetation is not only a potential controller of air movement; it also reduces noise, removes dust particles, absorbs carbondioxide and subtracts heat from the air while introducing moisture and oxygen into the air."

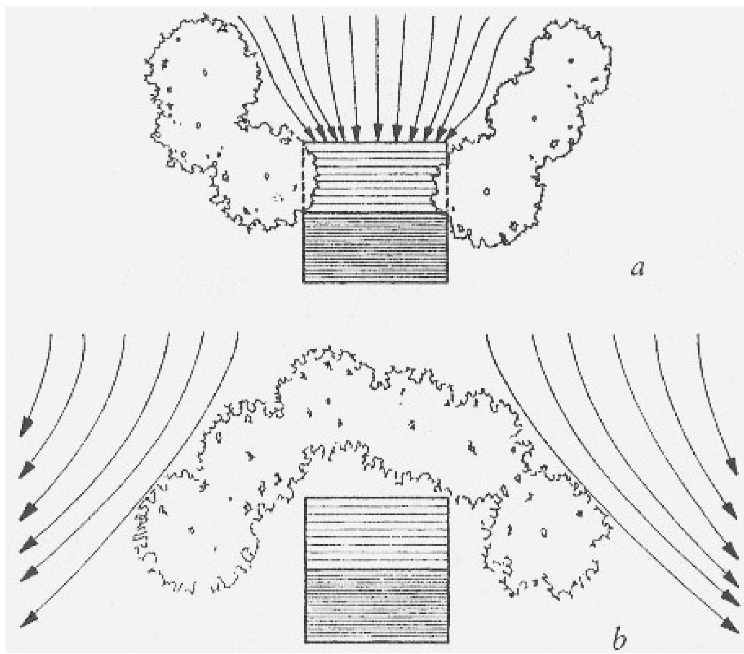

Figure 2.9. Vegetation is used to alter air movement
Source: Boutet (1987)

According to Boutet (1987) structures affect the movement of air by deflecting, obstructing, and guiding it, as well as reducing and accelerating the airflow velocity. Height, width, length and form of the structure are the variables that change the intensity, magnitude of the influence of buildings on air movement. According to the same author air pattern is divided into two of which two-thirds of the air flow downward and one-thirds move upwards (Figure 2.10).

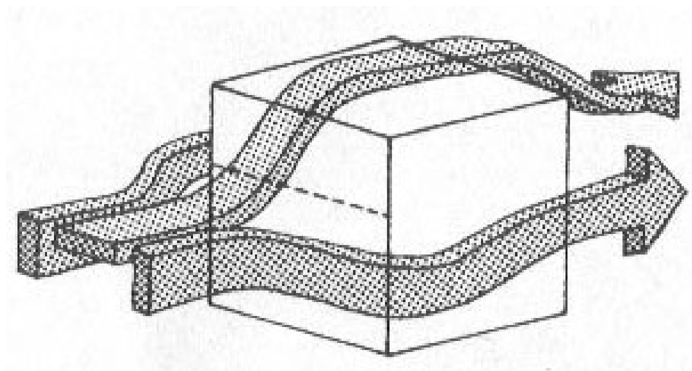

Figure 2.10. Airflow Distribution Around A Building
Source: Boutet (1987)

At the building level Boutet (1987, p.176) introduces some air movement control techniques that may be used in design decisions. About the relation to the adjacent structures to quote Boutet "If a building is more than double the height of its neighbors and is six stories or more in height, air movement around the building may become hazardous to persons on the ground." According to the same author, the points to pay attention for the orientations of the buildings are as follows:

> The orientations of the building should induce air movement into the building, the location of the building should minimize adverse air movement, buildings should not be oriented for a particular air movement direction: they should be designed for effective air movement in prevailing directions, and building orientation influences the location of inlet and outlet openings (Boutet, 1987, pp.176-77).

In shaping of the buildings, Boutet (1987, p.177) states that "Building configuration may assist in cross-ventilation" and "textures, vines, fins, wing-walls, and recesses in the building's form may assist in air movement control." Openings in buildings are another set of variables that contribute to control of air movement. Arrangement, location, and control of openings should assist to pressure differentials and buoyancy forces and openings should be located to employ prevailing air movement. Cross ventilation should be encouraged and openings should be designed to direct the airflow to wherever it is needed. Leeward side of the building where negative pressure occurs is the appropriate place to locate outlet openings; and finally occupants should have access to openings to operate them. In Figure 2.11 is shown the openings that are designed in conjunction with the vegetation around to provide cross ventilation inside the building. This situation is provided by the appropriate and careful design of positive and negative pressure zones on a building. Figure is important to show that natural ventilation design does not only depend on the wind direction.

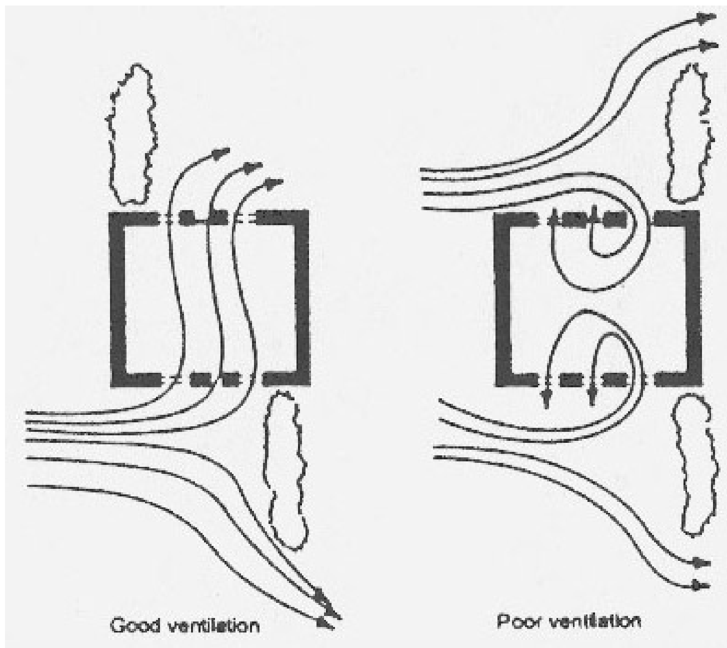

Figure 2.11. Opening Design in Relation to Placement of Vegetation
Source: Boutet (1987)

Boutet (1987) also discusses the characteristics of various wind based on the velocities. In Table 2.6, Boutet gives the classification as well as the specifications and description of air movement types. According to the same author there are 13 types of winds depending on the velocity. Those wind types varies from calm air to hurricanes whose speeds are below 88 feet per minute (0.45 m/s) and above 5984 feet per minute (30 m/s) respectively.

Table 2.6. Characteristics of Various Wind Speeds

Source: Boutet (1987)

Feet per minute	Miles per hour	General description	Specifications
Less than 88	Less than 1	Calm	Smoke rises vertically.
88–264	1–3	Light air	Wind direction shown by smoke drift but not by vanes.
352–616	4–7	Slight breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind.
704–968	8–11	Gentle breeze	Leaves and twigs in constant motion; wind extends light flag.
1056–1408	12–16	Moderate breeze	Dust and loose paper moved; small branches are moved.
1496–1936	17–22	Fresh breeze	Small trees with leaves begin to sway.
2024–2376	23–27	Strong breeze	Large branches in motion; whistling in telephone wires.
2464–2992	28–34	Moderate gale	Whole trees in motion.
3080–3608	35–41	Fresh gale	Twigs broken off trees; progress generally impeded.
3696–4224	42–48	Strong gale	Slight structural damage occurs; chimney pots removed.
4312–4928	49–56	Whole gale	Trees uprooted; considerable structural damage.
5016–5896	57–67	Storm	Very rarely experienced; widespread damage.
Above 5984	Above 68	Hurricane	Extremely rare; extensive damage common.

Air movement speeds are measured at 20 ft above the ground.

The relation between wind pressure, temperature difference and natural ventilation is clarified by Balazs (1988, p.243) such that

> Pressure coefficient differences between the windward and leeward surfaces are characteristic to the acting wind forces” and wind as being one of the driving forces of natural ventilation, plays an important role in ventilation flow rates. The other driving force of natural ventilation is indoor-outdoor temperature difference and following situations occur between wind pressure, temperature difference and natural ventilation: (1) high winds accompanied to low outdoor temperatures give the potential to high ventilation rates; (2) no wind, no temperature difference cause stagnation in ventilation; (3) high outdoor temperature and no wind potentially cause reversed stack-effect and reversed flows at usually low rates.

Balazs (1988, pp.243-45) indicates that it is a design problem to use the potential explained above and provide desired level of natural ventilation for most part of the year. The same author also argues that if mechanical ventilation is disregarded the following points are left to the designer to ensure an inner environment with controlled ventilation:

- “building design, including provision for controllable flow paths to ventilation air, and provisions for preventing unwanted inter- zonal flows,”
- “application of air-tight components and joints wherever the envelope or partitions have to be tight,”
- “application and proper positioning of controllable air vents, shafts and other purpose-made openings for ventilation purposes,”
- “ventilation-conscious arrangement of premises with special regard to those requiring separate treatment from ventilation aspects /gas appliances, etc.,”
- “ventilation-conscious consideration of environmental factors such as local climate, shielding, terrain effects, outdoor pollution, etc.”

2.4.2 Levels of Natural Ventilation Design

Priolo examines the levels of natural ventilation design under four topics: site design, design programme, building design and opening design. For the site design Priolo (1998) specifies the main objectives to take into account. The first objective is to locate the building according to best airflow pattern to increase the ventilation rate of interior spaces. According to the same author designer should find the best compromise between the summer and winter comfort conditions. Another objective is to avoid permanent unwanted wind sheltering conditions. Designer should also avoid the uncomfortable conditions occurring due to the excessive wind speeds and outdoor conditions. Also, airflow that transports dust and pollutants should be avoided.

Generally speaking if a building is to be located in an urban site, its position should be selected relative to other buildings. Priolo (1998, p.197) states that “Its [building’s] location should be at a distance from other buildings that is greater than the depth of their wake so that they will not shelter it from summer winds." If this condition cannot be satisfied building should be located randomly considering the upwind buildings and its longitudinal axis should be perpendicular to prevailing summer wind in order to catch the stream. In general building's location and position should be optimized in order to exploit summer winds and avoid cold winter winds.

At the design programme stage Priolo (1998, p.202) specifies the information needed to provide proper level of natural ventilation. Those information are the

> Type of the building (residential, commercial, tertiary, industrial, etc.); the type of space (living room, bedroom, bathroom, office, drafting, etc.); the schedule of use for each space; within that hottest period of the year, the hours of the day in which heat gains within the space induce discomfort; the quantity of heat to be removed in such a periods; the type structure and, particularly, the dimensions of the exposed thermal mass.

The third part that Priolo takes into account is the building design. In this part Priolo (1998) defines the aspects of a building that will affect the air movement pattern. The first aspect of a building is the form of the building envelope, second aspect is the internal distribution of spaces and functions, third is the dimension and location of the openings, fourth aspect is the characteristics and the dimensions of the exposed thermal mass, and the last aspect is the interactions with the HVAC system. For the last part, namely the opening design, Priolo's concern is on the selection of the opening type and the operational features.

2.4.3 Types and Uses of Natural Ventilation

According to Yeang (1999), natural ventilation improves comfort in two ways. One is the direct psychological effect, the other is an indirect one. First one is based on making the occupants feel cooler by letting in more wind and increase the speed of air inside the room. This approach is called 'comfort ventilation' by Yeang. Second method is based on ventilation of the building only at night and use the cooled thermal mass of the building during daytime. This method is called 'nocturnal ventilative cooling'. Allard & Alvarez (1998) define the use of natural ventilation during daytime in three objectives. The first objective is to cool the building by natural ventilation provided that outdoor temperature is lower than the indoor temperature. The second is cooling the structure of the building and third is creating a direct cooling effect on human body through convection and evaporation.

Allard (1998) discusses the techniques of natural ventilation to improve comfort in detail. He argues that air movement helps human body exchange the convective heat and mass with the surrounding air. This air movement around the body also helps to attain a thermal comfort level. Higher air velocities increase the evaporation rate at the skin surface and enhance the cooling sensation. Natural ventilation can shift the thermal comfort zone to higher temperatures but there is another problem associated with air speed inside a room. It is recommended by Allard that the velocity of air should not be more than 0.8 m/s, because velocities higher than this may disturb the loose paper. Allard states that this air speed can help to maintain a comfortable environment with $2^{\circ}C$ warmer air at 60% relative humidity. In general, it is argued that natural ventilation helps to reach the comfort level at higher temperatures.

Second effect of natural ventilation on comfort is to eliminate the excessive heat inside the building by ventilating it. Through this internal gains are reduced. According to Allard (1998), this is a traditional cooling strategy in moderate and southern climates. The same author states that this technique is applicable where outdoor temperature is in the range of comfort conditions. Allard further states that it is hard to apply this technique where higher control of indoor air velocities is needed during the occupancy period. Then he proposes the third technique, which is nighttime cooling. Allard (1998) points out that in night-time ventilation, the structure of the building is cooled down during the unoccupied period. A heat sink is created to be available during the occupied period of the building.

Also Kolokotroni & Aronis (1999) discuss the concept of nighttime cooling. According to the authors, this is a very suitable solution especially for office buildings, where occupancy period is daytime. To quote them verbatim `"Night ventilation works by using natural or mechanical ventilation to cool the surfaces of the building fabric at night and is more effective where a building includes a reasonably high thermal mass, so that heat can be absorbed during the day". Authors also argue that there are four ways of which night ventilation can affect internal conditions. First one is "reducing the peak air temperatures;" second is "reducing air temperatures throughout the day, and in particular during the morning hours;" fourth, "reducing slab temperatures;" and third "creating a time lag between the occurrence of external and internal maximum temperatures."

2.4.4 Natural Ventilation - High Rise Building Relation

Integration of natural ventilation is a subject discussed by scholars in different ways. In general it can be said that there are two approaches. One is against and the other is for natural ventilation with proper design.

First one argues that natural ventilation is disadvantageous to high-rise buildings and it is something that should be avoided. On this side of the discussion, Boutet (1987) argues that as the height of the building increases the airflow pattern about the building changes. The top one-third floors of the building experience a constant upward movement of air. As a result, the interior spaces of those top floors also experience an upward air movement.

Boutet (1987) also argue that increased height of the building has side effects to building's energy demand. As the height increases, it is less likely to protect the building from undesired wind conditions, shelter from direct solar heat gain, ventilate the building at a proper height within interior spaces and employ precise air movement control. The same author adds to this argument that the stack effect becomes a problem in high buildings and controlling cold and warm air becomes harder. Boutet (1987, p.63) finalizes his argument by pointing out that "Increasing building height should be avoided in the desire to achieve comfortable living spaces and optimum air movement within these spaces."

Yeang, who approaches to special wind conditions on high-rise buildings as an element to be adjusted in design, represents second side in this discussion. His argument is based on design aspects of the building adopted for desired conditions. Yeang (1999) indicates that high-rise buildings should be located and positioned to maximize the summer wind exposure of the building. They also should be designed with shallow plan in order to employ cross ventilation inside the building.

Yeang (1999, p.254) points out that as wind moves up on the façade, its performance grows exponentially. But unlike Boutet, Yeang proposes some systems to overcome the disadvantages situations. He argues, "If natural ventilation is used in the building, then a series of modified venting devices for different height zones is needed. The external façade can consist of a series of systems (eg. double-skin, flue wall, etc.) depending on the desired thermal effect and venting system"; Yeang also states that "the taller the building, the greater should be its potential to ventilate itself by stack effect."

For the problems that occur in cold and temperate climates, Yeang (1999) points out that natural ventilation is not used in most user areas in tall buildings. This is because of excessive wind speeds at higher levels and problems of stack effect. Then he indicates the use of minimal mechanical ventilation with natural ventilation.

Yeang (1999) divides the level of operational systems provided in a skyscraper into the following categories: 'passive mode,' 'mixed mode,' 'full mode,' and 'productive mode'. Passive mode, he indicates ecologically ideal if acceptable to occupants. According to him, to avoid ventilation and energy penalties in winter, 'mixed mode' and displacement ventilation systems emerged in large buildings to conserve energy.

According to Arnold (1999b, p.40) the 'mixed mode' is using natural ventilation and air conditioning in the same building, at different times of the year. To quote the same author "It is an alternative strategy that attempts to combine the best features of natural and mechanical systems." Building is intended to use natural means whenever possible and mechanical systems are used at excessive temperatures of outdoor conditions. This approach helps to minimize energy use of the building. Despite the fact that the applicability of natural ventilation to high-rise buildings is discussed, there are skyscrapers, such as Chrysler and Woolworth Buildings, which depend on natural means for lighting and ventilation (Arnold, 1999a). Those are the examples built during the 1930s, and there are contemporary examples of office buildings such as Colognia Building in Cologne or Commerzbank Headquarters Building in Frankfurt, which challenge the sealed building idea.

2.5 Human Comfort

Comfort in an environment is one of the key elements for human well-being. There are elements of climatic environment that effect human comfort. According to Olgyay (1969) those elements are air temperature, radiation, air movement, and humidity. Olgyay (1969, p.14) also argues that "Man's physical strength and mental activity are at their best within a given range of climatic conditions, and that outside this range efficiency lessens, while stresses and the possibility of disease increase."

According to Olgyay (1969) there is no exact criterion that comfort can be evaluated. He indicates that comfort can be defined as the situation where any feeling of discomfort does not occur. Moreover, elements such as level of clothing, nature of the activity performed, sex, age and geographical location affect human comfort. Women, Olgyay states, in general prefer temperature 1 degree [Fahrenheit] higher than men for comfort: and people over the age of 40 1 degree effective temperature higher than people below this age. So, according to Olgyay (1969, p.18) "comfort zone does not have real boundaries".

In this chapter the relation of air movement to human comfort and other comfort elements are presented and then, bioclimatic chart is introduced to demonstrate how different elements interrelate to define a comfort zone although it is not absolute according to Olgyay.

2.5.1 Air Movement

Givoni (1976) states that there are two ways that air movement affect the human body. First one is that air movement determines the convective heat exchange of the body and it improves the evaporative capacity of the air and enhances the cooling efficiency of sweating.

According to Givoni (1976), air velocity affects the convective heat exchange in the way that, convection is a function of the product of some power of the velocity of air and the temperature difference between the skin and the environment. Moreover, air velocity is effective on evaporative capacity together with the effect of humidity. The more increases the air velocity, the more raises the evaporative capacity, offsetting the effect of high humidity.

Those two effects of air velocity work differently depending on the air temperature. If the air temperature is below the skin temperature, those effects work in the same direction providing a cooling effect. This cooling effect increases as the air temperature decreases. On the other hand, when the air temperature is above skin temperature, those two affects work in the opposite directions. Increase in velocity, in this situation, means that convective heat exchange is increased, which warms the body. But increase in air velocity raises the evaporative capacity, leading to a cooling effect in the same situation (Givoni, 1976).

To quote Givoni (1976, p.67) "Therefore at high air temperatures there is an optimum value of the air velocity, at which the air motion produces the highest cooling. Reduction of the velocity below this level causes discomfort and heating, by reduced efficiency of sweating, and increasing it beyond this level causes heating by convection. This optimum velocity is not constant but depends on the temperature, humidity, metabolic level and clothing."

2.5.2 The Bioclimatic Chart

Bioclimatic chart is a diagram on which different climatic elements are plotted. It shows how comfort is attained with respect to different elements and it shows the relationship of different elements to each other. In this chart, lies the comfort zone in the center. Lines around the comfort zone indicate the corrective measures needed to restore the feeling of comfort. In this chart, dry bulb temperature was plotted on ordinate and relative humidity on abscissa and any climatic conditions represented by its dry bulb temperature and relative humidity can be plotted on the chart (Figure 2.12). If this point falls into the comfort zone, it means that someone would feel comfortable in shade, if not corrective measures would be needed (Olgyay, 1969).

If the plotted point is above the comfort zone winds are needed. The almost parallel lines above the comfort zone indicates the wind velocities needed to restore the feeling of comfort in ft/m. If the plotted point is on a region where relative humidity is low and temperature is high, the feeling would be too dry and hot and winds will no effect here. Evaporative cooling would be the tool to correct this feeling. "Dotted lines indicate grains of moisture per pound of air needed to reduce the temperatures to a level at the upper comfort perimeter" (Olgyay, 1969, p.22). To get around the low dry bulb conditions below the shading line, radiation is necessary; and finally, "at the left are charted the mean radiant temperature values (mrt) necessary to restore the feeling of comfort by either radiant heating or cooling (control of surface temperatures of the surrounding" (Olgyay, 1969, p.23).

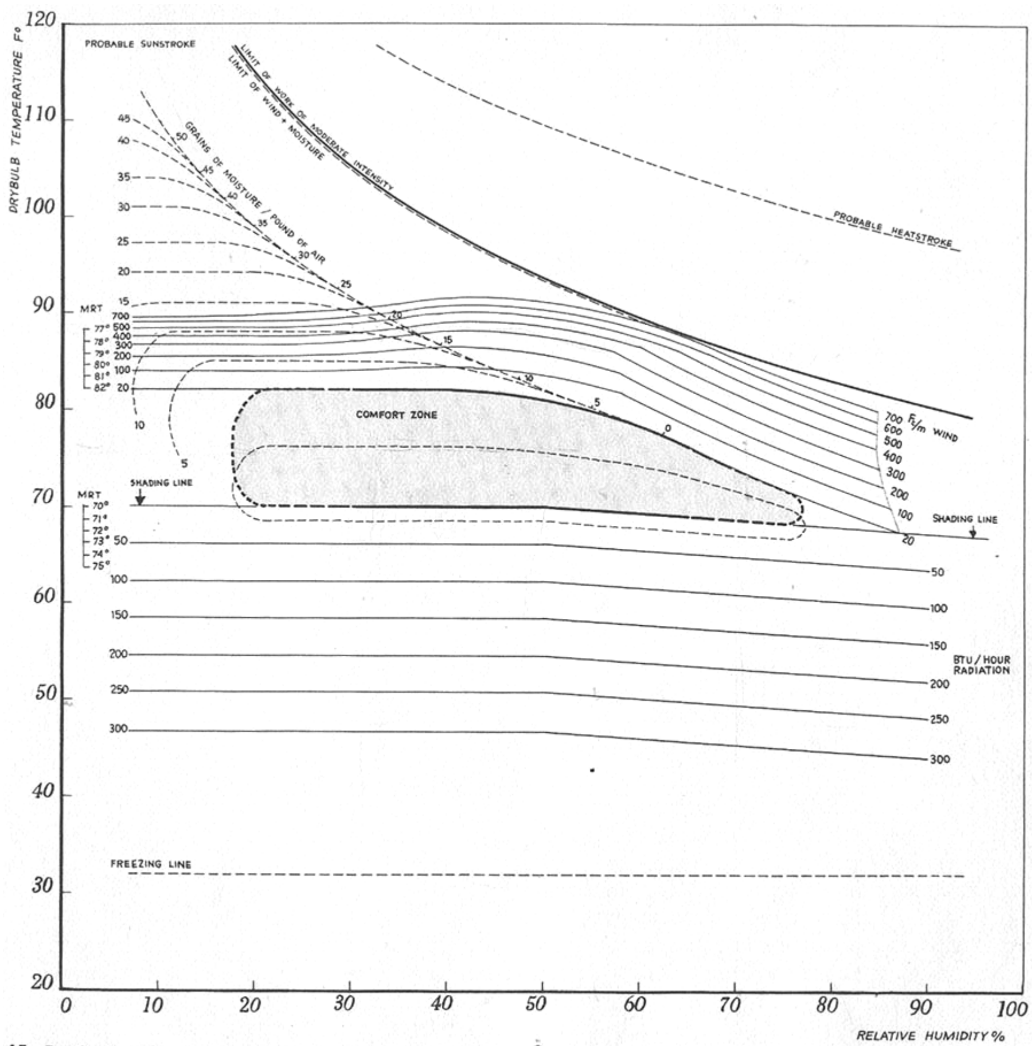

Figure 2.12. The Bioclimatic Chart

Source: Olgyay (1969)

CHAPTER 3

USER SATISFACTION AND VENTILATION EFFECTIVENESS SURVEY AND ANALYSIS OF DATA

Here is presented the material, method and results of the user satisfaction and ventilation effectiveness survey, conducted on the Emek İşhanı (Emek Office Building). First is presented 'The Survey Material.' Following this is presented the method of the survey and analysis as 'The Survey Methodology.' Finally results of the survey are discussed under 'Results and Discussions.'

3.1 The Survey Materials

In this part is explained the survey material under two topics as 'Emek İşhanı' and 'The Questionnaire.' In 'The Emek İşhanı,' location of the building is explained with respect to the city of Ankara and Kızılay district. General characteristics of the building is also presented in this part. In the second part, namely 'The Questionnaire' is explained the questionnaire prepared to conduct the survey on the Emek İşhanı.

3.1.1 The Emek İşhanı

The Emek İşhanı (Figure 3.1) is an office structure located in the Kızılay district of the city of Ankara, which is the capital of Turkish Republic. Ankara is located in the mid-Anatolia at {40° 7'} northern latitude and {32° 58'} eastern longitude and 949 m. above sea level. Kızılay, located in the city center of Ankara, is one of the major business districts of the city with a dense urban character, composed of mainly multi-storey buildings. In Figure 3.2, Kızılay district is depicted in color on the city map of

Ankara. The Emek İşhanı is located in the center of Kızılay district at the intersection point of two major routes namely Ziya Gokalp Street and Ataturk Boulevard.

The Emek İşhanı is a 21-storey structure. The first three floors consist of a horizontal structure and the remaining 18 floors constitute a high-rise office block (Appendix A). Floors 4 to 18 have 12 offices, half of which are located along the south facade and half along the north. The 19th floor is occupied by the Ziraat Bankasi and is not partitioned. The 20th floor is used as a social center of T.C. Emekli Sandığı Genel Müdürlüğü, and the 21st floor is a mezzanine looking onto the 20th floor (Sönmez, 2001).

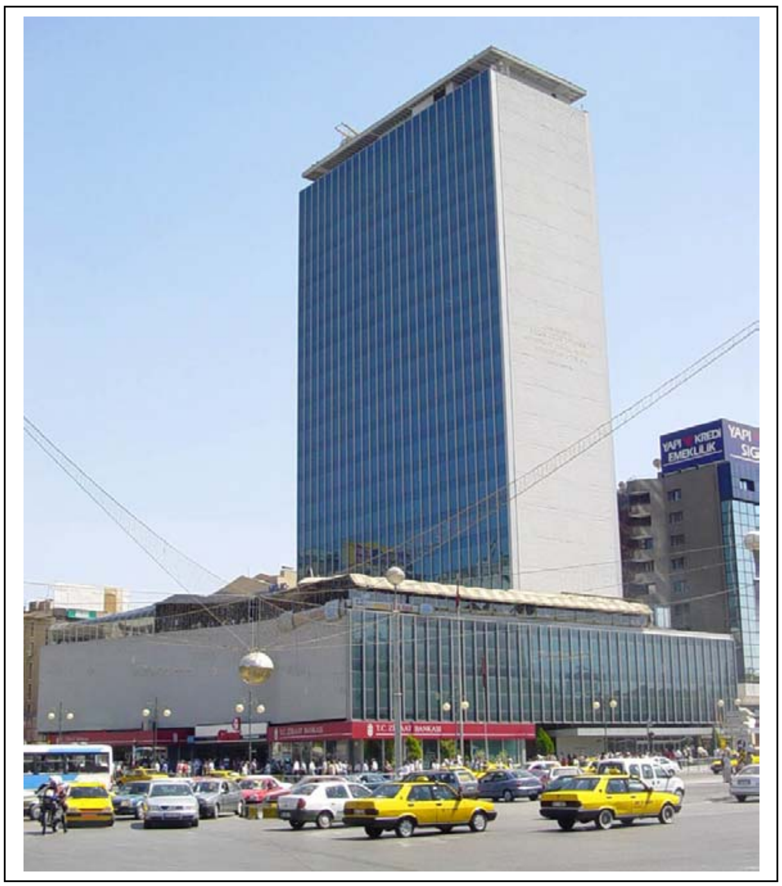

Figure 3.1. The Emek İşhanı

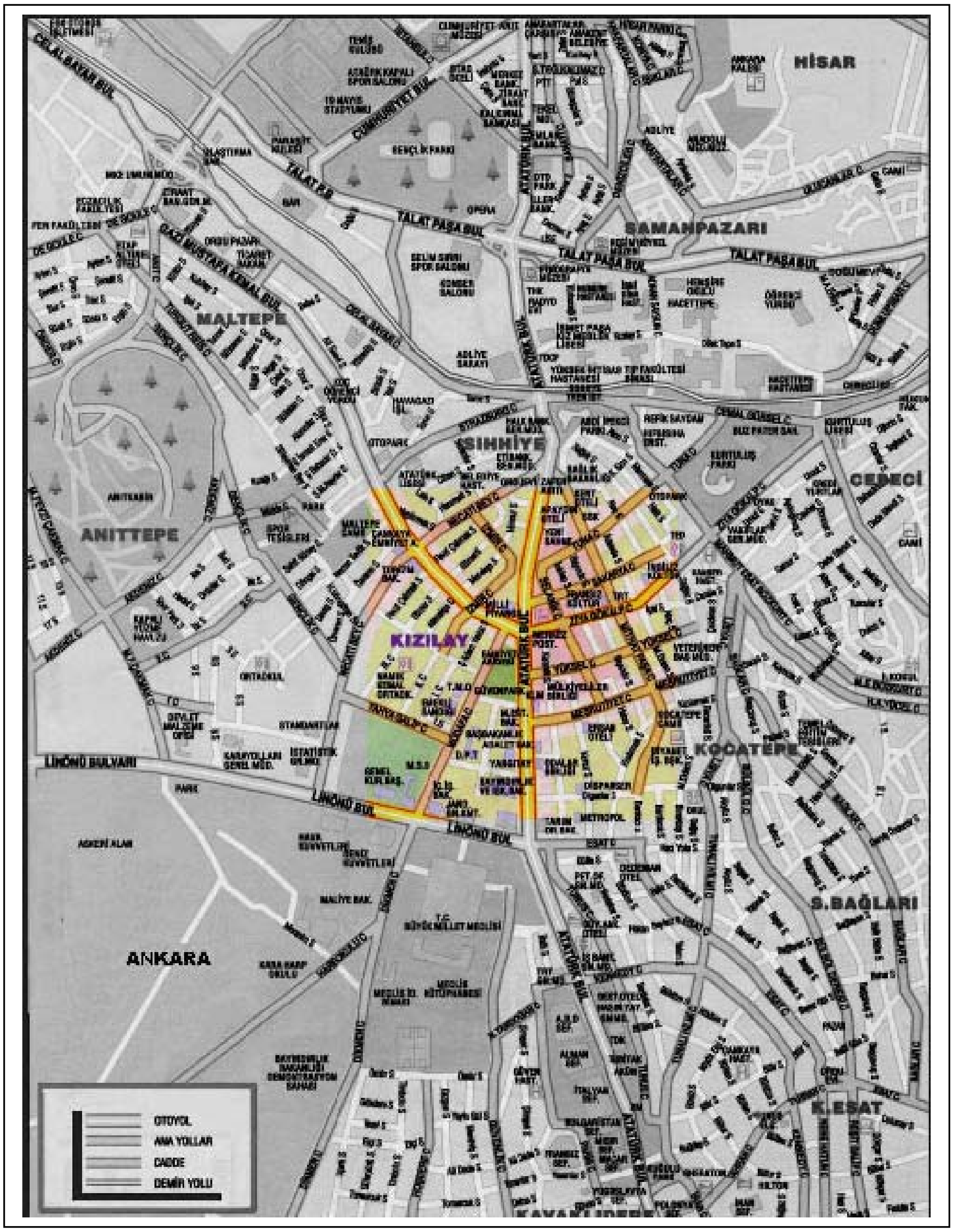

Figure 3.2. Kızılay district is depicted in color on the Ankara map

3.1.2 The Questionnaire

In July 2003 a survey was conducted among forty occupants of the Emek İşhanı. The basis of the survey was a questionnaire aimed at gaining the data of subjective responses of the occupants towards their work environment. The survey was formatted to investigate first, the overall satisfaction of the occupants and second, the effectiveness of the ventilation system together with any health problems that could be considered as indicators of Sick Building Syndrome.

The questionnaire used for the survey on the Emek İşhanı was prepared based on Haghighat & Donnini (1999), Nakano, Tanabe & Kimura (2002), Sönmez (2001) and Engelhart, Burghardt, Neumann, Ewers, Exner & Kramer (1999) and was adjusted to investigate the specific concern of the Emek İşhanı study. It was composed of 25 items under four categories (Appendix B).

In the first category, namely “Room Information,” the related questions were about the location of the room with respect to the orientation, floor, room area and number of occupants in the room.

In the second category, namely “Personal Information,” were collected the data about the gender, age, education, occupation, marital status and smoking habits of the occupants.

In the third category, namely “Environmental Evaluation,” was aimed to gain information on the user satisfaction regarding the environmental conditions such as temperature, humidity, air movement, and air quality. Questions 14 and 15 referred to the renovation of the façade system to obtain a general idea on the results of the renovation two years after its completion. Questions 16-19 were about the responses to the temperature of the environment in both winter and summer. Questions 20, 21 and 22 were about humidity, air movement and air quality respectively. Question 23 is a hypothetical one about the types of control that individuals can adjust in an environment. Question 24 is an open ended one that looked for the user complaints about the HVAC system of the building.

In the fourth category, namely "Health Problems," 11 symptoms of Sick Building Syndrome were listed and respondents were asked to indicate the frequency of the complaints for each symptom. Respondents were also asked to mark the ones that they think HVAC system is the source of problem.

In the analysis of data, Excel software, version 2000, was employed together with a PC. The data obtained was analyzed according to issues related overall user satisfaction and ventilation effectiveness of the building. Issues related to overall user satisfaction were analyzed to be able to reach conclusions on building's capacity to satisfy its occupants. For the ventilation effectiveness of Emek İşhanı, three issues were investigated, namely, air movement, air quality, and health condition of workers.

3.2 The Survey Methodology

For the survey, typical office floors, which are 4 to 18, were chosen as subject. The first three floors are occupied by Gima shopping center, which is out of concern of this study. Also, since the last three floors, namely 19, 20 and 21, have specific conditions as explained earlier, occupants of these floors were not contacted.

Forty occupants of the Emek İşhanı who work between 4th and 18th floors were contacted. To be able to make a comparative analysis, the author decided to take equal number of people from north and south facades. Two office floors from north and south facades were chosen for each floor. To provide the randomness of the samples, a sampling method was determined. To carry out a draw to determine the office units to contact, cards were prepared on which numbers from 1 to 6 were written, one for each card. There were six cards representing the six office units on each side of the building. To determine each office unit to contact, one card was drawn from an opaque bag and in total sixty office units were determined. As a substitute, the office floor next to the drawn office was decided to contact, following the clockwise direction on each side in itself. Two architects, one being the author himself, conducted the survey in two days. Since most of the occupants, determined at draw, were not accessible and the time was limited, available inmates were contacted.

The information gathered with the survey was first tabulated as raw data. In the tabulation numbers were employed to represent the responses in the analysis (Appendix C). In the 23rd question responses to different adjustment methods were separated from each other; and if a respondent liked to have a specific adjustment, it was labeled as 1, if not 0. Another method was employed in the 25th question. Each symptom in this question was separated into two, one representing the frequency of the symptom; another representing whether the respondent thinks that ventilation system is the source of that specific problem. If any symptom was marked as caused by the ventilation system, it was labeled as 1, if not 0.

3.3 Results and Discussions

In this part is presented the survey results under two major topics, namely 'Overall Satisfaction Analysis' and 'Ventilation Effectiveness Analysis.' 'Air Quality Perception,' 'Air Movement Perception' and 'Health Condition' are the three subtopics investigated under 'Ventilation Effectiveness Analysis.'

3.3.1 Overall Satisfaction Analysis

Here is presented the satisfaction analysis of building occupants based on question 15 which asked for the comfort level of the space in general. First is given, total satisfaction in relation to factors such as façade direction and preference of opening a window out-of-doors. Other factors that might effect the overall satisfaction are then analyzed. Those factors are smoking habits, gender and date of starting to work and unavailability of an operable window to the outside.

The overall comfort satisfaction of the building users is shown in Figure 3.3, in the form of a bar chart. The scale of satisfaction level is composed of six responses and one category for occupants who did not respond. The first three responses in the scale represent the feeling of comfort, and the last three, excluding the non-respondents represent feeling of not being comfortable. To summarize, 32.5% of the occupants feel comfortable in the Emek İşhanı. The second largest group consist of those inmates feeling uncomfortable which stood at 20%. 17.5% of the occupants feels that their working environment is slightly comfortable, and another 17.5% slightly uncomfortable. There are two groups of people consisting of 5% and 2.5%, feeling very comfortable and very uncomfortable, respectively. From the chart it is evident that 55% of the inmates are on the comfortable side of the scale and the other 40% on the uncomfortable. Moreover, 35% of all responses are seen to fall in the middle of the scale, which ranges from slightly comfortable to slightly uncomfortable. Some other variables were also checked and presented in order to have a better insight on the satisfaction level of occupants.

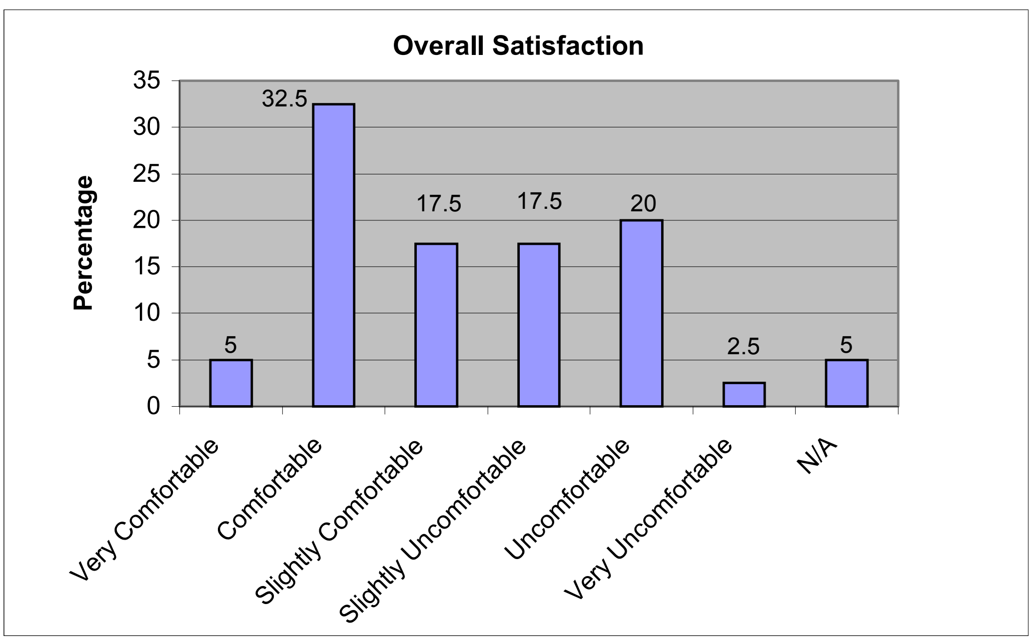

Figure 3.3. Overall Satisfaction Chart of Occupants

Façade orientation was another of the variables checked, since both south and north were identical in façade system. In Figure 3.4, is presented the distribution of overall satisfaction depending on façade orientation. Since the number of respondents is not equal for each façade, percentages are presented separately for each façade direction. As presented on the graph, percentages do not show big differences between the two façade. It would mean more to the author if one of the facades has higher values on one side of the scale and lower values on the other side. Then it could be concluded that façade direction might have an effect on the comfort level of the occupants. However, from the chart presented author did not reach to such a conclusion.

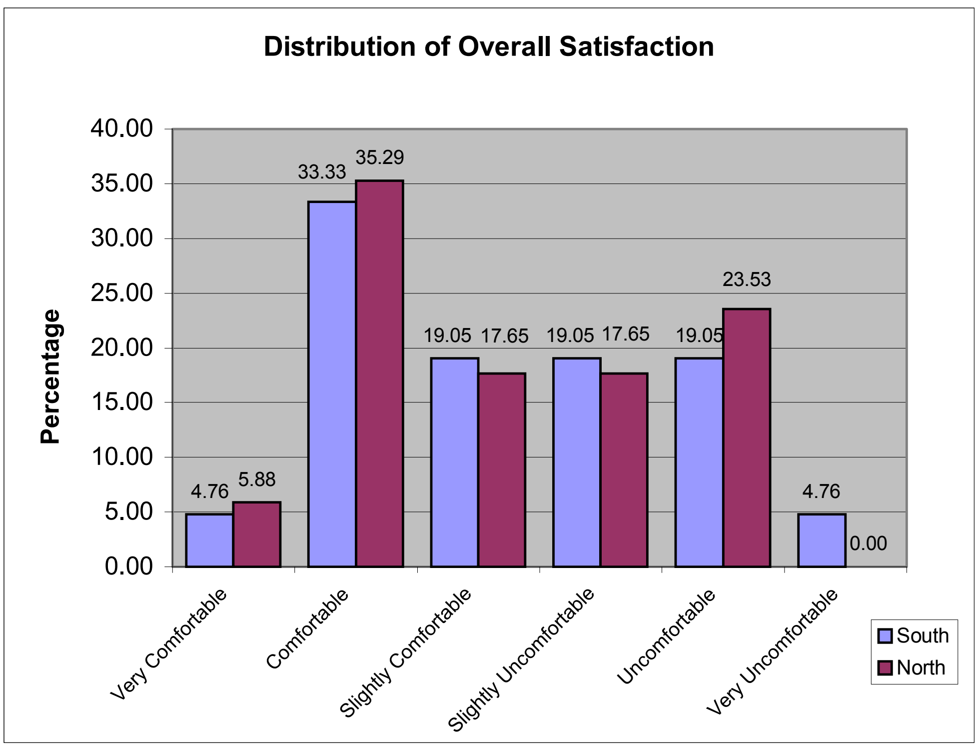

Figure 3.4. Distribution of Overall Satisfaction to Façades

As presented in the following discussions, 80% of the occupants liked to have an operable window to out-of-doors in order to adjust the inner environmental conditions. Since opening a window to out-of-doors is an important issue in this study, the dependency of having such an opportunity on overall satisfaction of the occupants was also investigated. Respondents were grouped into two according to their overall feeling of the environment as shown in Figure 3.5. As it was noted earlier, the first three responses, namely, very comfortable, comfortable, and slightly comfortable were grouped under 'comfortable' in this chart. The second set of responses, namely, slightly uncomfortable, uncomfortable, and very uncomfortable were grouped under 'uncomfortable'. In Figure 3.5, it is seen that, 72.7% of the comfortable respondents liked to have an operable window to outside, and 27.3% did not mention such a desire. On the other hand, 93.8% of the uncomfortable respondents have the desire to have the opportunity of an operable window to outside, and only 6.3% do not like to have that opportunity. This huge difference in the uncomfortable group of people made the author further detail this variable to verify the relation between comfort and the opportunity mentioned above.

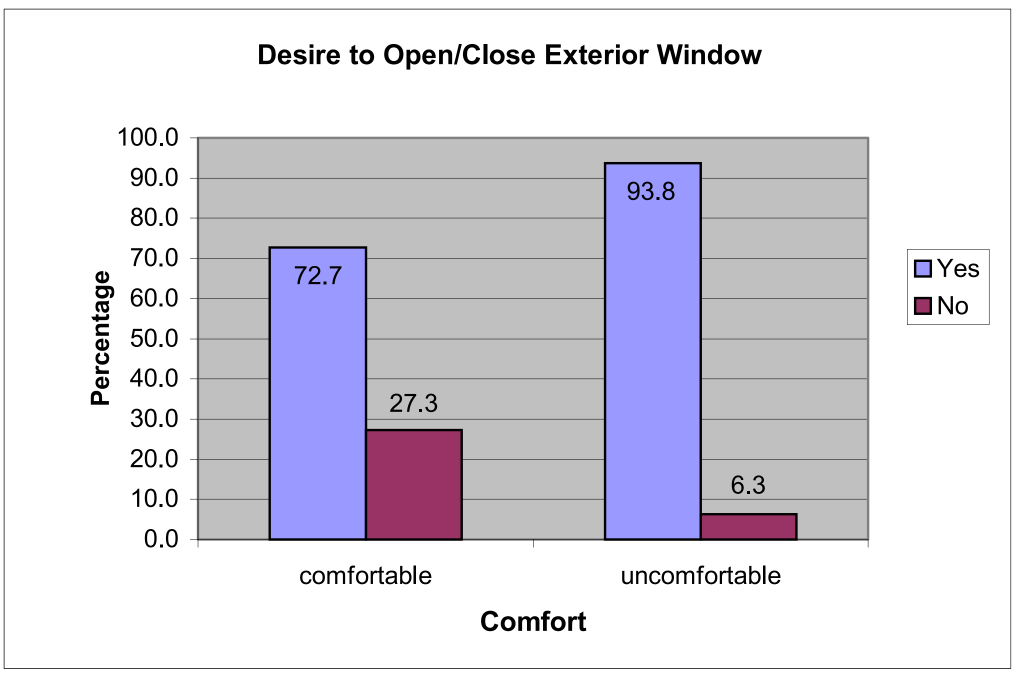

Figure 3.5. Desire to Open/Close An Exterior Window

The chi-square analysis was applied to categorical variables 'comfort level' and 'desire to open/close a window to the out-of-doors' to verify the relationship between them. As it is presented in Table 3.1, on the 'comfortable' part of the scale 16 out of

22 respondents mentioned the desire to open a window to the outside, and 6 didn't. In the uncomfortable part of the scale, only 1 didn't like to have the opportunity of an operable window and the rest 15 did. In total 38 users responded to question 23 and 2 didn't. So valid number of samples in this analysis is 38.

Table 3.1. Desire to Open/Close an Exterior Window Distribution to Comfort

	Open or close an exterior window		
	Yes	No	Total
Comfortable	16	6	22
Uncomfortable	15	1	16
Total	31	7	38
	p-value	**0,09883**	
	df=1		

In the chi-square analysis, author derived the p-value of 0,098 at 1 degree of freedom.

$$p= 0{,}09883 \text{ at df}=1$$

It can be concluded on these variables that there is not significant evidence that there are differences in satisfaction level according to desire to have a window opening to exterior at alpha= 0,05.

$$p = 0{,}09883 > 0{,}05 = \text{alpha}$$

Another variable that was thought to be in relation to overall comfort is gender. Initial assumption was that there are differences in satisfaction level according to gender. Chi-square test was applied to those two variables namely 'comfort level' and 'gender'. Data related to those two variables were tabulated as in Table 3.2. This data was gathered out of questions 5 –gender- and 15 –overall satisfaction- and since there were a total of 38 responses to question 15, the valid number of responses is 38. From the chi-square test applied p-value of 0,046 was calculated at 5 degrees of freedom.

$$\text{p-value}= 0{,}04673 \text{ at df}= 5$$

Author reached the conclusion that there are significant differences in satisfaction level according to gender at alpha=0,05.

$$p = 0{,}04673 < 0{,}05 = \text{alpha}$$

It was concluded that gender makes a difference in satisfaction level; and this variable should be given due consideration and be investigated in further detail in future studies on this subject.

Table 3.2. Distribution of Comfort Level to Gender

	Male	Female	Total
Very Comfortable	1	1	2
Comfortable	10	3	13
Slightly Comfortable	6	1	7
Slightly Uncomfortable	1	6	7
Uncomfortable	4	4	8
Very Uncomfortable	0	1	1
Total	22	16	38
	p-value=	**0,04673**	
	df=5		

One other variable that was checked in relation to overall satisfaction level was the smoking habits of the respondents. The author created a three-group-scale for smoking habit; namely, 'non-smoker', 'quit', and 'smoker'. Raw data gathered from the questions 10 –smoking habits- and 15 –overall satisfaction- were tabulated as in Table 3.3. A chi-square analysis was also applied to this categorical data to check the relation of smoking habits with overall satisfaction, based on the initial assumption that smoking might affect the well-being of the occupant and thus his or her attitude towards the environment.

Table 3.3. Distribution of Comfort Level to Smoking Habits

	Very Com.	Comfort.	Slightly Com.	Slightly Unc.	Uncom.	Very Unc.	Total
Non-Smoker	0	5	5	5	6	0	21
Quit	1	0	0	0	0	0	1
Smoker	1	8	2	2	2	1	16
Total	2	13	7	7	8	1	38
	p-value	**0,00593**					
	df=10						

A p-value of 0,0059 at 10 degrees of freedom, was obtained from the analysis of these two variables.

p-value = 0,00593 at df = 10

It was concluded that there is significant difference in overall satisfaction according to smoking habits of the occupants at alpha= 0,05.

p-value = 0,00593 < 0,05 = alpha

Smoking habits appeared to be an important variable in total satisfaction level of Emek İşhanı occupants. Although this result is specific to this building, this variable should be taken into consideration in detail in similar studies.

The last variable that was analyzed in relation to overall user satisfaction of the occupants is the date that individuals started to work in the building. This part of the analysis is based on the questions 13 –starting date of work- and 15 –overall satisfaction- of the survey. December 11, 2000 was the starting date for the renovation of the building façade on site. Question 13 was directed to occupants to gather data on their starting date of work in Emek İşhanı relative to December 11, 2000. This analysis was conducted because, it was thought that having experienced the old facade might make a difference in satisfaction level of inmates today. Again chi-square analysis was applied to those two variables, namely 'overall satisfaction level' and 'starting date of working'. Data of the these variables were tabulated as in Table 3.4.

Table 3.4. Distribution of Comfort Level to Starting Date of Work

	Very Com.	Comfort.	A Little Com.	A Little Unc.	Uncom.	Very Unc.	Total
Before	2	8	4	2	5	0	21
After	0	5	2	5	3	1	16
Total	2	13	6	7	8	1	37
	p-value=	**0,35025**					
	df=5						

p-value of 0,35 at 5 degrees of freedom, was calculated at the analysis of variables.

p-value = 0,35025 at df = 5

It can be concluded from these results that there is no significant difference in overall satisfaction of the occupants according to the date of starting to work in the building at alpha= 0,05.

$$\text{p-value} = 0{,}35025 > 0{,}05 = \text{alpha}$$

Overall satisfaction is a very general attitude of an individual towards his environment. This feeling might be affected by many variables of the environment and person himself, some of which were investigated in this part. Specific to this study, two variables, namely 'gender' and 'smoking habits' appeared to have direct effect on the overall satisfaction in this building. These two variables are personal, which led author to a larger conclusion that personal variables might determine the satisfaction of individual in an environment. To put it another way, in evaluation of an environment, inputs from the person himself are as much important as the inputs from the environment.

3.3.2 Ventilation Effectiveness Analysis

In this part of the study were analyzed the effectiveness of HVAC system of the Emek İşhanı based on the perception of the occupants. Air quality perception, air movement perception, and health condition of the occupants were decided to be related issues of this analysis. Air quality is related to the filtering and fresh air supply function of the ventilation system. Air movement is related in the way that system provides necessary air movement to restore the comfort level. Health problems were also investigated to have an insight on SBS in the building. Here, humidity perception was not given the primary importance but examined under the topic of 'Air Quality Perception Analysis'.

(i) Air Quality Perception Analysis

Question 22 was directed to occupants to gain information on their perception of air quality of their working environment. The question has six-point scale ranging from 'very low' to 'very high'. In Figure 3.6, is presented that 40% of the respondents find the air quality ‘very low’. 30% answered as ‘low’, and 15% ‘slightly low’. On the other hand, 12.5%, 2.5%, and 0% find their environment ‘slightly high’, ‘high’, and ‘very high’, respectively. It is also presented on the chart that 85% of the respondents’ answers is on the low part of the scale.

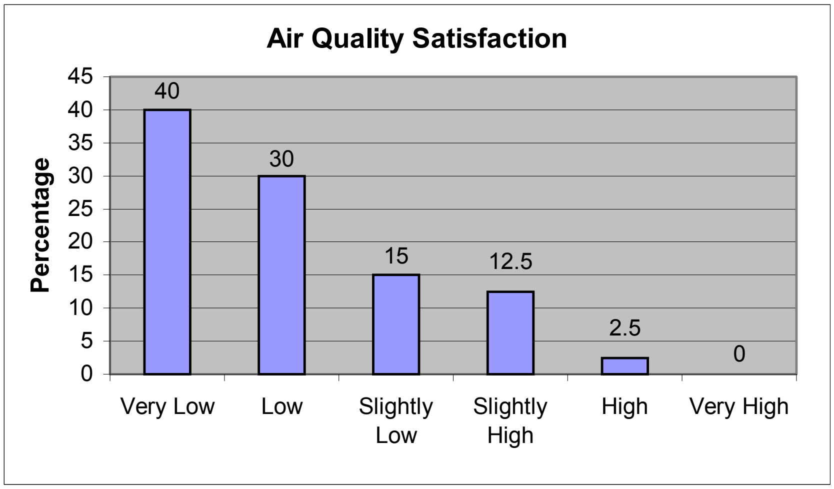

Figure 3.6. Air Quality Satisfaction of Occupants

Two variables that might contribute to the air quality level were investigated separately. First of these variables is the available room area per person. The author decided to check this variable thinking that less square meters, thus less volume of air available per person might decrease the affect the perception of air quality negatively. Area is a numeric value, thus regression analysis was applied to variables ‘occupation area’ and ‘air quality perception’. Occupation area per person was derived from the questions 3 –floor area of the room- and 4 –number of occupants in the room- such that

Occupation Area = Area of the Room / Population of the room

y-axis represents the air quality perception ranging from 1-6, representing the scale from ‘very low’ to ‘very high’. As presented in Figure 3.7, there is no direct correlation between the available area per person and air quality perception.

The value $R^2 = 1$, would represent the direct proportion, thus the relation between the two variables. But since the value $R^2 = 0{,}0198$ is much smaller than 1, it is concluded that occupation area per person does not directly affect air quality perception.

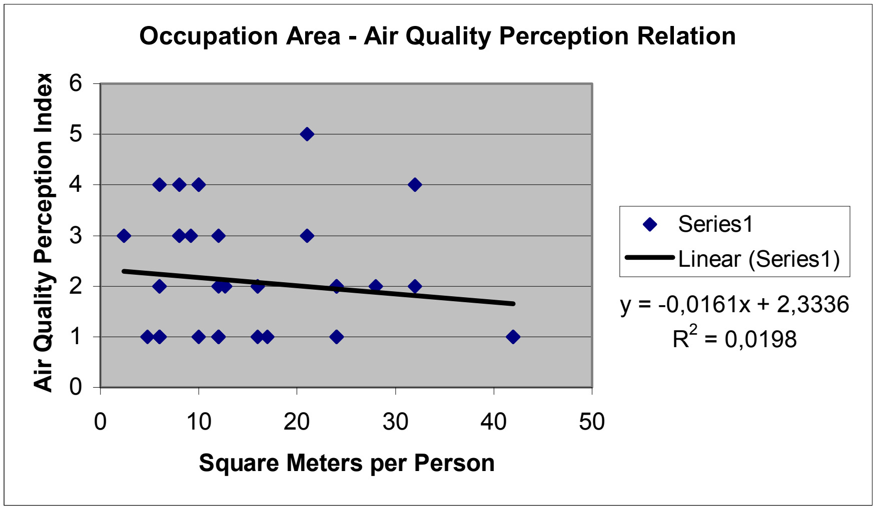

Figure 3.7. Occupation Area – Air Quality Perception Scatter Plot

One other variable that was checked in relation to ‘air quality perception’ is the ‘smoking habits’ of the occupants. Smoking is a respiratory system activity and respiratory system is the physical detector of air quality in an environment. So there is the possibility that ‘smoking habits’ affect the air quality perception. Chi-square analysis was applied to those two variables and the result is presented in Table 3.5.

Table 3.5. Distribution of Air Quality Perception to Smoking Habits

	Very Low	Low	Slightly Low	Slightly High	High	Very High	Total
Non-Smoking	12	5	3	2	0	0	22
Quit	0	0	0	1	0	0	1
Smoking	4	7	3	2	1	0	17
Total	16	12	6	5	1	0	40

p-value **0,14859**
df=8

p-value of 0,1485 at 8 degrees of freedom, was calculated at the analysis of variables.

p-value = 0,14859 at df = 8

It can be concluded from these results that there is no significant difference in air quality perception of the occupants according to the smoking habits at alpha= 0,05.

p-value = 0,14859 > 0,05 = alpha

As opposed to the expectations of the author, smoking habits did not appear to be the function of air quality perception. Two different variables, namely ‘occupation area per person’ and ‘smoking habits’ were checked separately. These two are physical or in other words relatively objective factors that might affect the perception. However, since there appeared no direct relation, author concludes that individual preferences and subjective feelings might play important role in perceiving the indoor air quality.

Relative humidity is a factor that also contributes to the perception of an environment. In Figure 3.8 is presented the relative humidity perception of occupants in the Emek İşhanı. 50% of the respondents finds the interior dry and in total 75% of the occupants is on the ‘dry’ half of the scale. ‘Dry’ half consists of three points, namely ‘slightly dry’, ‘dry’ and ‘very dry’. Only 15% of the respondents find interior air humid, ranging from ‘slightly humid’ to ‘very humid’. It is obvious in this figure that there is a problem of dryness in Emek İşhanı. Ventilation system should be adjusted to provide the desired conditions in the interiors.

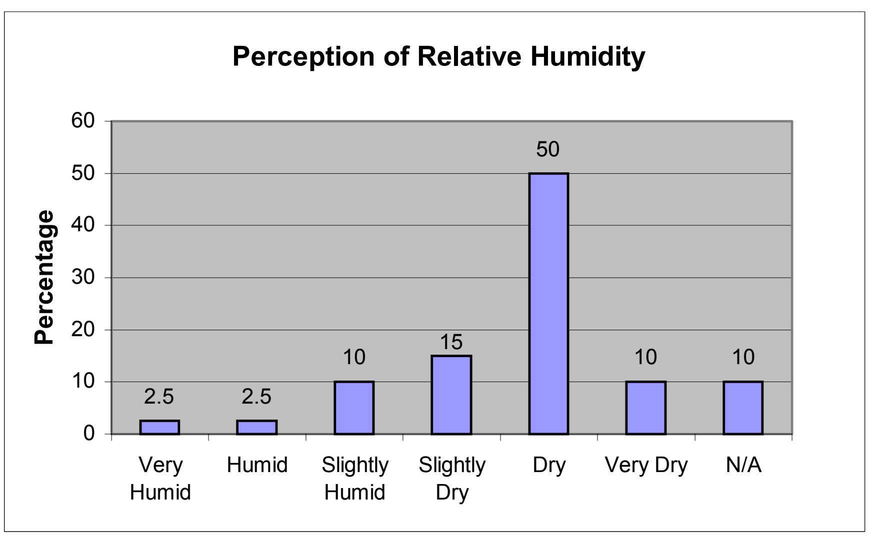

Figure 3.8. Relative Humidity Perception of Occupants

(ii) Air Movement Perception Analysis

In question 21, respondents were asked to evaluate the air movement in their offices. Again a six point scale was prepared for the question ranging from 'no air movement' to excessive air movement'. As presented in Figure 3.9, 27% of the respondents finds the air movement inadequate. 20% of the occupants claimed that there is no air movement and for 15% of the occupants air movement is very low. On the other side of the graph, 17.5% thinks that air movement is fair, and another 17.5% thinks that air movement is adequate. Only 2.5% finds the air movement excessive.

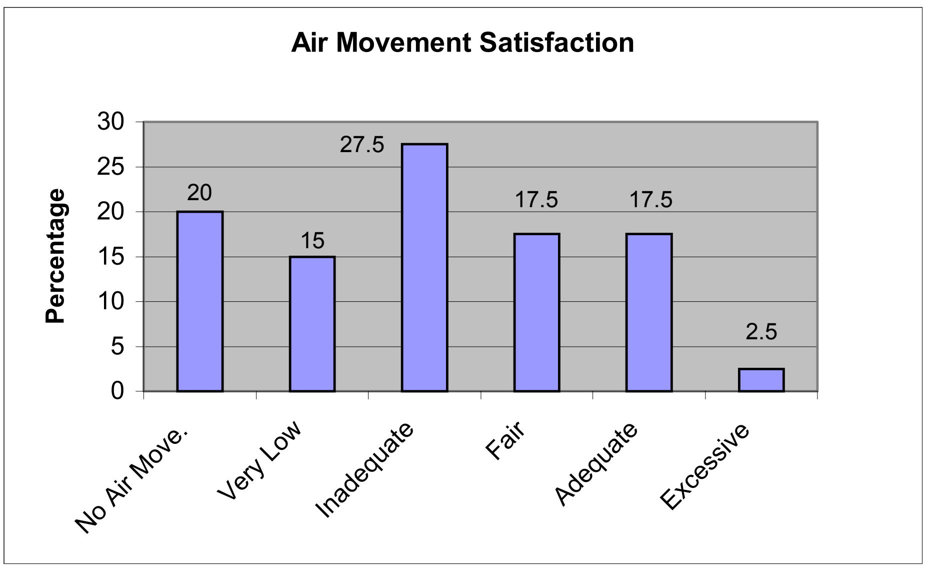

Figure 3.9. Air Movement Satisfaction of Occupants

As shown in the same graph, air movement perception distribution is relatively close to each other. This might be a result of many variables interacting to create such a complex situation; or it might mean that any factor in the building, as being an external determinant, does not play a major role in air movement satisfaction. If there was a distinctive value in the graph, it would be concluded that this might be a result of a feature of the building.

It was concluded earlier that occupation area is not an effective factor in the evaluation of the environmental conditions. So, other external determinants or individual preferences should be considered to verify any relationship to air movement perception. It should also be noted that 'occupation area' might play an important role in any other case study.

In question 23, users of the building were asked to mark the type of adjustment that they would like to have over their environment. Inmates of the building have some of the adjustments types, but question 23 was mainly a hypothetical one asked to determine individual preferences in general. The result has distinctive features as presented in Figure 3.10. 80% of the respondents like to open/close an exterior window to adjust the interior conditions. The rest of the values are as follows: adjusting a thermostat is 22.5%, adjusting drapes or blinds is 12.5%, open/close an interior door is 7.5%, turn a local heater on/off is 17.5%, and finally turn a local fan on/off is 5%.

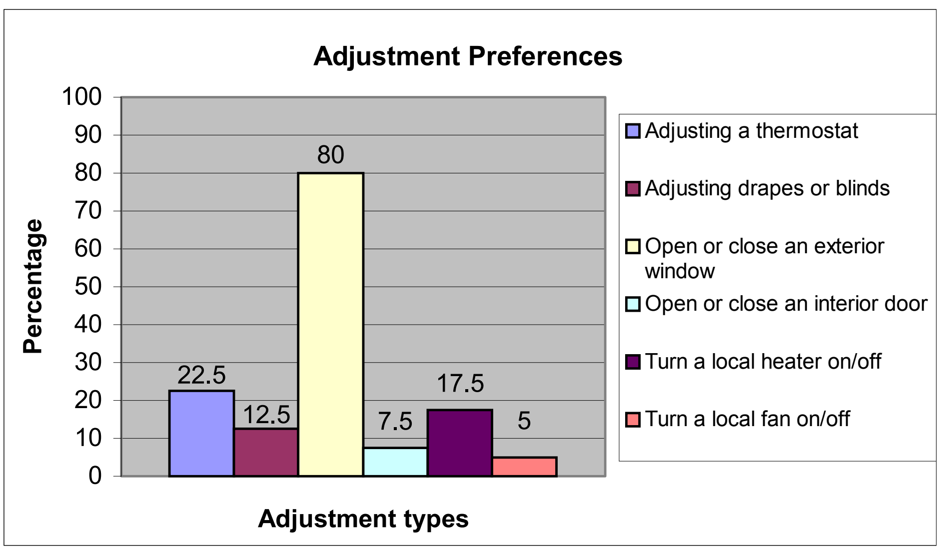

Figure 3.10. Adjustment Preferences of Occupants

This high percentage of desire to open/close an exterior window is probably the result of HVAC system's not meeting the needs of the occupants. Lack of fresh air, high or low level of moisture, low air movement are some of the problems that adjusting an exterior window can cope with. Availability of high level of individual control in window adjustment can be another factor that makes it preferable. One variable, which is the façade orientation, was analyzed in relation to this adjustment type. This is because when any other variable is constant, façade orientation makes an important difference in the quality of the environment. Therefore, this situation might have significance in adjustment preferences.

Table 3.6. Distribution of Desire to Open/Close an Exterior Window to Façades

	to open/close a window to outside		
	yes	no	total
South	19	3	22
North	13	5	18
	32	8	40
	p-value	**0,26597**	
	df=1		

Chi-square analysis was applied to the variables 'façade direction' and desire to 'open/close an exterior window'. The result of this analysis is presented in Table 3.6. A p-value of 0,2659 was derived at 1 degree of freedom.

$$\text{p-value} = 0{,}26597 \text{ at df} = 1$$

It is concluded that façade direction does not make significant difference in desire to adjust an exterior window. High percentage of the discussed adjustment preference is probably due to other features, which are common throughout building.

$$\text{p-value} = 0{,}26597 > 0{,}05 = \text{alpha}$$

(iii) Health Condition Analysis

Question 25 was aimed at determining the health condition of the Emek İşhanı occupants. Respondents were asked to mark the frequency of 11 symptoms of Sick Building Syndrome. A six point frequency scale was prepared and responses were valued as follows: 'never' is 0, 'rarely' is 1, 'sometimes' is 2, 'often' is 3, 'usually' is

4 and 'always' is 5. Respondents were also asked to mark the symptoms that they think the cause is the HVAC system.

In tabulation of the data, each question was divided into two parts. In the first part written was the frequency value of the disease and in the second part written was whether the respondent thinks the cause is ventilation system. In this part '1' represents 'the cause is ventilation system, '0' represents the opposite. In the following investigations 'health index' was used as an important variable. Health index of each respondent was calculated by summing up the frequency of each symptom. The highest value for health index is 55, derived from 11 multiplied by 5, in which 11 is the total number of symptoms and 5 is the highest frequency value; lowest value for health index is 0.

In Figure 3.11 is represented the percentage of people suffering from each symptom and percentage of people who attribute each disease to the ventilation system. The percentage of people that suffers from each health problem varies from 55% to 93%. In total this appeared to be a serious problem in Emek İşhanı. Sleepiness and headaches are the most severe problems of which 93% of the occupants are affected by.

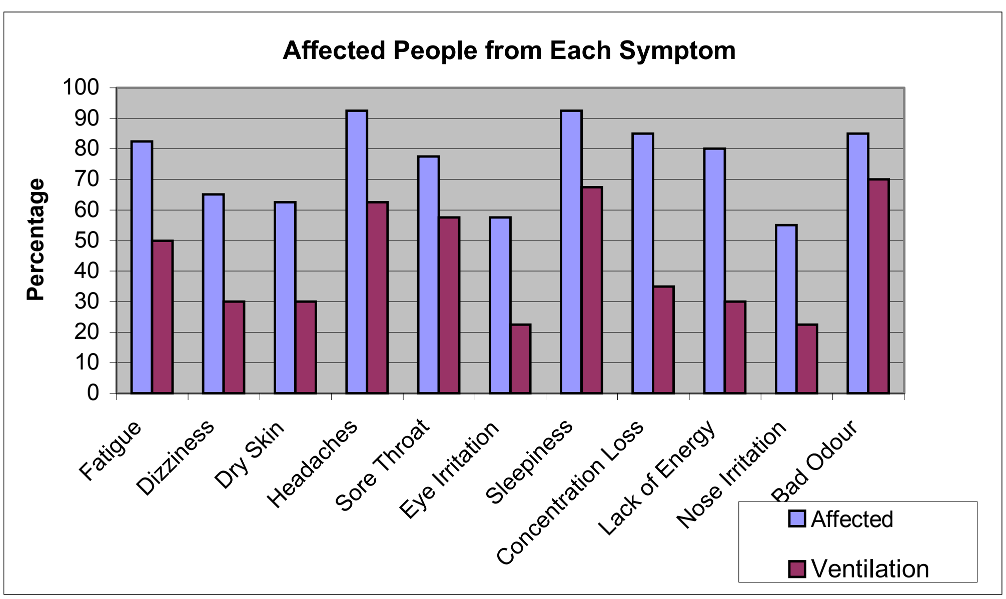

Figure 3.11. Percentages of Affected Occupants from SBS Symptoms

As presented in Figure 3.11, most of the people suffering from fatigue, headaches, sore throat, sleepiness and bad odour also attribute them to the ventilation system.

In Figure 3.12, is represented the effectiveness of each disease. Effectiveness of each disease is calculated by adding up the frequency values of each symptom. In other words, the column of each symptom in the tabulation of the data is summed.

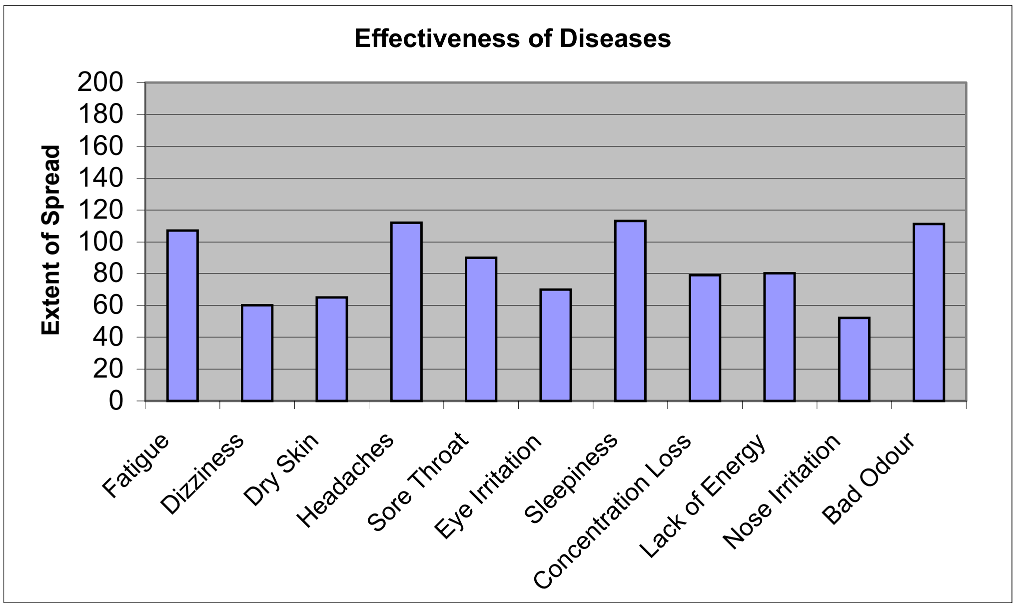

Figure 3.12. Effectiveness of Diseases

Effectiveness is mainly the indicator of how seriously any specific health problem is effecting occupants negatively in the overall population of Emek İşhanı. Maximum value for effectiveness is 200, and calculated from 40, total number of respondents, multiplied by 5, highest frequency value for symptoms. This is a case where every respondent marked ‘always’ for the same symptom. Minimum value for effectiveness is 0. In the overall population any specific disease is considered twice as effective when 16 occupants marked ‘always’ (value=5) in the frequency range while 40 occupants marked ‘rarely’ (value=1) in the same range. In the same graph, sleepiness, headaches, fatigue, and bad odour are the most effective problems on human well-being. Nose irritation and dizziness are the least effective problems.

One of the important variables that might cause health problems is the smoking habit of the occupants. Linear Regression analysis was applied to check if there is a relation between health index and smoking habits. In Figure 3.13, is presented the relation between the smoking habit and health index. '1' on y-axis represents non-smoking, '2' represents quit users, and '3' represents smoking occupants.

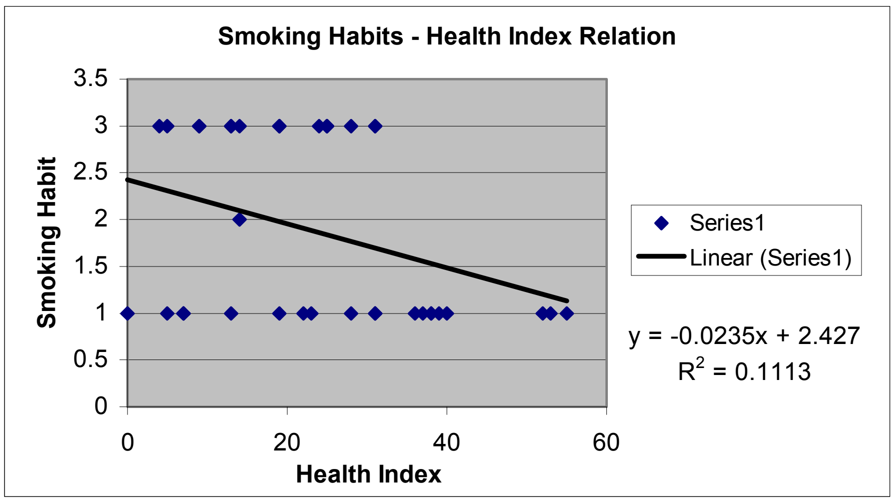

Figure 3.13. Health Index – Smoking Habits Scatter Plot

Since R^2 = 0,1113 is much smaller than R^2 = 1, then it can be claimed that there is no correlation between the smoking habits and health index of each occupant.

The variable smoking habits was also checked with another index. 'Number of symptoms' index is the total number of health problems that an occupant suffers. For example a non-smoking occupant (1 on y-axis) is suffering from 11 diseases in total (11 in x-axis) (Figure 3.14). This analysis was conducted to see if smoking makes difference in the number of health problems a worker suffers.

In the analysis was derived R^2 = 0,0117, which is much smaller than R^2 = 1. Then it can be claimed that there is no correlation between the smoking habits and number of symptoms a worker suffers.

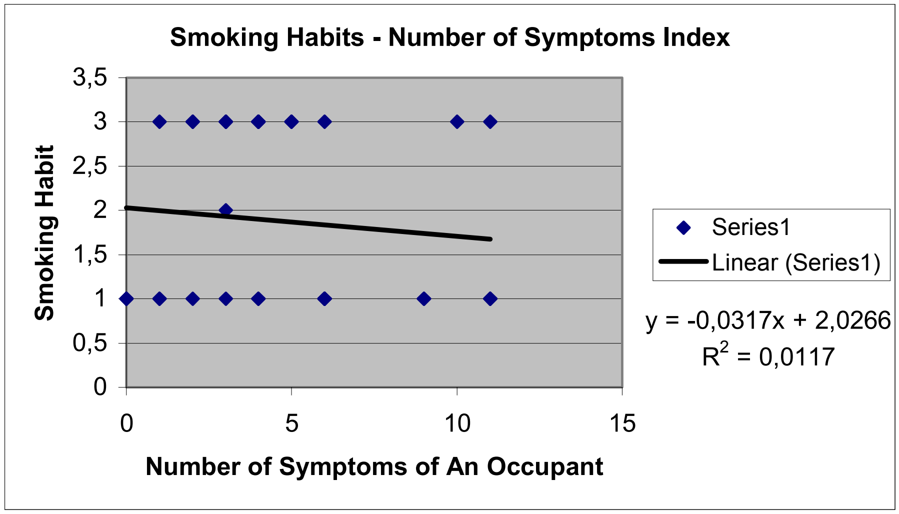

Figure 3.14. Number of Symptoms – Smoking Habits Scatter Plot

Regression Analysis was applied to two more variables to check if there is significant relation to health index. One of those variables is the number of years that an occupant spent working in the Emek İşhanı. Author assumed a correlation between the two variables such that health index increases as the years worked in this building increase. According to the author it might have been a dependable proof of building's causing health problems if there was an evident correlation between these two variables. Results of the analysis is presented in Figure 3.15.

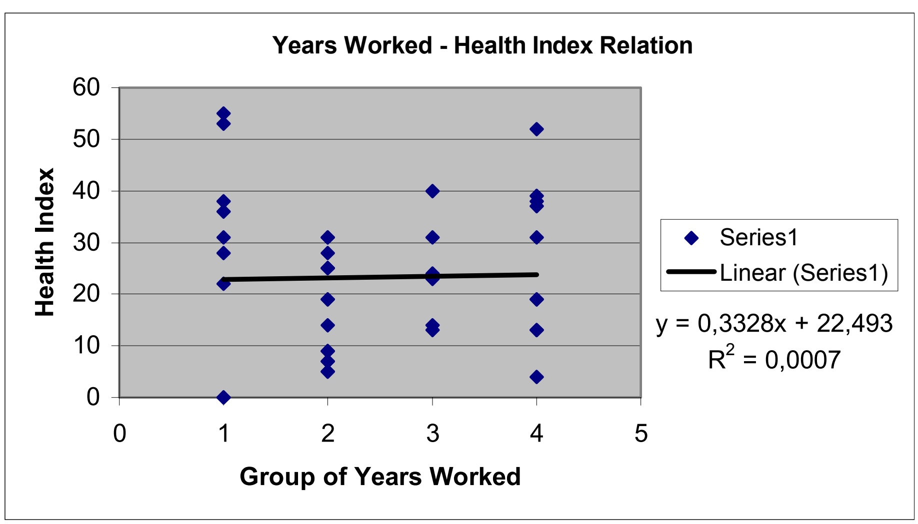

Figure 3.15. Health Index – Number of Years Worked Scatter Plot

In Figure 3.15, '1' represents the group of people who has worked less than 1 year. '2' represent the ones has worked between 1-5 years, '3' the ones between 5-10 years and '4', the occupants who has worked more than 10 year. As presented on the same graph, there is no direct relation between the group of years worked and health index.

Since the value R^2 = 0,0007 is very much smaller than R^2 = 1, it can be assumed that health is not a function of time spent in the building. In other words, having worked for a longer time in Emek İşhanı does not necessarily have a relation to occupant health.

The last variable analyzed is the age group of occupant. Author assumed at the beginning that age group might be effective, such that as the age increases, health index also increases. Proving this preposition might have meant that health problems in the building are mainly because of personal factors instead of building itself. To verify the preposition, analysis presented in Figure 3.16 was conducted. Age groups presented are as follows: 1 is 'less than 17', 2 is 17-25, 3 is 26-35, 4 is 36-45, 5 is 46-55, and 6 is 'more than 55'.

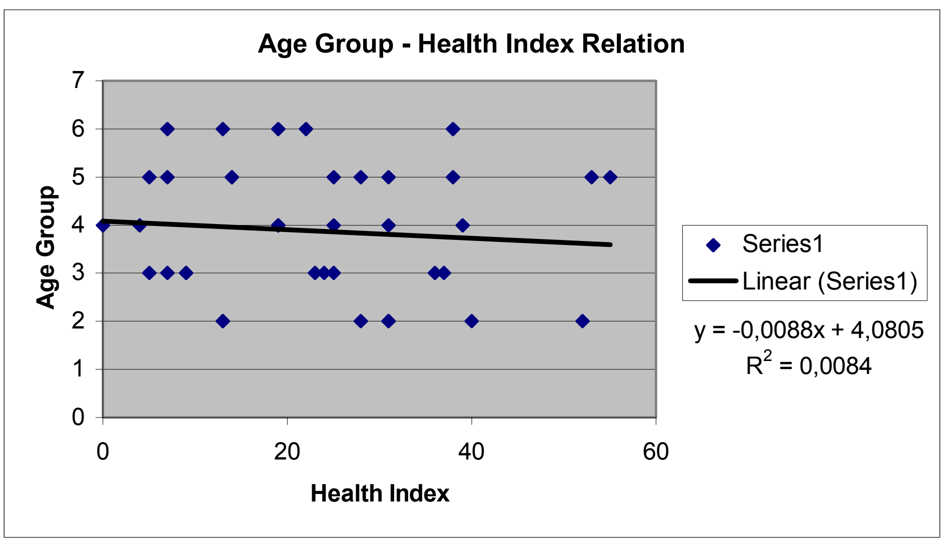

Figure 3.16. Health Index – Age Scatter Plot

Since R^2 = 0,0084 is very much smaller than R^2 = 1, it can be concluded that there exists no correlation between those two variables. In other words, age is not an effective factor in occupants' suffering from health problems. With this analysis, age as being an important personal variable in health condition of man, is eliminated in the Emek İşhanı study.

In this part of the analysis were investigated the health condition of occupants in relation to their smoking habits, number of years spent in the building and age. These variables were the first-hand ones that do not require detailed measurements. However, no correlation was found between the health index and those variables; but this situation does not change the fact that people, working in this building have severe health problems. So, improvement in the building is essential for the well-being of the occupants as well as the well-being of the corporations located in this building. While making any improvement detailed investigation should be conducted in the building, not to lose labor, money and time.

Finally, HVAC system of the building has appeared to be one of the important points that needs detailed investigation. From the analysis conducted, building still has the potential to be the major obstacle for the well being of the occupants. Author concluded from the survey results that any improvement on the ventilation system towards passive measurements, such as integration of natural ventilation strategies, at Emek İşhanı would be a big contribution to a better indoor environment, thus the human well-being.

CHAPTER 4

SIMULATION OF EMEK İŞHANI WITH ENERGY-10 SOFTWARE

In this chapter is presented the computer simulation of the Emek İşhanı in terms of energy performance. Materials, methodology, and results and discussions of the simulation are presented under seperate headings. Under ‘The Simulation Materials’ is first given the technical details of the Emek İşhanı needed to simulate the building in digital environment. Then, information on the Energy-10 software is given. In ‘The Simulation Methodology,’ is explained the application of the software to the same building. In the last part, namely ‘Results and Discussions’ is presented the simulation results and discussion.

4.1 The Simulation Materials

In this part, first is presented the dimensional properties and HVAC system of the Emek İşhanı under the topic ‘Technical Properties of the Emek İşhanı’ as they are needed in the simulation. Then is given the general information on Energy-10 Software.

4.1.1 Technical Properties of Emek İşhanı

As noted earlier, Emek İşhanı is composed of mainly two parts, one of which is the high-rise block of 21 storeys. Typical office floor has dimensions of 35.80 m. to 14.40 m. and has the floor height of 3.00 m. The clear height of typical office floor is 2.85 m. There are three elevators, a staircase and restroom at one end of the rectangular shape, and a fire escape on the other end. Services area, which consists of the main staircase, elevators and restroom is seperated from the office units with a door. So, this part is excluded in the simulation. The remaining part is roughly 14 x 28 m. in rectangular shape. The area of fire escape is compensated with the area of office located behind the elevators.

For the Emek İşhanı Building case, a typical office floor, which is between 4th and 18th floors, was simulated. About the HVAC design of the building, air comes to the offices through fan coil units located under the glazing of the offices (Figure 4.1); and air used in the offices is transferred to the corridor through the openings located next to each office door (Figure 4.2).

Figure 4.1. Fan Coil Units Located under the Glazing in Offices

Figure 4.2. Ventilation Opening Between the Corridor and Office Unit

Air that was transferred to the corridor is discharged from the openings located at the entrance of each corridor (Figure 4.3). Since the HVAC system of individual offices is coupled with the corridors, whole floor area was accepted as one zone; and since each floor is closed in itself, which means that there is no connection with the other floors in terms of the HVAC system, number of storeys was accepted as one in the simulation.

Figure 4.3. Discharge Opening Located at the Entrance of Corridors

4.1.2 Energy-10 Software

Energy-10 is a conceptual design tool for low energy buildings. It is specialized on buildings mainly smaller than 1000 square meters of floor area, which are defined with one or two zones. According to Energy-10 Software manual, daylighting, passive solar heating, and low-energy cooling strategies are integrated with energy efficient shell design and mechanical equipment. Energy-10 is the software development of a project called *Designing Low-Energy Buildings with Energy-10*, which is conducted for U.S. Department of Energy (DOE). The collaborators of the project are The Sustainable Building Industry Council (SBIC), the National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL), and the Berkeley Solar Group (BSG).

4.2 The Simulation Methodology

In this part is presented the simulation of Emek İşhanı with Energy-10 software. At first, existing situation of the building was simulated; thereafter, some variables such as HVAC type and the amount of air infiltration from outside were changed to simulate the naturally ventilated situation of the building. Comparative results are presented for both the existing and the hypothetical situation.

When starting a new project, in the first dialogue box of the program, variables of weather data, building use, HVAC system, floor area, number of storeys, aspect ratio (length/width) and some utility rates were defined[1]. In the second dialogue box, dimensions of facades and the ceiling, roof, wall and floor construction types, number of windows and type and information on occupancy, thermostat, working schedule of the building, building rotation were defined (Appendix F).

Energy-10 software, by default, creates two buildings to make a comparison between. For this simulation, two identical buildings based on the existing situation of Emek İşhanı were created. Changes on the variables were applied to second building in the simulation to be able to compare with the initial condition. In this simulation, first building was titled as 'existing building' and the second one as 'corrected building'. Here corrected means the hypothetical situation where passive measure of natural ventilation and fresh air infiltration from outside were applied.

[1] Energy-10 Software summarizes the defined variables on a separate page at the beginning of each project (Appendix E)

One of the most important variables of a building in the simulation was HVAC system. At the workshop that was held in April 2003 at the Ball State University in Indiana, USA, it was stated by the programmers that the closest HVAC system could be chosen if there was no exact match with the existing system. ‘DX Cooling with Gas Furnace’ was chosen for the existing situation and for the ‘corrected building’ this option was changed to ‘Gas Fired Unit Heater’. It was again stated at the same workshop that program accepts fresh air infiltration directly from outside and discharge with mechanical means if there is no cooling option in the selected HVAC system. This was the situation desired for the corrected building.

Another important variable that changes the building performance was the amount of air infiltration from outside. In the infiltration dialogue box of the program (Figure 4.4), there are two parts that air infiltration can be specified. Since ‘Effective Leakage Area’ and ‘ Constant Air Change Rate’ are additive values, only one of them was specified. As presented in Chapter 2, Figure 2.3, ASHRAE standard’s ventilation requirements in office buildings are 1.7 and 0.25 l/s m^2 for smoking and non-smoking conditions, respectively. From the survey that was conducted in Emek İşhanı, it was found that 23 out of 40 occupants are non-smokers, and the rest 17 are smokers. Then, the ventilation requirement of Emek İşhanı Building was determined from the following equation:

$$[(1.7 \times 17) + (0.25 \times 23)] / 40 = 0.87 \text{ l/s m}^2$$

The ventilation requirement of the building in an hour was determined as:

$$0.87 \times 3600 = 3132 \text{ l/h m}^2 = 3.13 \text{ m}^3\text{/h m}^2$$

Since the height of a typical office floor is 2.85 m, then there is 2.85 m^3 of air for per square meters. Thus the air change rate per square meters was calculated as:

$$3.13 / 2.85 = 1.1$$

Then, Air Changes per Hour (ACH) of 1.1 was specified as the desired value for air infiltration in the ‘corrected building’ of the simulation. Air infiltration for the ‘existing building’ was specified as 0, which means that the ‘existing building’ is totally sealed.

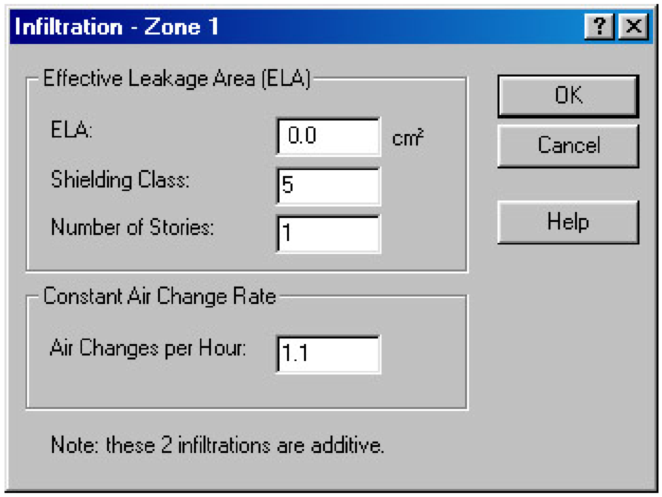

Figure 4.4. Infiltration Dialogue Box of Energy-10 Software

In this specific simulation, variables other than HVAC system and air infiltration were kept the same, because the concerned subject was the integration of natural ventilation, and building performance was evaluated accordingly. Full mode strategy of HVAC system stood at one end, and naturally ventilated office with ACH of 1.1 stood at the other. Here air change rate of 1.1 with the fresh air supply from outside, was accepted for the whole year and this might create disadvantageous situations for the winter conditions. This situation is discussed in the following parts.

4.3 Results and Discussions

In this part is presented first the results such as total energy consumption, change in gas emissions of the building for the energy performance simulation in a typical year. Then cost breakdown and energy reduction figures are presented for summer time, which was defined as from May 1 to September 30. The numbers on the charts might not give the exact values of the existing building, but they are needed for comparison and understanding the level of significance of the recommended system.

4.3.1 Whole Year Simulation

In this part, results of the energy simulation of the both existing and corrected buildings for a typical year, which is between January 1 and December 31, are presented. In Figure 4.5, it is given on the graph that heating requirements of the building increases from 53.1 kWh/m^2 to 109.9 kWh/m^2, which is 207%. This was because Energy-10 calculates the air infiltrating from outside the whole year in the 'corrected building'. It can be inferred that additional measures are needed at the extreme conditions. In this analysis energy requirement for cooling loads decreased from 29.4 kWh/m^2 to 0 kWh/m^2, which means that cooling loads of the building is totally eliminated. Energy load for lighting did not change because none of the variable that affects the lighting loads was changed. Energy requirement for other facilities of the building decreased from 125.7 to 105.3, a reduction of 16%. In total, energy expenses of the building increased from 236 kWh/m^2 to 243 kWh/m^2, an increase of 3%, which is almost the same with the reference case.

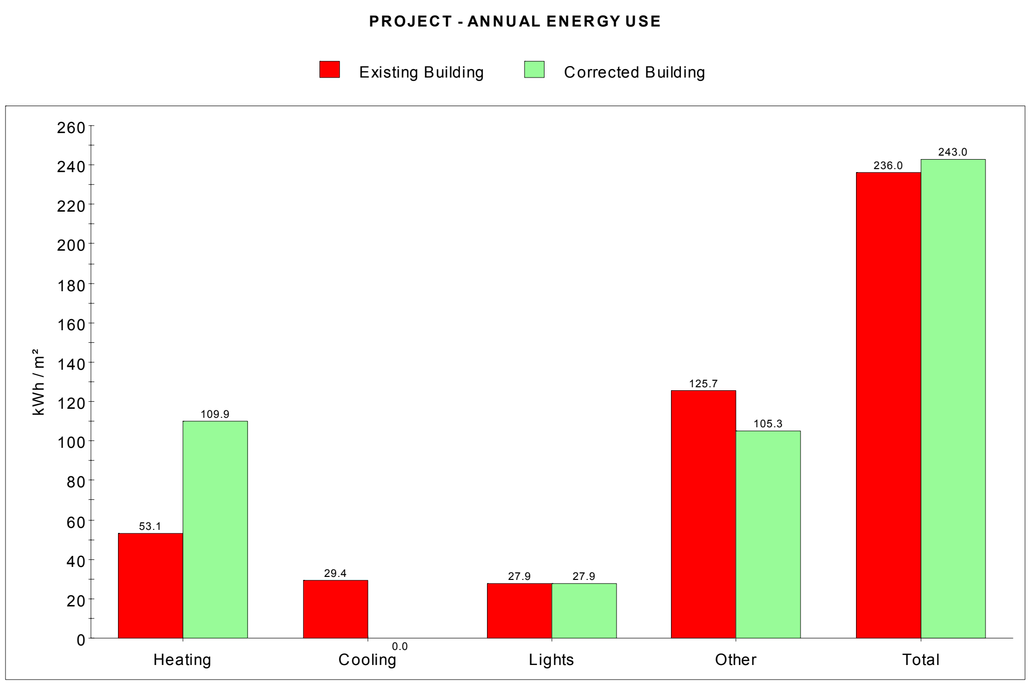

Figure 4.5. Annual Energy Use of Existing and Corrected Buildings

As noted earlier, the defined situation might not be the exact solution for the winter conditions of Ankara, where number of heating days is significantly more than the cooling days. Thus instead of introducing a totally naturally ventilated office, it might be more appropriate to introduce a mixed mode strategy of HVAC system, in which passive measures are supported by mechanical means whenever outside weather conditions exceed the acceptable limits. So the best compromise between the new technologies and passive measures can be attained.

On the other hand, natural ventilation is not only provided through operable windows. The problem of excessive energy consumption for heating in winter times, because of cold air infiltration to inside can be solved in the detail level. Outside air can flow into the building through some inlets and be preheated at each floor and introduced to interior through raised floor. Therefore, naturally ventilated environment and energy savings can be attained with more detailed solutions without damaging the logic of integrating passive measures.

In Figure 4.6, are presented the emissions of three chemicals for both the existing and the corrected building. SO_2 emissions decreased by 27%, from 242 kg to 176 kg; and there was a 25% of reduction, from 129 kg to 97 kg in NOx emissions. Lastly, CO_2 emissions decreased from 45226 kg to 37391 kg. which is a reduction of 17%. These figures showed that integration of even one passive strategy could make a significant reduction in harmful chemical emissions of the building. This situation meant that integration of natural ventilation, as a passive measure would not only have economical gains but also ecological ones, which are more desirable for the ecosystem.

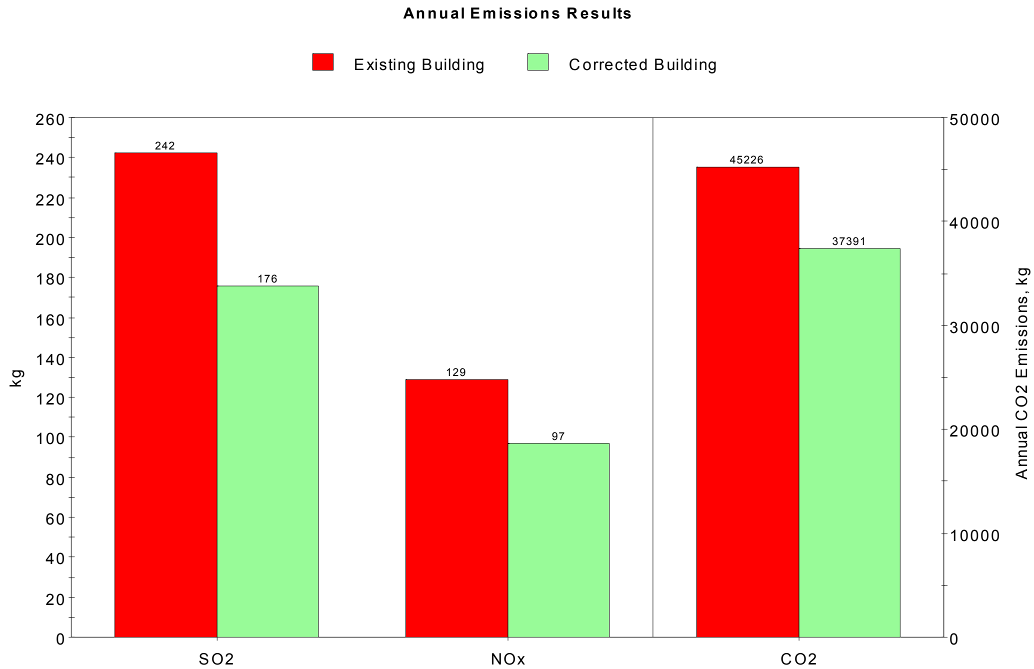

Figure 4.6. Annual Emissions Results of Existing and Corrected Buildings

In the following two graphs (Figure 4.7 and Figure 4.8) are shown the 'Monthly Average Daily Energy Use' of the both buildings. The changing figures between the two graphs were heating, cooling and fan energy loads of the buildings. Other variables were kept the same to be able to make a controlled comparison. It is shown in the same graphs that cooling and fan energy loads were eliminated in the 'corrected building', however, heating energy loads significantly increased especially in winter conditions. Another important point about the same graphs is that, cooling loads of the building expands from mid February to mid November. This is important because, if no cooling measures are taken, overheating inside the building occurs not only in summer but also in colder months. Point is that, in the given range of time natural ventilation can easily be a solution to cooling loads, especially in colder months. These results of the simulation showed that natural ventilation is not only applicable in summer conditions but also in winter times. Therefore, adjusting the building according to weather conditions is the ideal system for overall satisfaction.

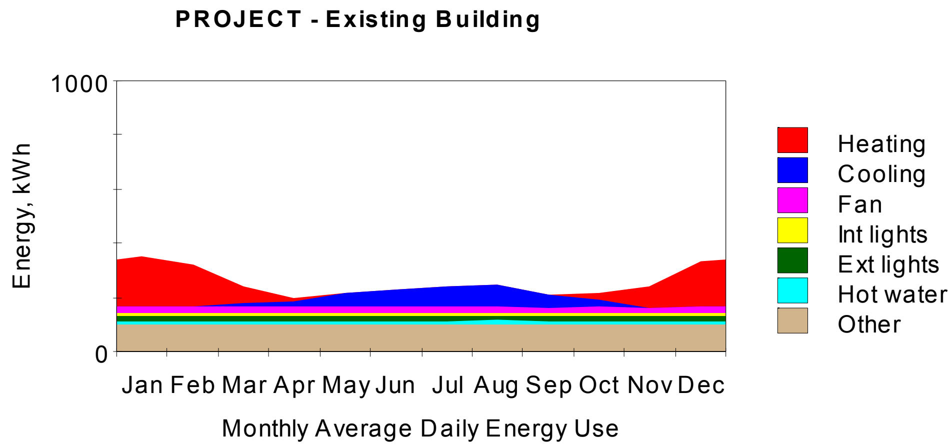

Figure 4.7. Monthly Average Daily Energy Use of Existing Building

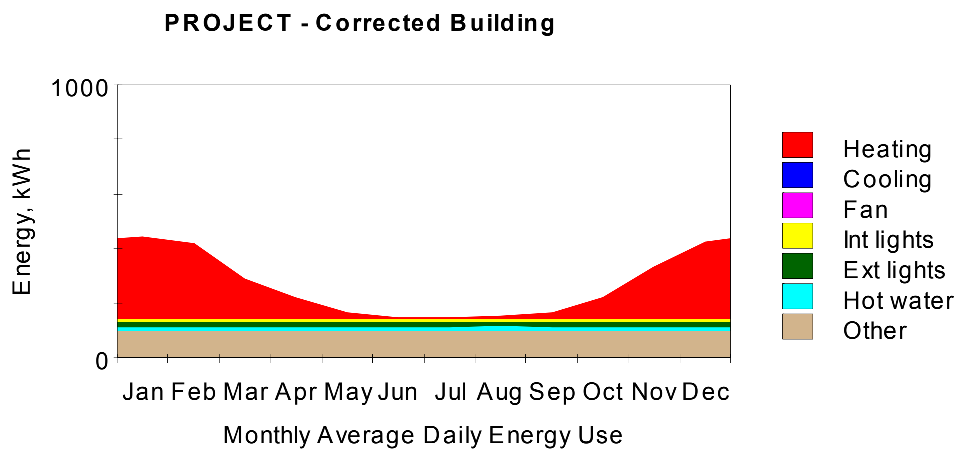

Figure 4.8. Monthly Average Daily Energy Use of Corrected Building

In the weather data of the city of Ankara, which was derived from the web site <http://www.eere.energy.gov/buildings/energyplus/cfm/weatherdata_int.cfm>, it is stated that maximum temperature of 88 °F (31.1 °C) occurs on the 26th of August. In Figure 4.9 and Figure 4.10, heating and cooling loads as well as the outside and inside temperatures were plotted for the 26th of August. In the case of the 'existing building' inside temperature is kept in a constant level with the backup system of cooling. On the other hand, in the case of 'corrected building' since there is no system to compensate the overheating of inside temperature, undesirable heating occurs in the afternoon.

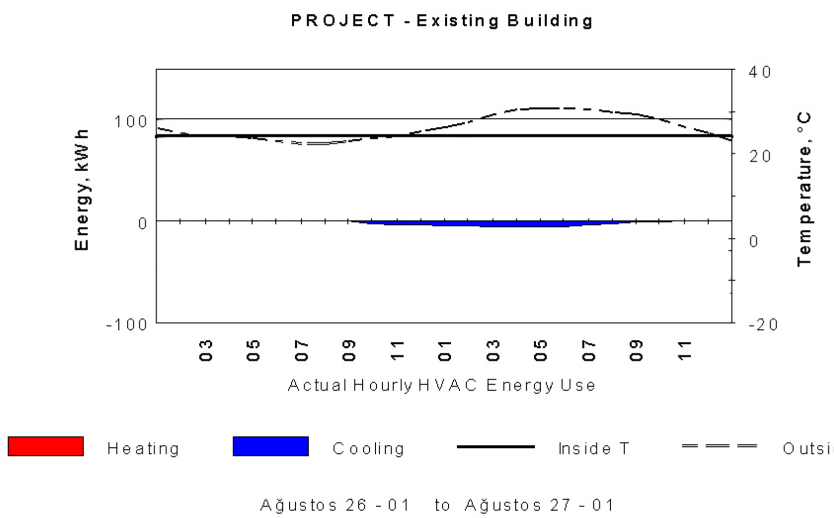

Figure 4.9. HVAC Energy Use of Existing Building on August 26th

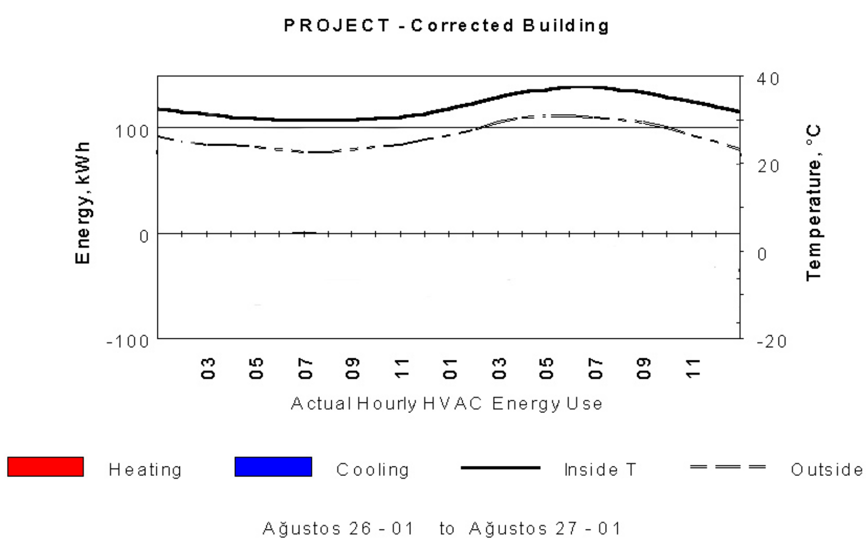

Figure 4.10. HVAC Energy Use of Corrected Building on August 26th

From the same weather data, noted above, it was determined that minimum relative humidity at 3 pm. in August is 29%. The relative humidity at 3 pm. was chosen as the appropriate value as being closest to 5 pm., the time when maximum inside temperature occurs. On the bioclimatic chart in Figure 4.11, the point with 88 °F temperature and 29% relative humidity is shown. The point falls out of the comfort zone in a part where air movement is the corrective measure. On the same chart, it was determined that 400 ft/m of air movement is needed to restore the comfort condition. According to Table 2.6, in chapter 2, the air velocity of 400 ft/m falls under the category of slight breeze at which wind is felt on face, leaves rustle and ordinary vane is moved by the wind.

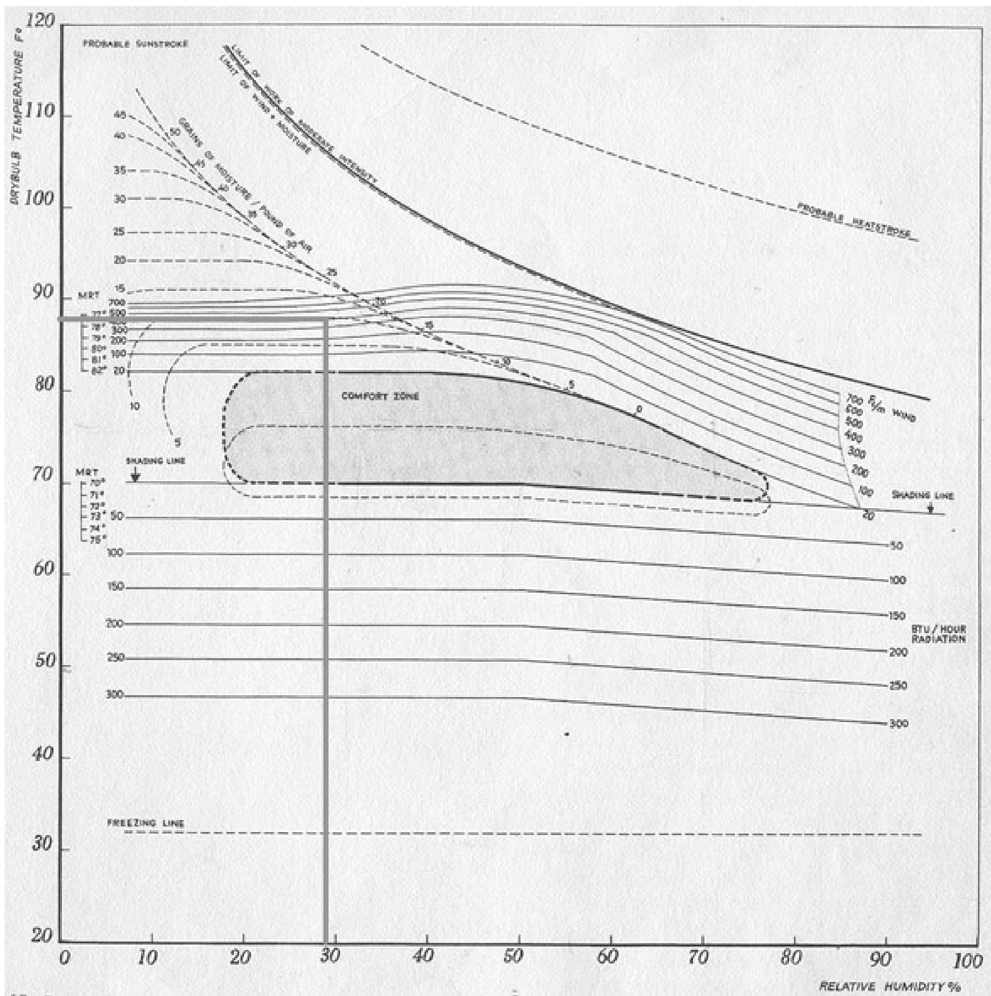

Figure 4.11. Corrective Measure for 88 °F and %29 Relative Humidity

According to the Bioclimatic Chart, maximum temperature allowed inside the building is accepted as 80 °F (24 °C) at 29% relative humidity-the minimum value in Ankara- to restore the desired comfort level. In Figure 4.12, are shown the daily average building temperatures for the whole year. In an average day indoor temperature exceeds the defined limits from May to September especially in the afternoons. In July and August, overheating of the interior occurs in the whole working schedule. However, since air movement can be employed as a corrective measure for the 26th of August -the day which the extreme summer conditions occur- air movement can be used to restore the desired comfort level in all summer months.

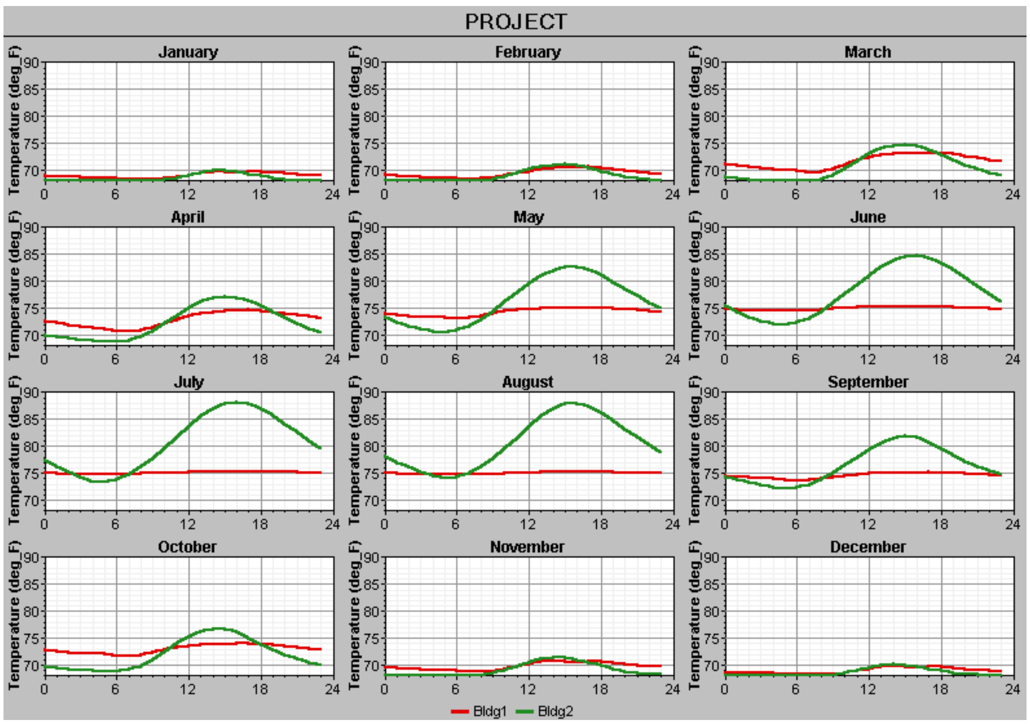

Figure 4.12. Energy Use in An Average Day for the Whole Year in the Emek İşhanı

4.3.2 Summer Months Simulation

Integration of natural ventilation for only summer months (May 1 to September 30) was also simulated and the results are presented. This part of the simulation was designed based on the idea that cooling loads is the major source of energy consumption in summer times, and eliminating this consumption is one of the most critical issues to energy-conscious desing. In Figure 4.13, energy consumption of the building in the summer months was plotted. It is presented in the same figure that total reduction in energy expenses is 32%. This is mostly because, cooling loads of the building can be eliminated with the integration of passive measures. This is the ideal situation for this specific case study. In practice, there might be some need for a backup system in summer months, when desired comfort level cannot be attained. But it is a fact that people depended on passive measures to provide the necessary comfort level for centuries; and this ingeniuty can be replicated today with the help of advance technologies more effectively.

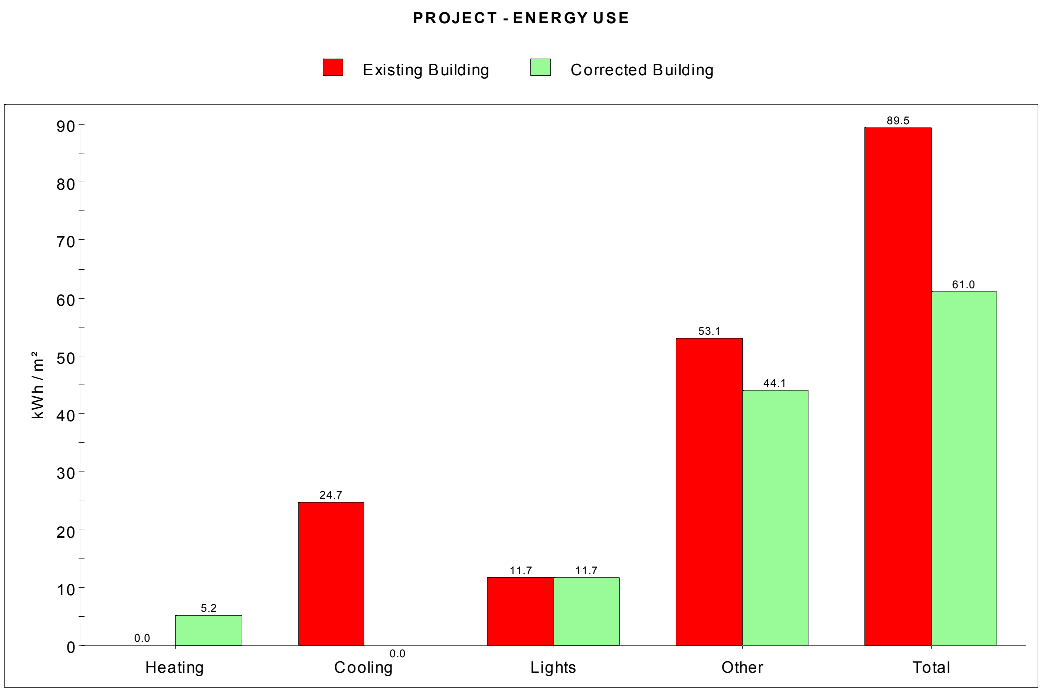

Figure 4.13. Total Energy Use Between May 1st and September 30th

Moreover, in Figure 4.14, is presented the benefits of integration of passive measures, which match with the determinations of the economic life of the new century. In the same figure is given the cost breakdown for the summer months, which consists of five months from May to September. It can be seen on the graph that majority of the costs is eliminated with the integration of passive measures during the summer time. Measurement on this graph is given as expanses per square meter. As presented on the same graph, cooling loads of the building determines the main difference between the existing and the hypothetical situations. Although energy load for the fans does not significantly change the total energy consumption, energy needed for operating them is almost totally eliminated. Values given on the graph may differ in the Turkish context but they are consistent and are helpful to make comparison within themselves.

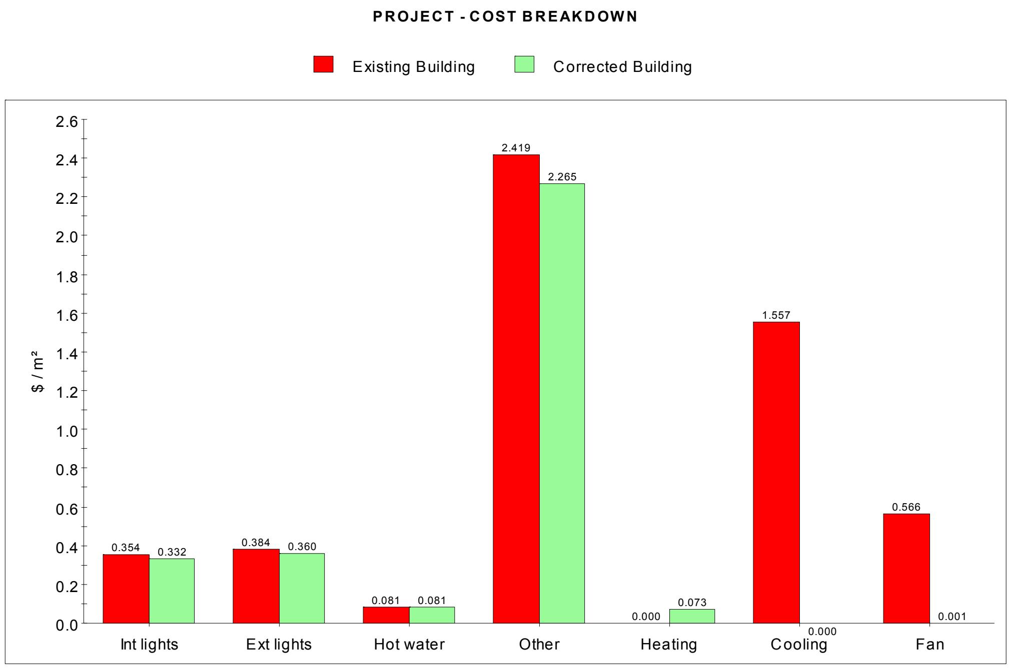

Figure 4.14. Cost Breakdown Between May 1st and September 30th

It was presented with the computer simulation of the Emek İşhanı that from the energy consumption viewpoint there is the potential of employing natural ventilation to office buildings. What is needed to attain more satisfactory buildings is a professional approach to energy consciousness. Sacrificing the human needs is a common attitude but justifying this attitude with only economical arguments do not have the expected sound basis. If the point is to earn more, than the solution is more energy conscious designs, not only the energy that building consumes but the energy the workers consume. In other words, efficiency of workers will be the utmost benefit of an employer if energy conscious design becomes a norm.

CHAPTER 5

CONCLUSION

Emek İşhanı is one of the remarkable objects in the urban context of Kızılay in Ankara. It is a high-rise building combined with a low-rise block. As being the first building with a curtain wall system in Turkey, it also has historical value. Moreover, there is one more feature that makes the building attractive especially for researches, which is the renovated façade. As noted earlier, north and south façades of the building were renovated in 2001 and the aged curtain wall system was replaced with a new system. Renovation made notable difference not only in character of the appearance but also but also in character of the interior spaces. A previous research conducted by Sönmez (2001), noted the positive contribution of the renovation to the occupant satisfaction. However, this study showed that building still has problems some of which might have been solved with renovation of the façade system.

The reasons for the renovation was explained by the supervising mechanical engineer, as the disturbing appearance of the building and the curtain wall system not functioning as required. Renovation project seemed to be successful in providing a more satisfactory thermal environment by improved filtering of sunbeams and in providing a clearer appearance. But this is only one side of the problem. On the other side stands the user preferences for their well-being and better renovation projects based on professional research.

In this study was investigated the Emek İşhanı buildings' potential for natural ventilation as a passive strategy and two studies were conducted on the building.

One of those studies focused on the user well-being and satisfaction in the building. Today Emek İşhanı still has problems especially related to health condition of the occupants, which can be solved with better ventilation strategies. From the survey conducted, the results indicated that over 90% of the occupants are suffering from a number of health problems and %80 of the occupants show a preference for natural means of ventilation. This situation was also presented in one of the analysis of Chapter 3. Therefore, utilizing passive measures for ventilation has the potential to contribute to higher level of user satisfaction.

Another study conducted on the building focused on the natural ventilation potential of the building in terms of energy consumption. It was concluded that annual energy consumption of the building does not increase significantly with the integration of natural ventilation. Moreover, energy consumption in summer months can be reduced by %32 which means that integration of natural ventilation does not only have humane benefits but also economical ones. Energy figures can be improved with more detailed analysis and also be generalized for Ankara context.

Emek İşhanı is a high-rise block in a dense urban context. It is known that air velocities in urban context decreases significantly because of the surface friction. This fact might result in low ventilation rates especially in low-rise buildings, but since Emek İşhanı is a high-rise building, it has the potential to utilize satisfactory level of airflow inside the building.

All the potential of the building, as explained, is noted as missed opporturnities by the author, since ventilation was not considered as a variable in the renovation of the building facade. However, it was aimed in this study that building strategies should be considered once to improve the environments that people live in. Integration of passive measures to especially large scale buildings requires specialization and careful work. This might mean time, and capital at the beginning of the projects but building compensates those expenses in its lifetime and living in a friendly environment is always the most valuable benefit.

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APPENDIX A

ARCHITECTURAL DRAWINGS OF THE EMEK İŞHANI

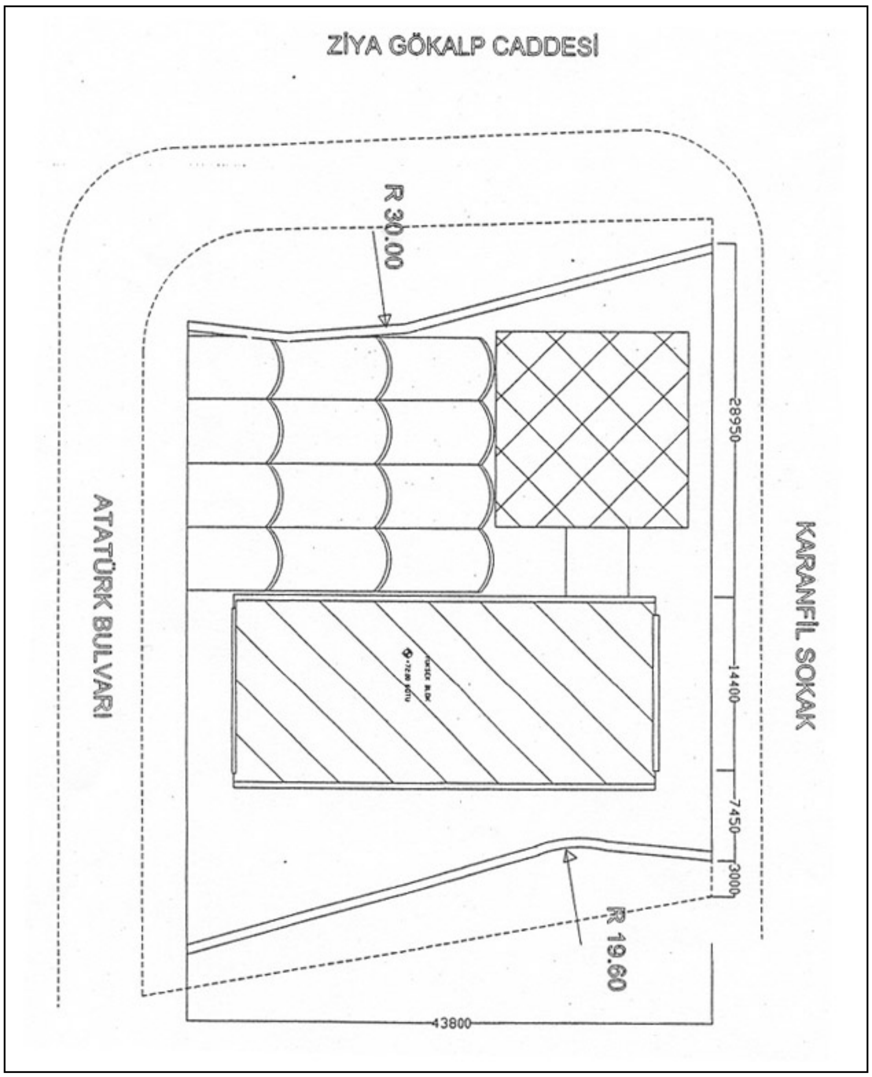

Figure A.1. Site Plan of Emek İşhanı

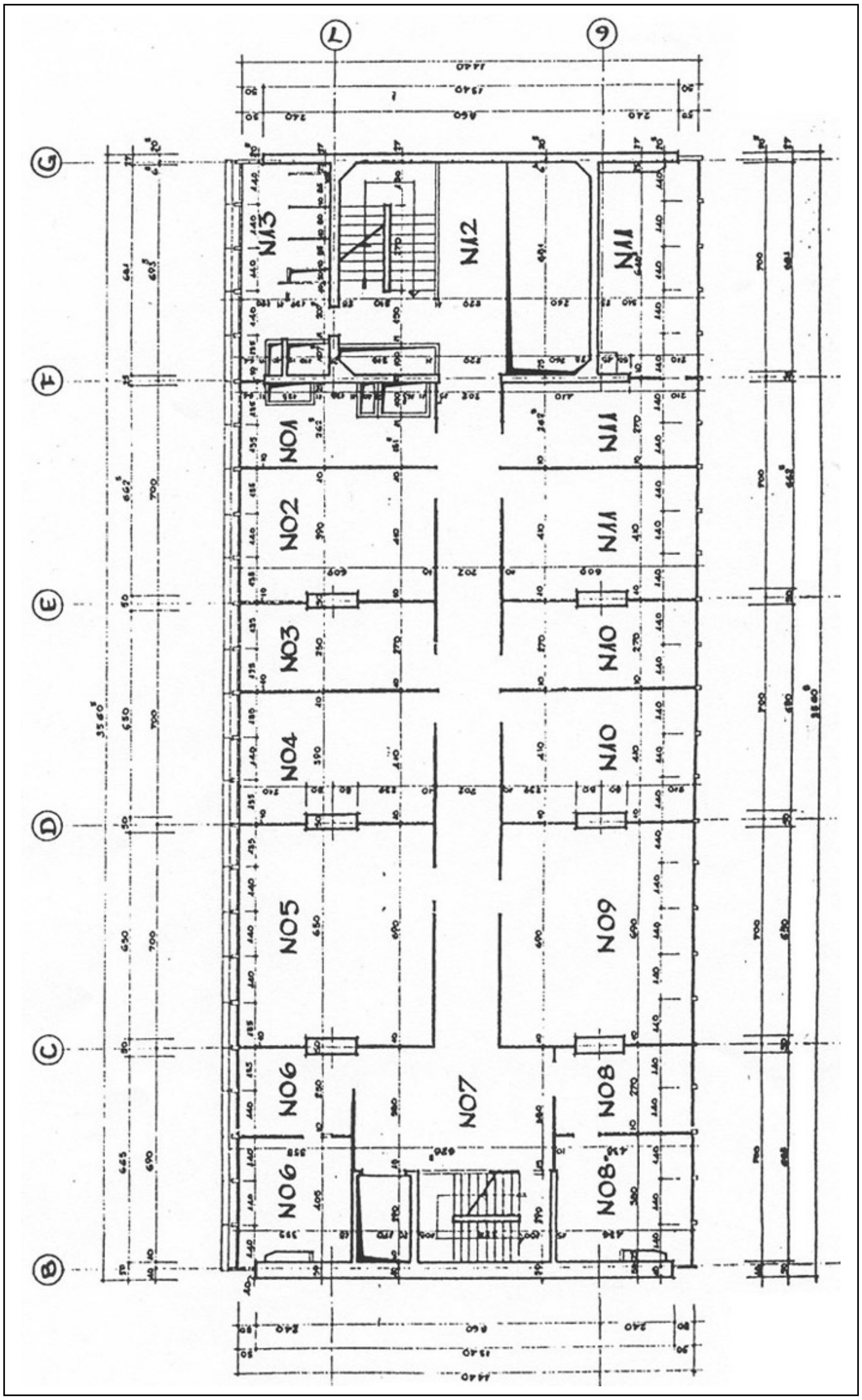

Figure A.2. Typical Floor Plan of Emek İşhanı

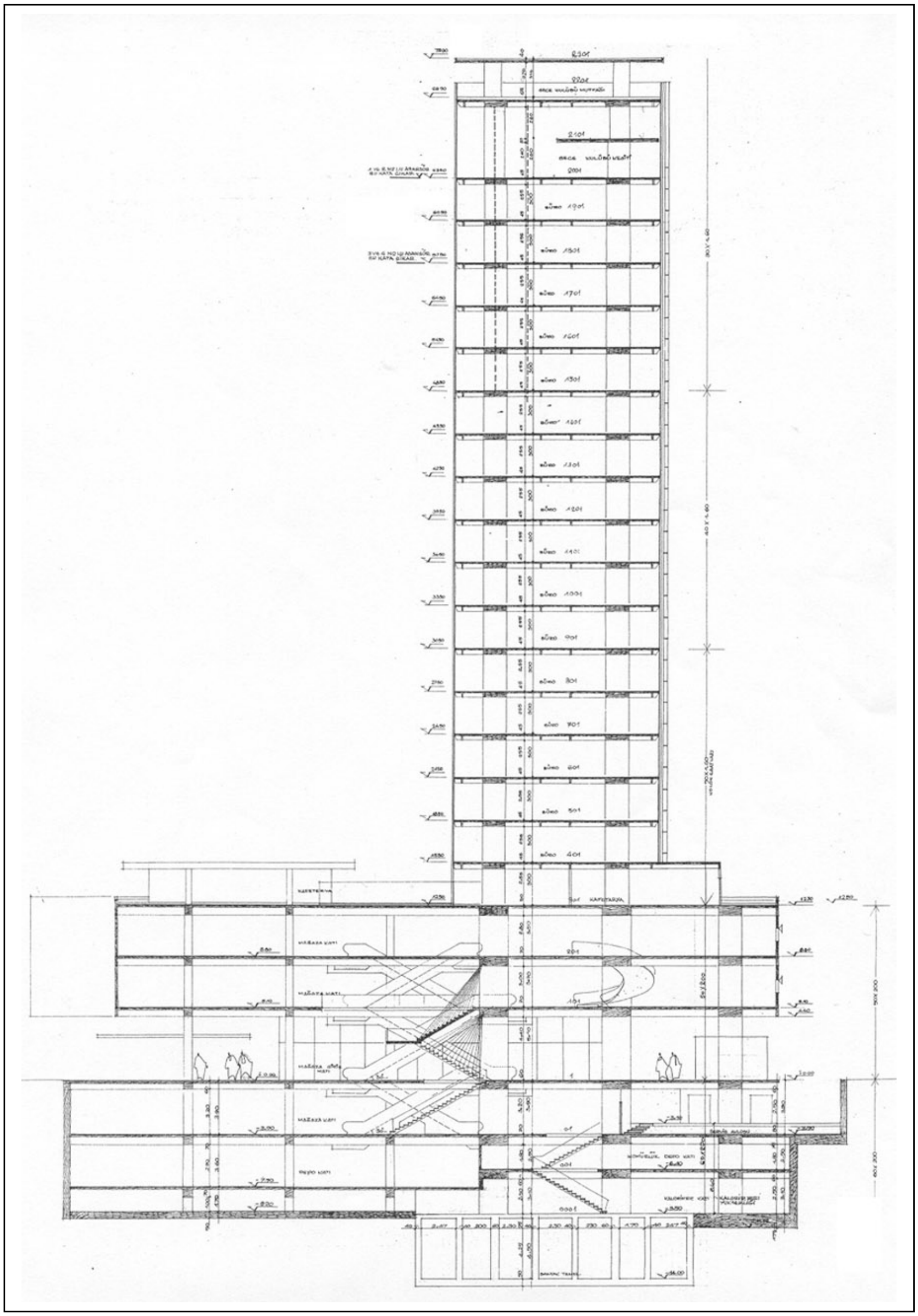

Figure A.3. Section of Emek İşhanı

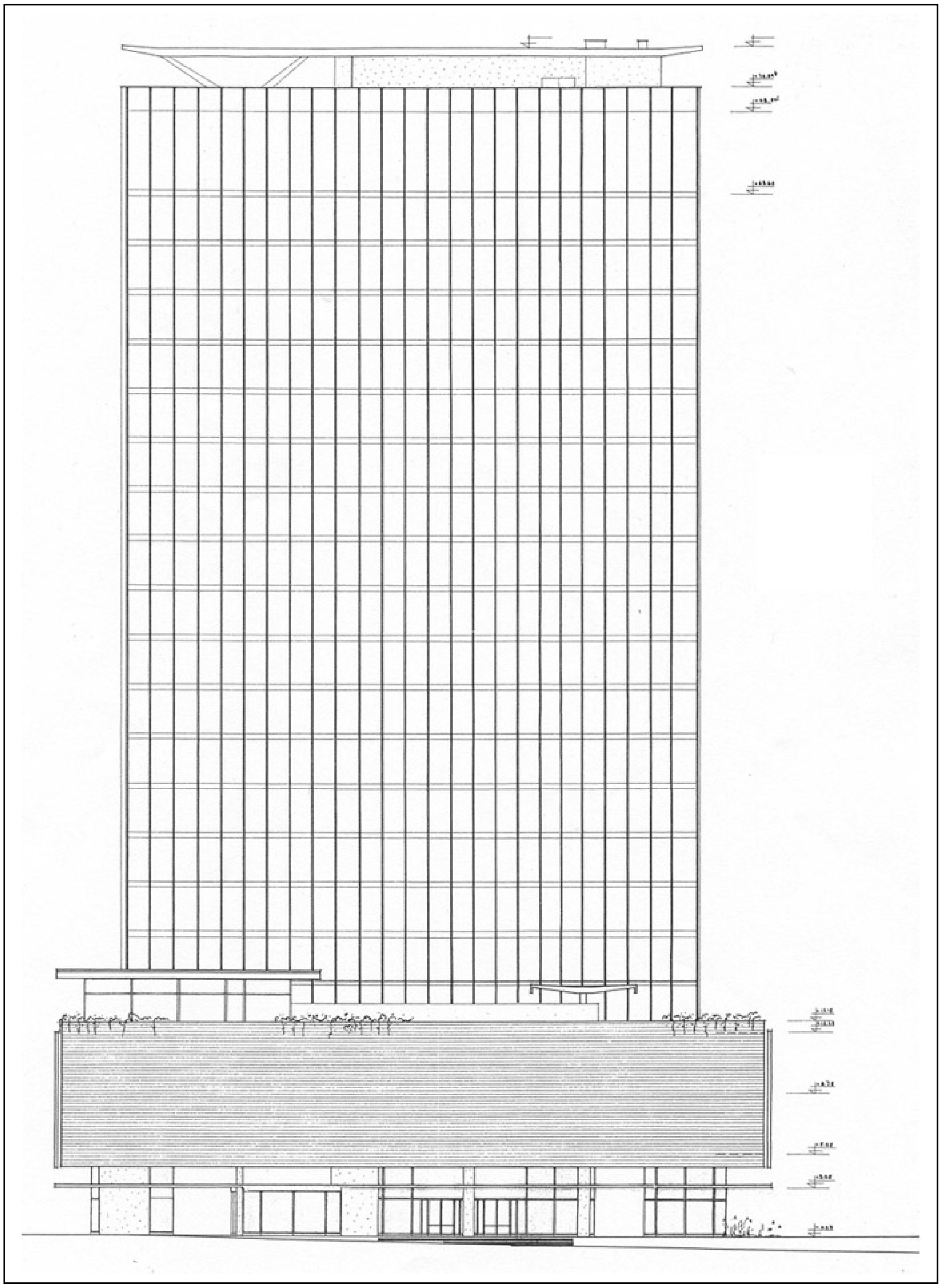

Figure A.4. North Elevation of Emek İşhanı

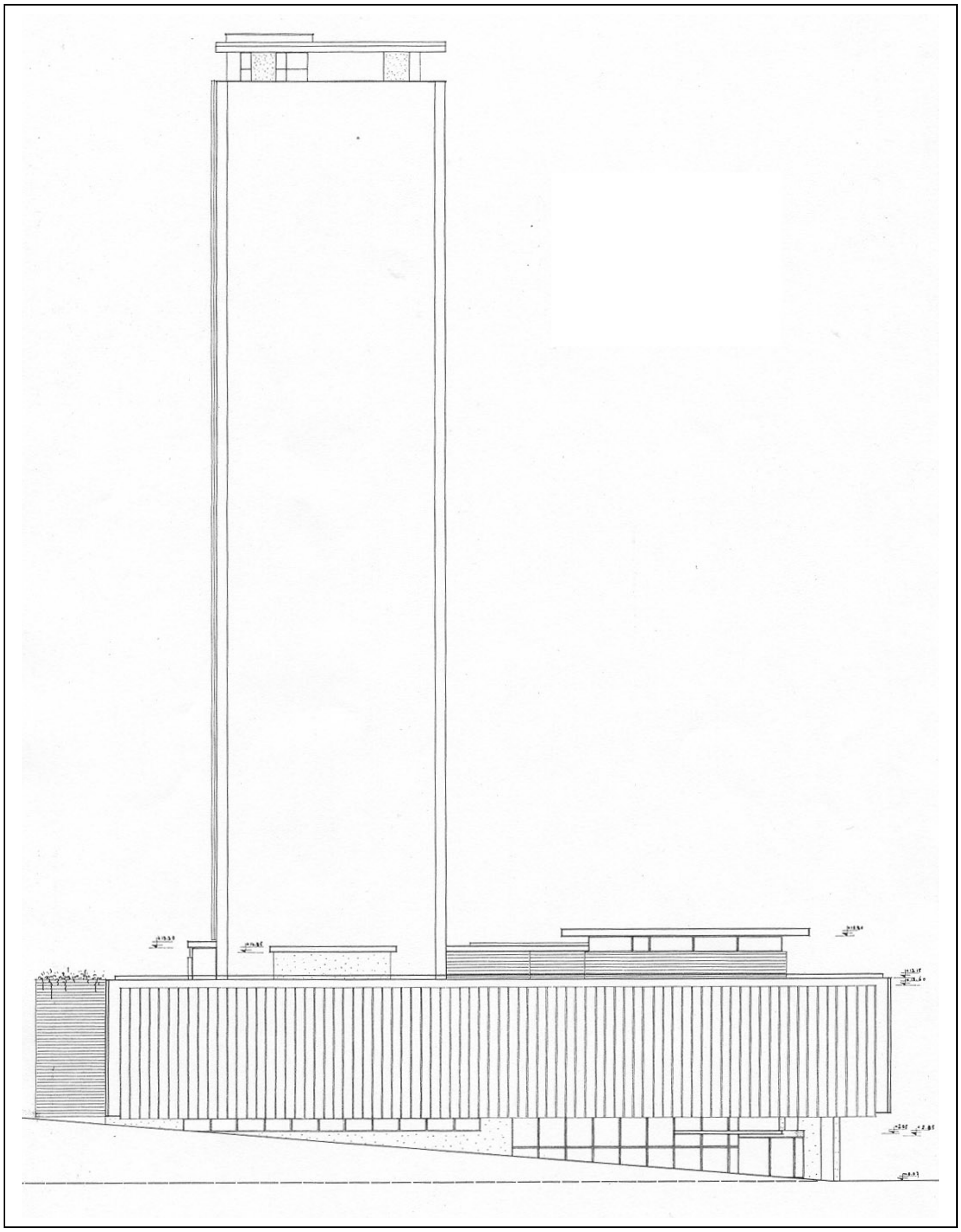

Figure A.5. East Elevation of Emek İşhanı

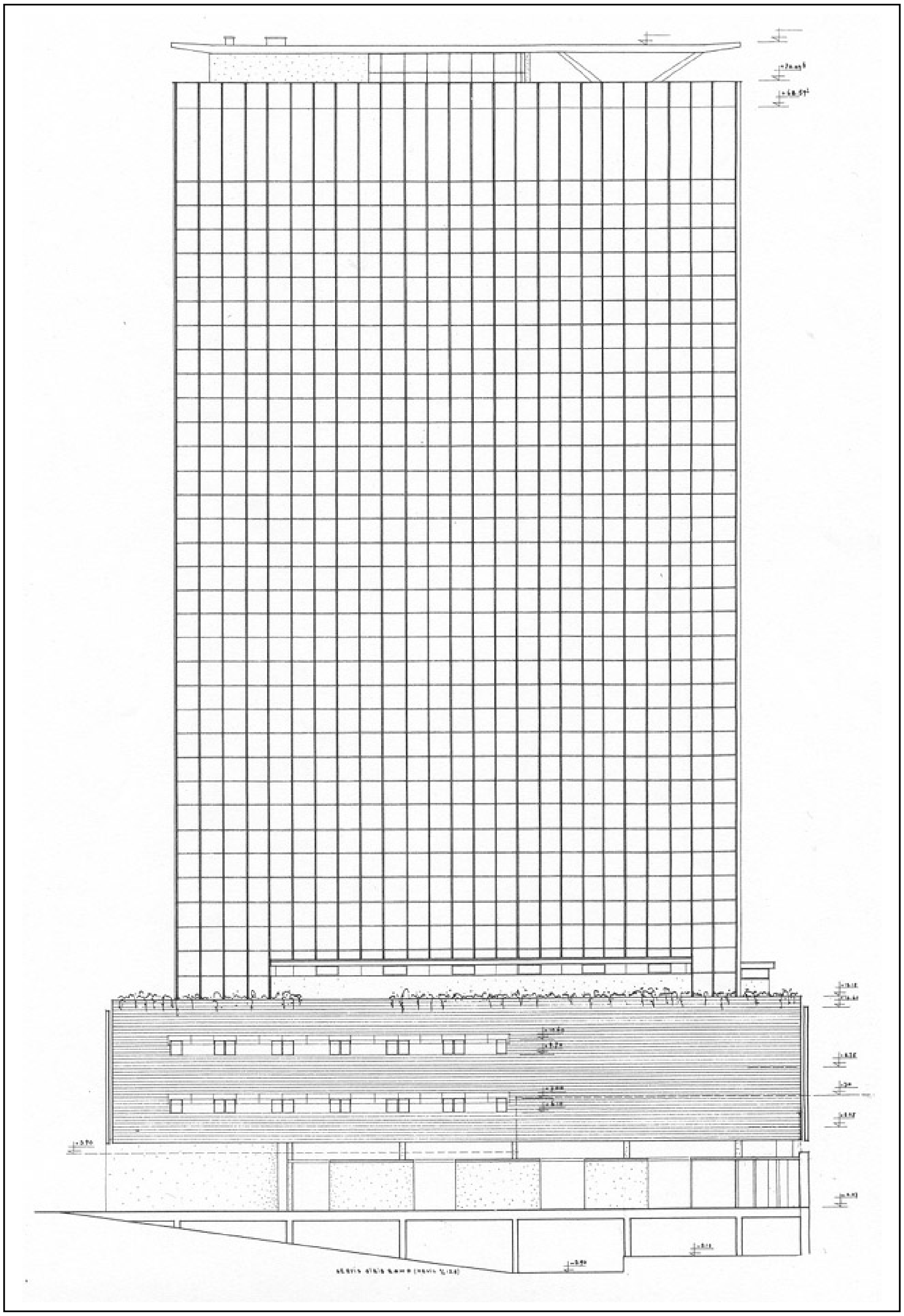

Figure A.6. South Elevation of Emek İşhanı

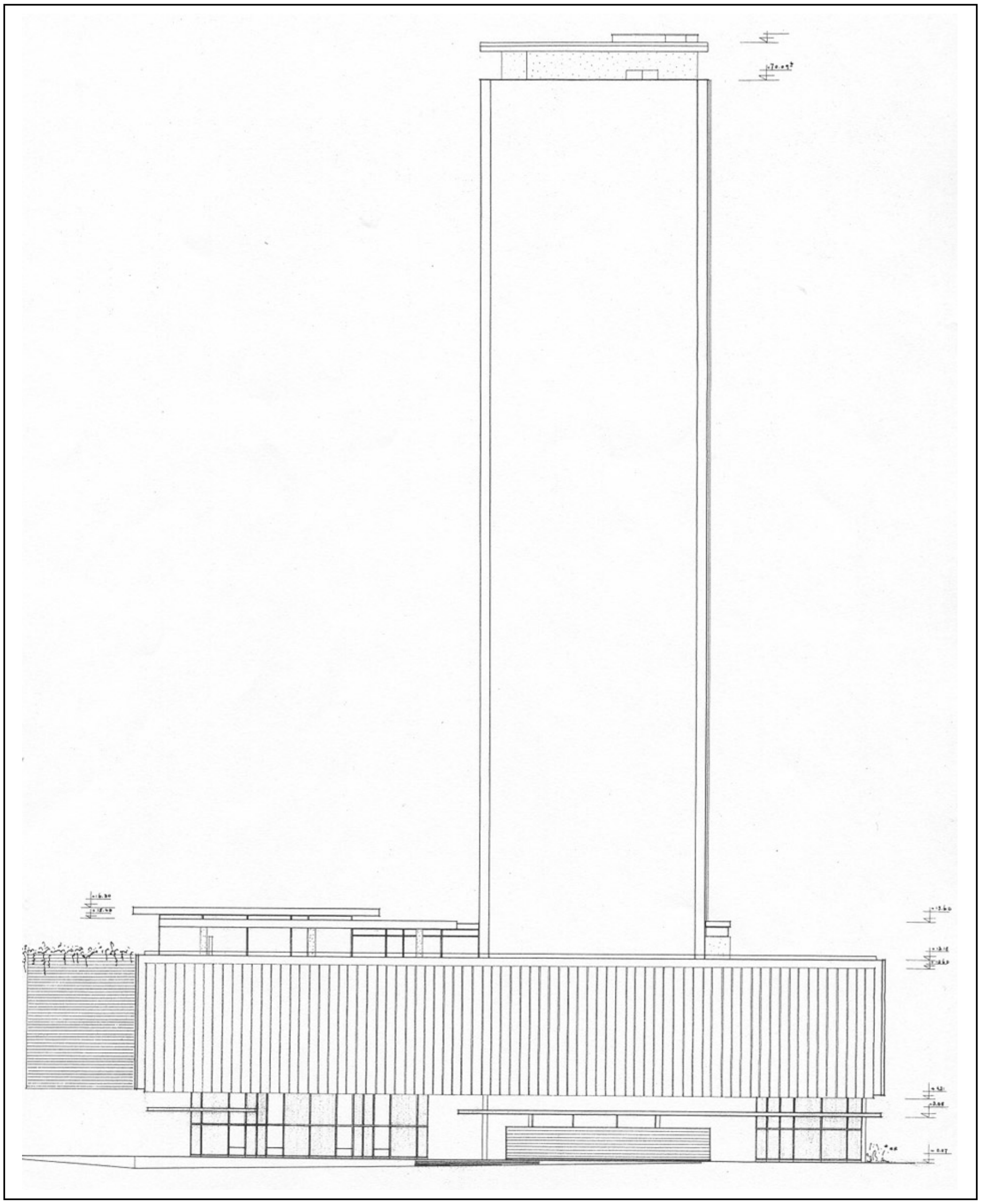

Figure A.7. West Elevation of Emek İşhanı

APPENDIX B

USER SATISFACTION AND VENTILATION EFFECTIVENESS QUESTIONNAIRE

Table B.1. User Satisfaction and Ventilation Effectiveness Questionnaire

Part A – Room Information

1. Location of the Room:

[1]☐ South Façade [2]☐ North Façade

2. Floor Number: _____

3. Floor Area of the Room: _____ m^2

4. Number of Occupants in the Room: _____

Part B – Personal Information

5. Gender:

[1]☐ Male [2]☐ Female

6. Age:

[1]☐ Less than 17 [2]☐ 17-25 [3]☐ 26-35 [4]☐ 36-45

[5]☐ 46-55 [6]☐ More than 55

7. Education:

[1]☐ Primary S. [2]☐ Secondary S. [3]☐ High S. [4]☐ University

[5]☐ Master [6]☐ Ph.D

8. Occupation:

[1]☐ Administrator [2]☐ Advocate [3]☐ MD [4]☐ Architect

[5]☐ Insur. Agent [6]☐ Engineer [7]☐ Other _______________

Table B.1 (continued).

9. Marital Status:

[1]☐ Married [2]☐ Single

10. Smoking Condition:

[1]☐ Non-Smoker [2]☐ Quit [3]☐ Smoker

Part C – Environmental Evaluation

11. For how many years have you been working in this building?

[1]☐ Less than 1 [2]☐ 1-5 [3]☐ 5-10 [4]☐ More than 10

12. Are you satisfied with your job?

[1]☐ Yes [2]☐ No

13. When did you start to work in this building relative to December 11, 2000, the date that the renovation of the façade started on site?

[1]☐ Before the mentioned date [2]☐ After the mentioned date

14. If you had started to work in this building before December 11, 2000, how did the new façade system affected your working conditions?

[1]☐ It was better before [2]☐ It made no change

[3]☐ It slightly improved the conditions [4]☐ It improved the conditions well

15. In general, your working environment

[1]☐ Very Comfort. [2]☐ Comfortable [3]☐ Slightly Comfortable

[4]☐ Slightly Unc. [5]☐ Uncomfortable [6]☐ Very Uncomfortable

16. In summer, your working environment is

[1]☐ Very Hot [2]☐ Hot [3]☐ Warm

[4]☐ Cool [5]☐ Cold [6]☐ Very Cold

17. In winter, your working environment is

[1]☐ Very Hot [2]☐ Hot [3]☐ Warm

[4]☐ Cool [5]☐ Cold [6]☐ Very Cold

Table B.1 (continued).

18. In summer, how would you like your working environment's temperature to be

[1]☐ Cooler [2]☐ The same [3]☐ Warmer

19. In winter, how would you like your working environment's temperature to be

[1]☐ Cooler [2]☐ The same [3]☐ Warmer

20. In general, the air in your working environment is

[1]☐ Very Humid [2]☐ Humid [3]☐ Slightly Humid

[4]☐ Slightly Dry [5]☐ Dry [6]☐ Very Dry

21. In general, the air movement in your working environment is

[1]☐ No air move. [2]☐ Very Low [3]☐ Inadequate

[4]☐ Fair [5]☐ Adequate [6]☐ Excessive

22. In general, the air quality in your working environment is

[1]☐ Very Low [2]☐ Low [3]☐ Slightly Low

[4]☐ Slightly High [5]☐ High [6]☐ Very High

23. What kind of controls do you like to have over your environment? (please check as many as you want) [1/0]

☐ Adjusting a thermostat [23-1] ☐ Turn a local heater on/off [23-5]

☐ Adjusting drapes or blinds [23-2] ☐ Turn a local fan on/off [23-6]

☐ Open/close a window to outside [23-3]

☐ Open/close a door to interior space [23-4]

24. If you have any complaints with your HVAC system, please specify.

____

____

____

Table B.1 (continued).

Part D – Health Problems

25. Here are some symptoms that people sometimes experience. Please mark how often you experience each symptom in your working environment by checking the appropriate box and mark the Ventilation box if you think the cause of a symptom is the ventilation system.

	Never [0]	Rarely [1]	Sometimes [2]	Ofte[n] [3]	Usually [4]	Always [5]	[25-n/1] Ventilation? [1/0]
Fatigue.................... [25-1]	☐	☐	☐	☐	☐	☐	☐
Dizziness................ [25-2]	☐	☐	☐	☐	☐	☐	☐
Dry Skin................. [25-3]	☐	☐	☐	☐	☐	☐	☐
Headaches.............. [25-4]	☐	☐	☐	☐	☐	☐	☐
Sore Throat............. [25-5]	☐	☐	☐	☐	☐	☐	☐
Eye Irritation.......... [25-6]	☐	☐	☐	☐	☐	☐	☐
Sleepiness............... [25-7]	☐	☐	☐	☐	☐	☐	☐
Concentration Loss [25-8]	☐	☐	☐	☐	☐	☐	☐
Lack of Energy....... [25-9]	☐	☐	☐	☐	☐	☐	☐
Nose Irritation........ [25-10]	☐	☐	☐	☐	☐	☐	☐
Bad Odour.............. [25-11]	☐	☐	☐	☐	☐	☐	☐

APPENDIX C

RAW DATA OF THE USER SATISFACTION AND VENTILATION EFFECTIVENESS SURVEY

The tabulation of the data is based on the number coding, in which numbers were assigned to each choice in the questions according to the position on the questionnaire sheet. In Table A.1, the numbers in brackets represents the code of each choice. Numbers given to each choice does not necessarily imply a degree among the other options. In the multiple choice questions which has a certain degree in its nature, six options were prepared to make the respondents think more on the question and decide which side to choose.

In the tabulation of the responses, question 23 was divided into six according to the user preferences presented. For each option either 1 or 0 was given in the tabulation. 1 indicates the desire for that specific option and 0 means that respondent didn’t mention any desire. In the tabulation of question 25, each symptom was divided into two parts. In the first column is tabulated the frequency of that symptom, and in the second column of that symptom, 1 is given as code if the respondent thought that ventilation caused that specific health problem, if not it is coded as 0.

Table C.1. Raw Data of the User Satisfaction and Ventilation Effectiveness Survey

#	Code	Part A				Part B					
		1	2	3	4	5	6	7	8	9	10
1	1	1	4	24	2	2	2	4	7	2	1
2	4	1	4	12	2	1	3	4	1	2	1
3	21	1	5	24	1	2	5	4	2	1	1
4	24	2	5	24	2	2	2	4	2	2	1
5	40	2	5	42	1	1	6	4	2	1	1
6	22	1	5	28	1	1	6	4	7	1	1
7	23	1	6	16	1	2	5	4	2	1	1
8	36	1	6	24	2	1	5	4	7	1	1
9	37	2	6	30	3	2	3	3	7	1	3
10	39	1	6	42	2	2	3	4	7	2	3
11	35	1	7	24	1	1	5	1	7	1	3
12	38	2	7	30	3	1	3	4	7	1	1
13	31	1	8	24	3	1	5	5	1	1	3
14	32	1	8	46	5	1	6	5	7	1	3
15	33	1	8	24	5	2	2	3	7	2	1
16	34	2	8	24	1	1	5	4	4	1	3
17	27	2	8	32	1	1	5	4	2	1	1
18	26	1	9	18	3	1	4	3	5	2	3
19	30	2	9	32	2	2	3	4	2	2	3
20	28	2	10	32	2	1	3	4	7	2	1
21	29	1	10	12	5	1	4	4	1	1	3
22	25	2	10	32	1	1	5	4	2	1	3
23	2	1	10	24	3	2	2	3	5	1	1
24	3	2	11	24	4	2	5	3	1	1	2
25	5	2	11	42	1	1	3	4	1	1	1
26	6	1	11	24	2	2	3	4	7	2	3
27	7	2	11	12	2	1	2	4	2	2	3
28	8	2	12	24	1	2	2	3	7	2	1
29	9	2	12	20	2	2	2	3	7	2	1
30	10	1	13	17	1	1	4	4	6	1	1
31	17	1	14	24	1	1	6	4	7	1	3
32	18	1	15	12	2	2	4	4	5	1	1
33	19	1	15	42	2	1	4	4	7	1	3
34	20	2	15	24	1	1	4	4	2	1	3
35	11	1	16	24	1	2	3	4	2	2	1
36	12	2	16	38	3	2	4	3	1	1	3
37	13	2	17	24	2	1	5	5	2	1	1
38	14	1	17	24	4	2	2	3	7	1	3
39	15	2	18	24	2	1	6	4	7	1	1
40	16	1	18	24	3	1	4	3	1	1	1

Table C.1 (continued).

#	Part C																		
	11	12	13	14	15	16	17	18	19	20	21	22	23-1	23-2	23-3	23-4	23-5	23-6	24
1	1	1	2	0	4	2	0	1	0	5	2	2	0	1	1	0	0	0	
2	2	1	2	0	4	3	5	1	3	1	2	1	0	0	1	0	0	0	
3	4	1	1	3	5	2	5	1	3	5	2	1	1	1	1	0	0	0	
4	1	1	2	0	5	2	5	1	3	5	3	1	1	0	1	0	0	0	
5	4	2	1	2	5	4	4	2	2	4	3	1	0	0	1	1	0	0	
6	4	2	1	1	3	2	3	2	2	5	3	2	0	0	1	0	0	0	
7	3	1	1	2	0	1	3	1	2	4	5	1	0	0	1	0	0	0	
8	4	1	1	3	5	3	3	2	2	2	1	1	0	0	1	0	0	0	
9	4	1	1	2	4	4	3	2	2	3	4	4	0	0	0	0	1	0	
10	2	1	1	4	2	4	2	2	2	5	5	5	0	1	1	0	0	0	
11	3	2	1	3	3	1	1	1	2	6	1	2	0	0	1	0	0	0	
12	1	1	2	0	2	4	2	2	2	0	1	4	0	0	0	0	1	0	
13	4	1	1	4	1	4	3	1	2	3	5	4	0	0	1	0	0	0	
14	4	1	1	3	2	1	3	1	3	4	6	3	1	0	0	0	0	0	
15	1	1	2	0	4	2	0	1	0	5	3	1	1	0	1	0	0	0	
16	4	1	1	1	0	2	2	1	2	5	1	1	1	0	0	0	1	0	
17	4	1	1	4	2	3	3	2	2	3	5	4	0	0	1	0	0	0	
18	2	1	2	0	3	2	3	1	3	0	1	1	0	0	1	0	1	0	
19	2	1	2	0	4	2	3	1	2	3	2	2	0	0	1	0	0	0	
20	2	1	1	2	2	3	3	1	2	5	2	2	1	0	0	0	1	1	
21	2	1	2	0	5	2	3	1	3	4	3	3	0	0	1	0	0	0	
22	3	1	1	3	2	2	3	1	2	5	2	2	0	0	1	0	0	0	
23	2	1	2	3	4	1	3	1	2	5	3	3	0	0	1	0	0	0	
24	2	1	1	3	1	4	2	1	2	0	4	4	0	0	0	0	0	1	
25	3	1	1	4	3	2	3	1	2	6	3	1	0	0	1	0	1	0	
26	3	1	1	4	2	4	2	1	2	5	5	1	0	0	1	0	0	0	
27	2	1	2	0	2	4	2	2	1	6	1	1	0	0	1	0	0	0	
28	2	1	2	0	3	4	2	2	2	5	4	2	0	0	1	0	0	0	
29	2	1	1	0	4	4	3	1	3	5	4	1	1	1	1	1	1	0	
30	2	2	1	0	3	4	2	1	2	5	1	1	1	0	1	0	0	0	
31	2	1	1	1	2	4	2	2	2	5	3	2	1	1	1	0	0	0	
32	1	1	2	0	2	4	2	2	2	5	3	2	0	0	1	0	0	0	
33	3	1	1	3	2	3	3	2	2	0	5	3	0	0	0	0	0	0	
34	1	1	2	0	2	4	2	2	2	4	4	2	0	0	1	0	0	0	
35	2	1	1	3	5	1	3	1	2	6	3	1	0	0	1	0	0	0	
36	1	1	2	0	5	4	0	2	0	5	3	2	0	0	1	0	0	0	
37	4	1	1	3	5	2	2	1	2	5	1	1	0	0	1	0	0	0	
38	1	1	2	0	6	4	0	1	0	5	4	2	0	0	1	1	0	0	
39	2	1	1	1	3	2	3	1	2	5	4	3	0	0	1	0	0	0	
40	1	1	2	0	2	4	2	2	2	4	5	3	0	0	0	0	0	0	

Table C.1 (continued).

#	Part D											
	25-1	25-1/1	25-2	25-2/1	25-3	25-3/1	25-4	25-4/1	25-5	25-5/1	25-6	25-6/1
1	2	0	1	0	3	0	4	1	3	1	1	0
2	4	0	4	0	2	0	4	0	3	0	3	0
3	5	1	5	1	5	1	5	1	5	1	5	1
4	3	1	2	0	3	0	5	1	4	1	3	0
5	4	0	2	0	4	0	4	0	5	1	5	0
6	4	1	0	0	0	0	2	1	5	1	0	0
7	5	1	4	1	5	1	5	1	5	1	5	1
8	3	1	2	1	2	1	3	1	3	1	3	1
9	2	1	2	0	0	0	2	1	0	0	0	0
10	1	0	0	0	1	1	1	1	2	1	0	0
11	4	0	2	0	2	0	3	0	2	1	2	0
12	1	0	0	0	0	0	1	0	0	0	0	0
13	0	0	0	0	0	0	4	0	3	0	0	0
14	2	1	1	1	1	0	3	0	1	0	1	0
15	5	1	2	0	4	0	3	1	5	1	0	0
16	1	1	0	0	0	0	0	0	1	1	0	0
17	0	0	0	0	1	0	1	0	0	0	0	0
18	2	1	2	1	1	1	3	1	3	1	2	1
19	3	1	2	0	0	0	3	1	1	0	0	0
20	0	0	0	0	0	0	2	1	0	0	0	0
21	2	0	1	0	1	1	2	1	3	1	2	0
22	2	1	1	1	3	1	2	1	3	1	2	1
23	3	0	1	0	0	0	3	0	1	1	0	0
24	2	0	0	0	0	0	1	0	1	0	3	1
25	5	1	4	1	0	0	4	1	0	0	0	0
26	3	1	2	0	5	1	1	0	0	0	2	0
27	2	1	1	0	1	0	4	0	2	1	4	0
28	5	1	2	1	2	1	5	1	3	1	3	0
29	5	1	5	1	5	0	5	1	4	0	5	0
30	3	1	1	1	1	1	3	1	1	1	0	0
31	0	0	0	0	0	0	2	1	3	1	0	0
32	5	0	3	0	3	0	5	1	4	1	3	1
33	4	0	0	0	0	0	2	0	1	0	4	1
34	0	0	0	0	0	0	1	1	2	1	0	0
35	5	1	2	1	3	1	4	1	4	1	3	1
36	5	0	2	0	2	0	3	1	3	1	3	0
37	4	1	4	1	4	1	4	1	4	0	4	0
38	1	0	0	0	1	0	3	1	0	0	2	0
39	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0

Table C.1 (continued).

#	Part D									
	25-7	25-7/1	25-8	25-8/1	25-9	25-9/1	25-10	25-10/1	25-11	25-11/1
1	3	1	3	0	3	0	1	0	4	1
2	3	1	3	0	4	0	1	0	5	0
3	5	1	5	1	5	1	5	1	5	1
4	2	1	1	0	2	1	2	0	4	1
5	0	0	4	0	0	0	5	1	5	1
6	2	0	3	0	2	0	0	0	4	1
7	5	1	5	1	5	1	4	1	5	1
8	5	1	2	1	5	1	2	1	1	1
9	1	0	1	1	0	0	0	0	1	1
10	1	0	2	0	1	0	0	0	0	0
11	5	1	2	1	1	0	1	0	4	1
12	1	0	1	0	1	0	0	0	2	0
13	4	0	0	0	0	0	0	0	3	1
14	4	1	2	0	1	0	1	0	2	1
15	5	1	2	0	4	1	0	0	1	1
16	1	1	1	1	0	0	0	0	1	1
17	1	0	1	0	1	0	1	0	1	0
18	3	1	2	1	0	0	3	1	4	1
19	4	1	4	0	3	0	1	0	4	1
20	3	1	0	0	0	0	0	0	0	0
21	1	1	1	0	1	1	1	0	4	1
22	4	1	2	1	1	1	3	1	2	1
23	1	0	1	0	1	0	0	0	2	0
24	2	1	0	0	1	0	1	0	3	1
25	2	1	2	1	2	0	0	0	4	1
26	4	1	1	0	1	0	0	0	5	1
27	4	1	4	1	3	0	1	0	5	1
28	5	1	3	1	5	1	2	0	5	1
29	5	1	3	0	5	1	5	0	5	1
30	2	1	1	1	3	1	0	0	4	1
31	4	1	1	0	0	0	3	1	0	0
32	2	1	2	0	4	0	4	1	4	1
33	2	0	2	0	2	1	0	0	2	1
34	0	0	0	0	1	0	0	0	0	0
35	4	1	3	1	3	1	3	1	3	1
36	3	0	3	0	3	0	2	0	2	0
37	4	1	4	1	2	0	0	0	4	0
38	2	1	2	0	1	0	0	0	1	1
39	4	0	0	0	3	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0

APPENDIX D

ADDITIONAL SURVEY RESULTS

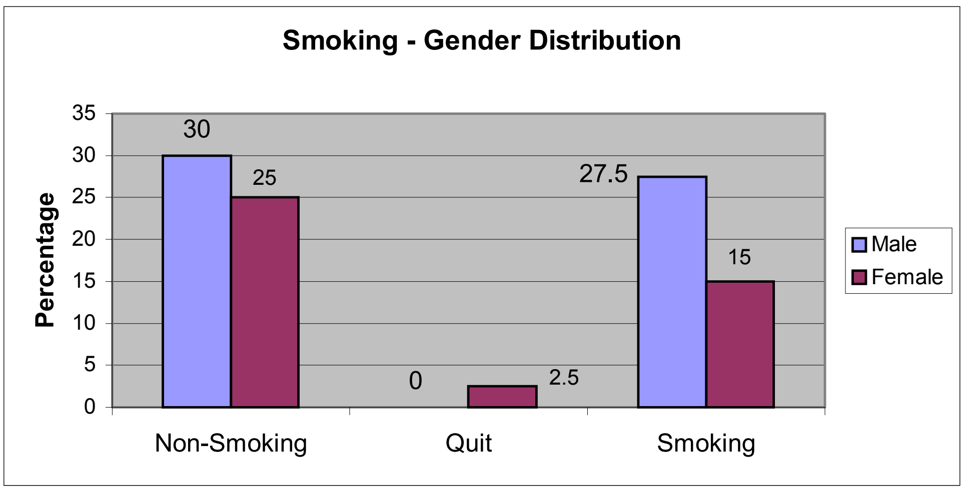

Figure D.1. Smoking Habit – Gender Distribution of Respondents

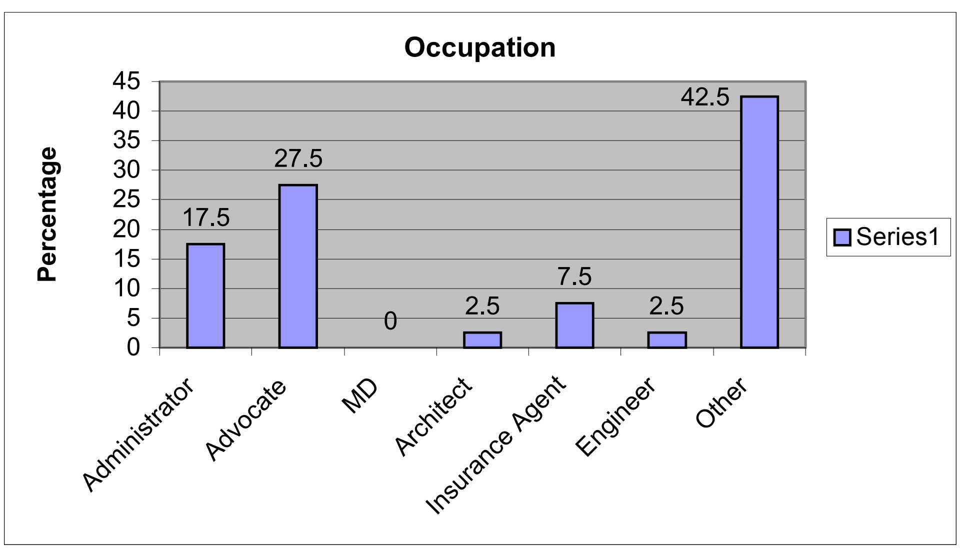

Figure D.2. Occupation Distribution of Respondents

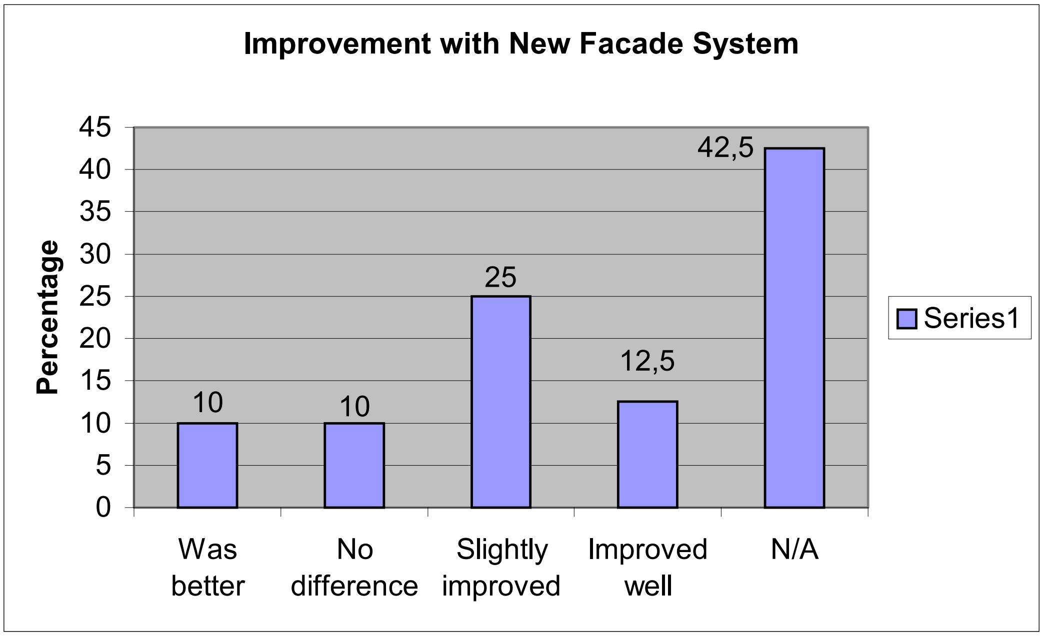

Figure D.3. Improvement with the New Façade System According to Respondents

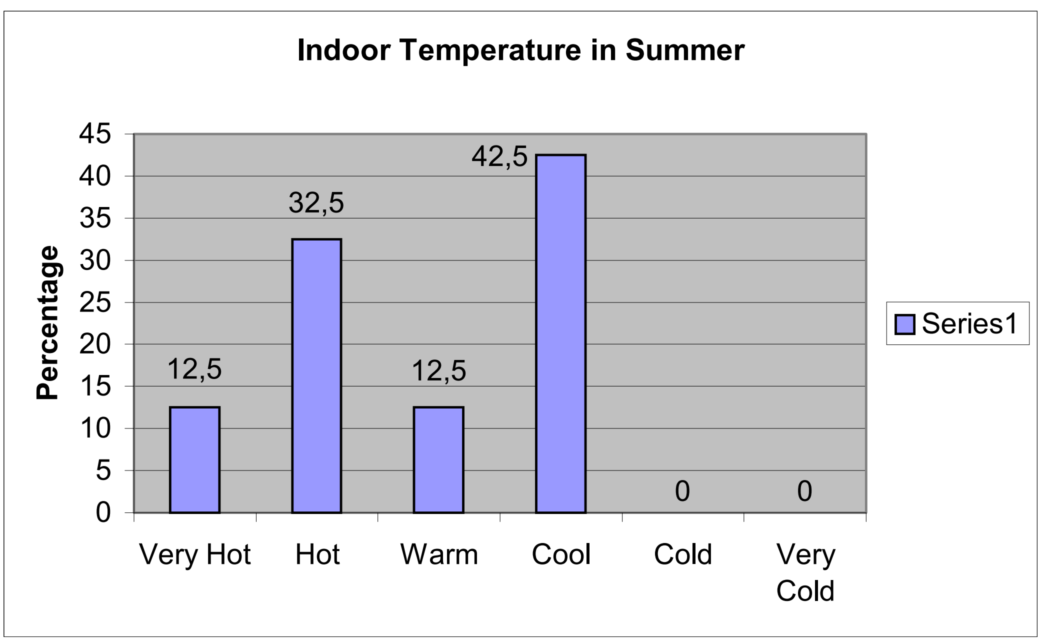

Figure D.4. Indoor Temperature Perception of Respondents in Summer

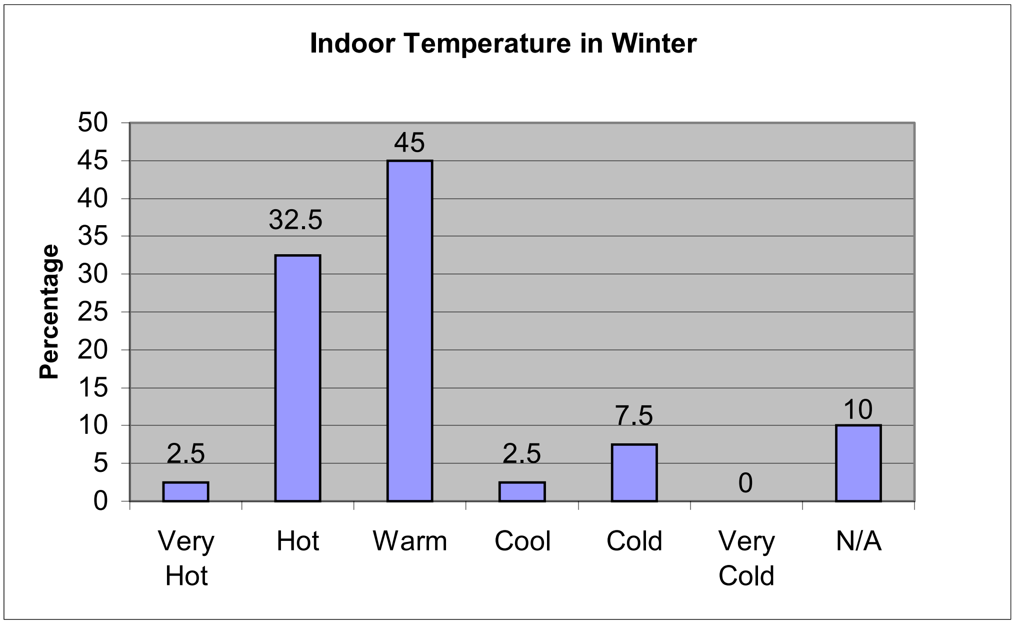

Figure D.5. Indoor Temperature Perception of Respondents in Winter

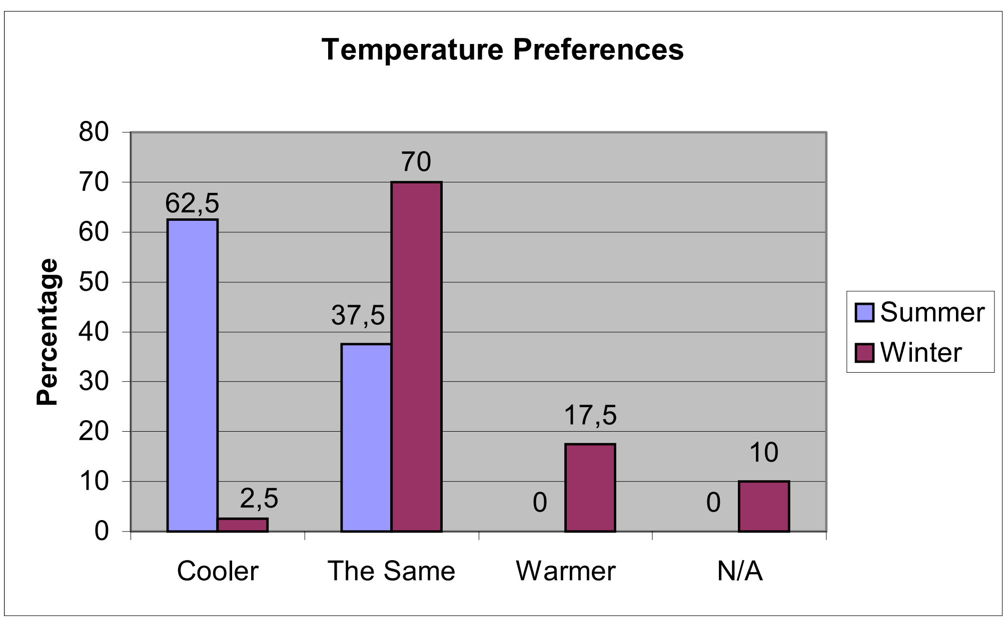

Figure D.6. Preferences of Temperature in Summer and Winter

APPENDIX E

ENERGY-10 SOFTWARE SIMULATION SUMMARY PAGE

Table E.1. Energy-10 Software Parameters Summary Page

Description:	Existing Building	Corrected Building
Scheme Number:	1 / Saved	2 / Saved
Library Name:	ARCHIVELIB	ARCHIVELIB
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	ANKARA.ET1	ANKARA.ET1
Floor Area, m²	392.0	392.0
Surface Area, m²	1036.0	1036.0
Volume, m³	1176.1	1176.1
Total Conduction UA, W/K	350.8	387.1
Average U-value, W/m²K	1.922	2.122
Wall Construction	4in steel stud, R=1.7,etc	4in steel stud, R=1.7,etc
Roof Construction	r1000, R=176.1	r1000, R=176.1
Floor type, insulation	Slab on Grade, Reff=3.0	Slab on Grade, Reff=3.0
Window Construction	3040 double, low-e, U=1.85	3040 double, low-e, U=1.85
Window Shading	None	None
Wall total gross area, m²	252	252
Roof total gross area, m²	392	392
Ground total gross area, m²	392	392
Window total gross area, m²	86	114
Windows (N/E/S/W:Roof)	15/0/15/0:0	20/0/20/0:0
Glazing name	double low-e, U=1.80	double low-e, U=1.80
Operating parameters for zone 1		
HVAC system	DX Cooling with Gas Furnace	Gas-Fired Unit Heater
Rated Output (Heat/SCool/TCool),kW	42/40/53	37/0/0
Rated Air Flow/MOOA,L/s	2769/299	843/299
Heating thermostat	20.0 °C, no setback	20.0 °C, no setback
Cooling thermostat	24.0 °C, no setup	24.0 °C, no setup
Heat/cool performance	eff=80,COP=2.6	eff=78,COP=0.3
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	0/0
Peak Gains; IL,EL,HW,OT; W/m²	4.00/3.55/2.80/16.36	4.00/3.55/2.80/16.36
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	none	ACH=1.1

APPENDIX F

ENERGY-10 SOFTWARE DIALOGUE BOXES AND SPECIFIED VARIABLES

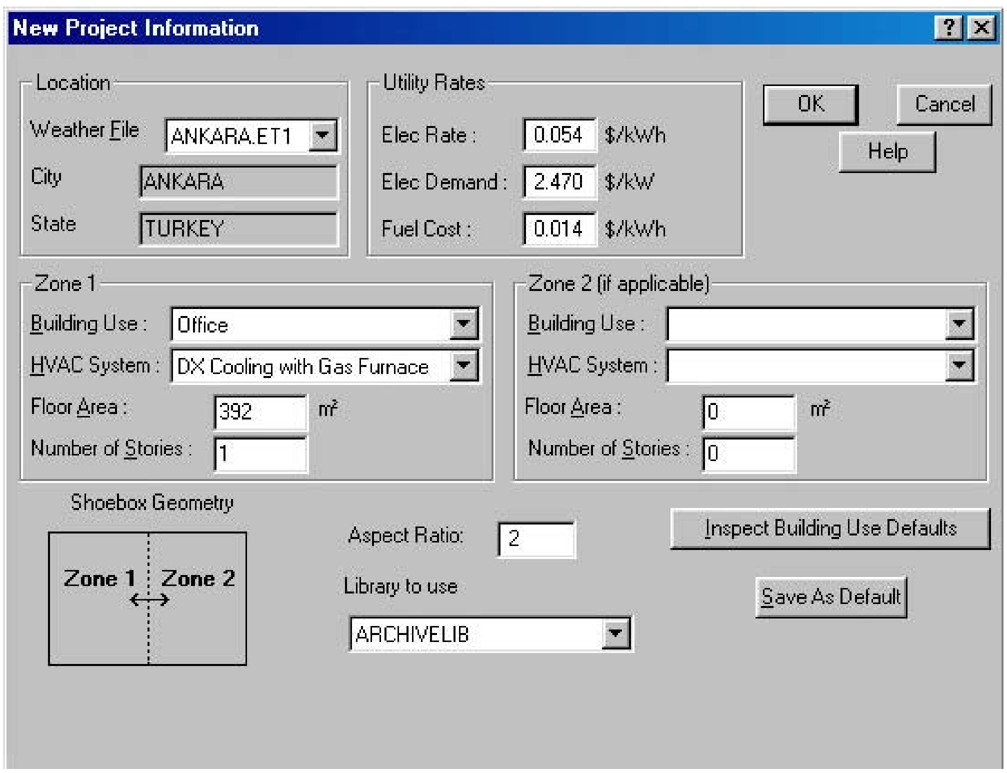

Figure F.1. First Dialogue Box of Energy-10 Software

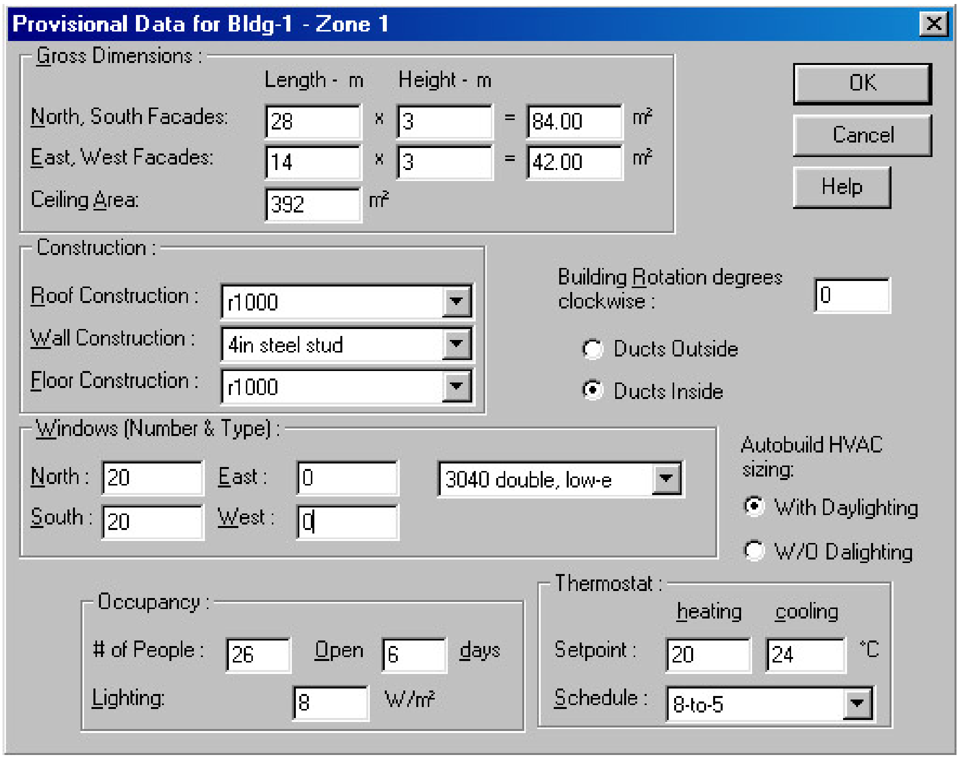

Figure F.2. Second Dialogue Box of Energy-10 Software

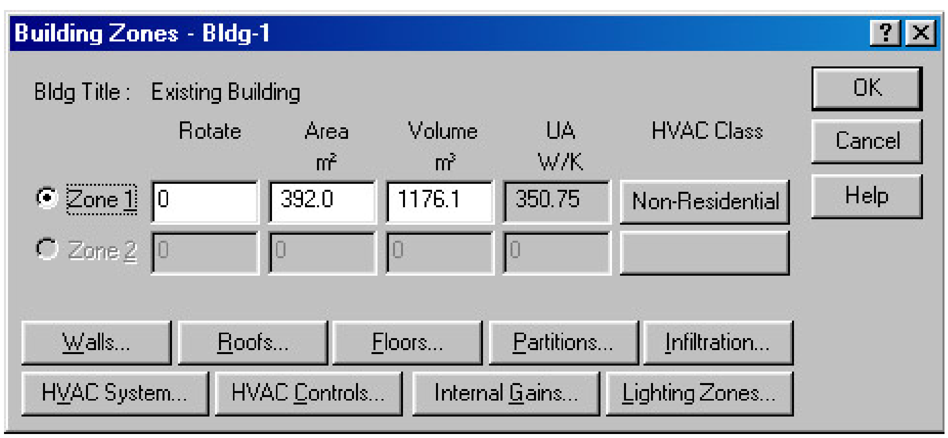

Figure F.3. Building Controls Dialogue Box of Energy-10 Software