SHADE IN THE TROPICS

A PHENOMENOLOGICAL APPROACH TO MAN AND HIS ENVIRONMENT

MOHAMED ABDO EL RAGHY DAWOUD

SHADE IN THE TROPICS

A PHENOMENOLOGICAL APPROACH TO MAN AND HIS ENVIRONMENT

MOHAMED ABDO EL-RAGHY DAWOUD

B.Sc. (Arch.) Cairo

Ph. D. THESIS

DEPARTMENT OF ARCHITECTURE

UNIVERSITY OF EDINBURGH

1984

To the beloved ones

Nagia, Nahla and Nagla

DECLARATION

This thesis has been composed entirely by myself and the work presented is my own

MOHAMED ABDO EL-RAGHY DAWOUD

The photographs of Figures 1, I.2, III.4, III.5, IV.1, IV.2, IV.5(a), IV.5(b), IV.6, IV.7, IV.10, IV.13, IV.15, IV.18, IV.19, IV.20 and IV.21 are from R Constable, 1976, U Ghaidan, 1975, Intergraphics Ltd., 1982, G Lippsmeier, C Monty, 1973 and W Thesiger, 1979. The remainder of the photographs were either by the author or by friends. The author expresses his gratitude to the latter.

CONTENTS

ACKNOWLEDGEMENTS

I have been fortunate in the last five years in being supervised by Professor C.B. Wilson, Professor of Architectural Science in the Department of Architecture and Dean of Faculty of Social Sciences, University of Edinburgh, whose inspiring ideas and discussions, valuable criticism and constant guidance have been profoundly influential in the development of this thesis. I therefore take the opportunity to express my sincere gratitude and indebtedness to him for all the support and encouragement given to me throughout the study.

I wish to thank Dr. F. Smith, Dr. T. Hanson and Dr. D. Sommer for the assistance I received during operating the computer program.

My thanks also go to my fellow research students in the Department for their stimulating discussions and constructive comments.

Further sincere thanks are due to Mrs. Elizabeth Burchell who generously accepted the difficult task of typing this thesis with great concern and efficiency.

Finally, my sincere gratitude to my wife, Nagia, who, along with my two daughters, Nahla and Nagla, endured the life in Abu Dhabi with patience and grace during my years of study in Edinburgh.

ABSTRACT

This thesis is concerned with the study of aspects of shade in the tropical urban environment. It attempts to reveal the primacy of the qualitative nature of this phenomenon and puts its quantitative description in its proper place.

A phenomenological analysis of the meanings and values of shade leads to the qualitative choice of the courtyard as a viable and relevant form [both socio-culturally and climatically] upon which a systematic quantitative investigation of shade is carried out by developing a mathematical model which represents the interaction taking place between solar shading and groups of courtyard forms. Taking the city of Abu Dhabi as a typical example of the prevailing climatic conditions in the Gulf, the model is implemented on a computer and utilized to generate detailed data of the time-averaged distribution of shade on the ground.

This quantitative investigation identifies the ranges and the effects of the geometrical parameters of courtyards on the time-averaged distribution of shading and defines their inter-relationships. The generative potentials of the model are illustrated through the interplay between research and design.

NOTATION

Symbol		Units
A_b	Built-up area of the courtyard form	m^2
A_c	Area of the ground surface of the courtyard space	m^2
A_s	Area of site	m^2
H_c	Height of the courtyard form	m
H_s	Height of the surrounding courtyard forms	m
P_c	Perimeter of the courtyard form	m
R_1	Ratio of the area of the courtyard space to the built-up area of the courtyard form = A_c/A_b	dimensionless
R_2	Ratio of the built-up area of the courtyard form to the area of site = A_b/A_s	dimensionless
R_3	Ratio of the height to the perimeter of the courtyard form = H_c/P_c	dimensionless
R_4	Ratio of the height of the courtyard form to the height of the surrounding forms = H_c/H_s	dimensionless
SH_{tad}	Time-averaged distribution of shade on the ground	dimensionless

INTRODUCTION

In the Gulf region the contrast between the indefinite extension of the desert landscape and the compactness of traditional settlements can be seen in urban built forms and the resulting intimate places around and within them. In their traditional forms both the settlements and houses in this region have, until recently, always been built in response to local social, cultural and climatic demands.

These responses are behavioural as well as physical. In a hot climate like that of the Gulf region such a behavioural response is expressed through the way in which people flee from the burning sun, dust and sand storms into the shade.[1] This attitude is also expressed physically in the traditional settlement through the generation of shaded private and urban spaces within and between its dwelling units.

Shade manifests itself in traditional settlements in two distinct ways. First, physically, by providing people with protection through the forms of their houses and immediate surroundings, generating shaded private and communal spaces suited to cope with the par

INTRODUCTION

---

1 The appendix presented at the end of this work gives the main climatic features of U.A.E. with reference to the city of Abu Dhabi.

INTRODUCTION

In the Gulf region the contrast between the indefinite extension of the desert landscape and the compactness of traditional settlements can be seen in urban built forms and the resulting intimate places around and within them. In their traditional forms both the settlement and the house in this region have, until recently, always been built in response to local social, cultural and climatic demands.

These responses are behavioural as well as physical. In a hot climate like that of the Gulf region such a behavioural response is expressed through the way in which people flee from the burning sun, dust and sand storms into the shade.[1] This attitude is also expressed physically in the traditional settlement through the generation of shaded private and urban spaces within and between its dwelling units.

Shade manifests itself in traditional settlements in two distinct ways. First, physically, by providing people with protection through the forms of their houses and immediate surroundings, generating narrow private and communal spaces suited to cope with the hot

1 The appendix presented at the end of this work gives the main climatic features of U.A.E. with reference to the city of Abu Dhabi.

climate; second, by creating places with qualities that attract people and facilitate their daily urban activities. Shade can, in the behavioural sense, be regarded as a phenomenon that gives people a sense of gathering.

The interplay between physical and behavioural responses can also be seen through the way in which traditional settlements are laid out, built and used. An examination of traditional settlements in the Gulf region shows that urban built forms and spaces were shaped (designed!) in such a way as to provide as much shade as possible; that is, the individual buildings were laid out in a communal manner which provides shade and mutual protection against the heat and reduces the areas exposed to the sun.[1]

These qualities are echoed in the establishment of dwelling units looking inwards from the hostile

---

[1] The communal grouping of buildings is perhaps the most dominant feature of traditional settlements in hot dry zones. Olgyay (1963) has observed in a number of settlements around the world a remarkable correspondence between special architectural features and certain climatic zones. He asserts that groups of different continents, creeds, and cultures appear to have come independently to similar solutions in their struggle with similar environments, and to have established basic regional characteristics. Perhaps this might reasonably be related to Schumacher's argument (1977) about what he calls "convergent problems", to which various solutions converge until a design emerges which is simply the "answer".

climate, and expressed in the form of traditional courtyard houses. The spatial pattern of these traditional forms not only reflects climatic demands but also expresses social and cultural values held and shared by local people.[1] In this respect, the traditional courtyard house, as the basic dwelling unit of the traditional settlement, seems to have offered the spatial interpretation which satisfied both socio-cultural and climatic demands.[2]

In these traditional forms the use of local building materials and indigenous technology illustrates sensible ways in which local people have utilized efficiently resources available to them in dealing with climatic problems. These courtyard houses were often built of sun-dried mudbrick because of its natural low thermal conductivity and its mass.[3]

---

[1] In considering the influences that social and cultural forces have on house form the reader is referred to Rapopert's House Form and Culture [1969].

[2] The traditional courtyard house seems to embody what might be called double protection; that is, the actual presence of shade within the courtyard implies, in one form or another, protection against the glaring sun, whereas seeking privacy within it entails protection against intrusion.

[3] For a thorough examination into the composition and properties of the sun-dried mudbrick, the reader is referred to Fathy's Architecture for the Poor [1973] and Cain *et al*. [1975].

The thickness of mudbrick walls was utilized to delay heat impact, and thus reduce the daily heat peaks [Figure 1]. The omni-directional wind towers were also built of mudbrick and wooden stiffeners.[1] A horizontal section through one of them shows an X configuration so that winds from any direction are admitted into the house, providing some degree of cooling [Figure 2].

The courtyard's modification of the micro-climate is enhanced when it is provided with greenery and water. It acts as a cooling well which in turn helps lower ground temperatures and reduces radiation impacts. Moreover, when a shady courtyard is used in conjunction with a sunny one, in which the heated air rises, cool air may flow from the shady courtyard into the sunny one through an outdoor living area [Figure 3].

Unfortunately, due to recent sudden changes in the economy of this region many of these traditionally built forms have already been replaced by modern buildings, though a few of them have been left standing in the rush towards modern forms of urbanization [Figure 4].

The problem began when all town planning

---

[1] In the United Arab Emirates there are some traditional settlements in which omni-directional wind towers were made of demountable cloth which can be taken down and stored during winter months.

Figure 1 The remains of a courtyard house showing the thickness of its mud-brick walls

Figure 2 Traditional courtyard houses with their wind towers

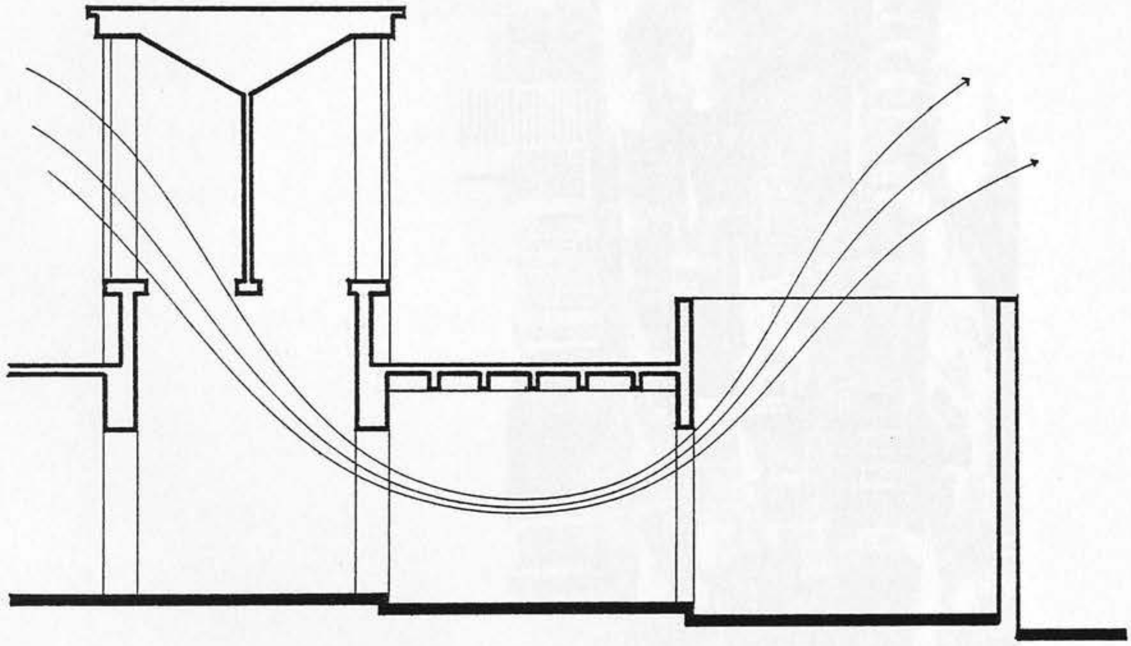


Figure 3 The ventilation concept of the courtyard and wind catcher

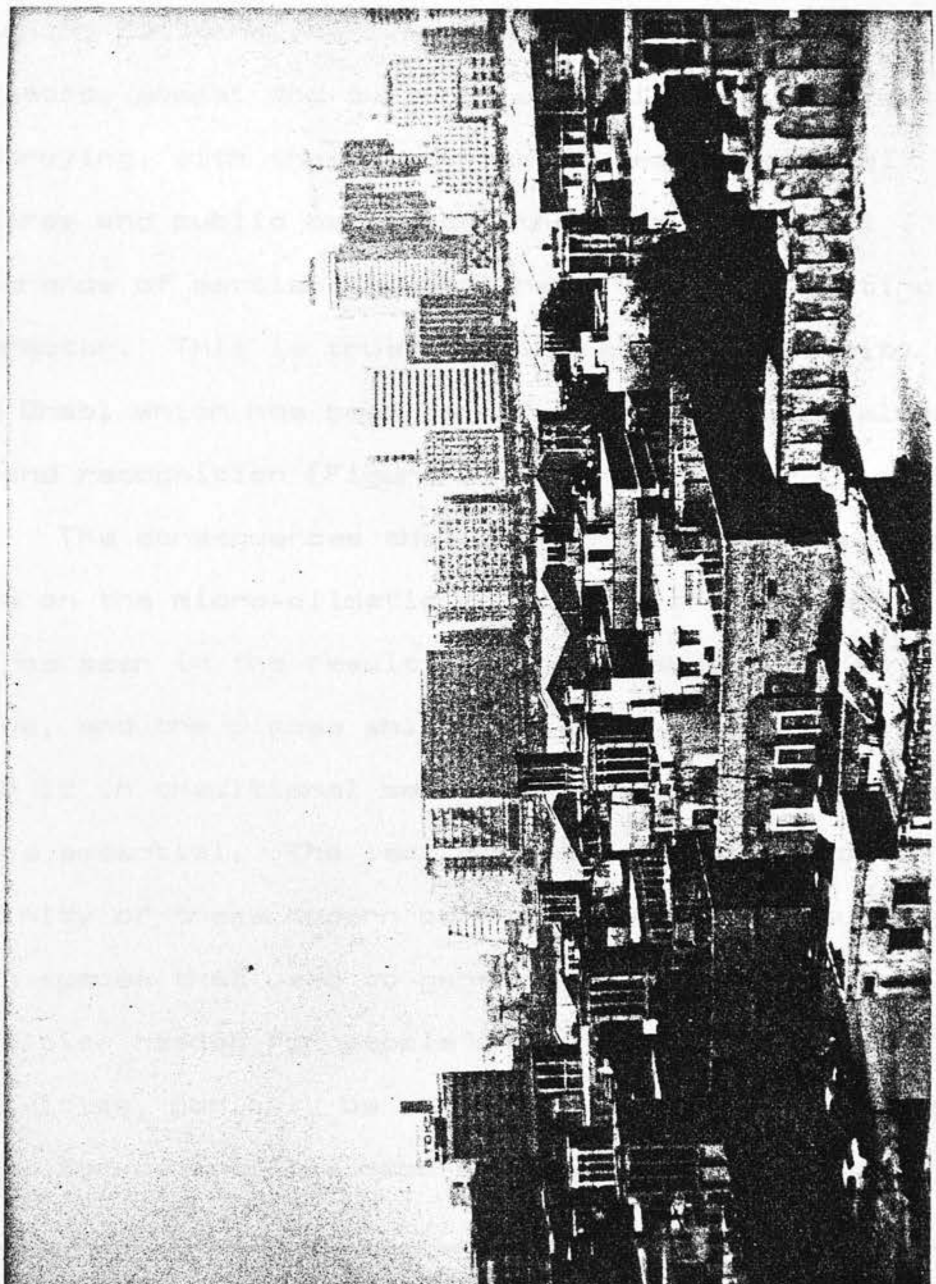


Figure 4

authorities, without exception, ignored those essential qualities that have characterized traditional settlements and started to introduce alien architectural and planning patterns, derived from the quite different climatic, social and cultural conditions of the West, destroying, with their imported houses, commercial centres and public buildings, the last structural coherence of settlements that have their own distinct character. This is true, for instance, of the city of Abu Dhabi which has been transformed physically almost beyond recognition [Figure 5].

The consequences that these modern replacements have on the micro-climatic conditions of Abu Dhabi city can be seen in the resulting urban spaces in which shade, and the places which have always been associated with it in traditional settlements, were no longer felt to be essential. The lack of shade in the immediate vicinity of these modern buildings meant that public open spaces that used to generate the environmental qualities needed for people and their daily urban activities, can only be utilized as roads and parking areas for cars.[1] The maps shown in Figures 6 and 7

---

1 Due to the poor thermal performance of modern buildings it is quite common in the Gulf region, and perhaps peculiar to the city of Abu Dhabi that most people flee from their modern houses and seek refuge in their airconditioned cars when electricity fails,

Figure 5(a) An aerial photograph of the traditional settlement of Abu Dhabi
(date of photography : May 1965)
(source : Hunting Surveys Ltd., 1965)

Figure 5(b) An aerial photograph showing recent development of the same area of Abu Dhabi
(date of photography : 12 June 1976) (source : Town Planning Dept., 1976)

Figure 5 A comparison between the traditional settlement and the modern city of Abu Dhabi

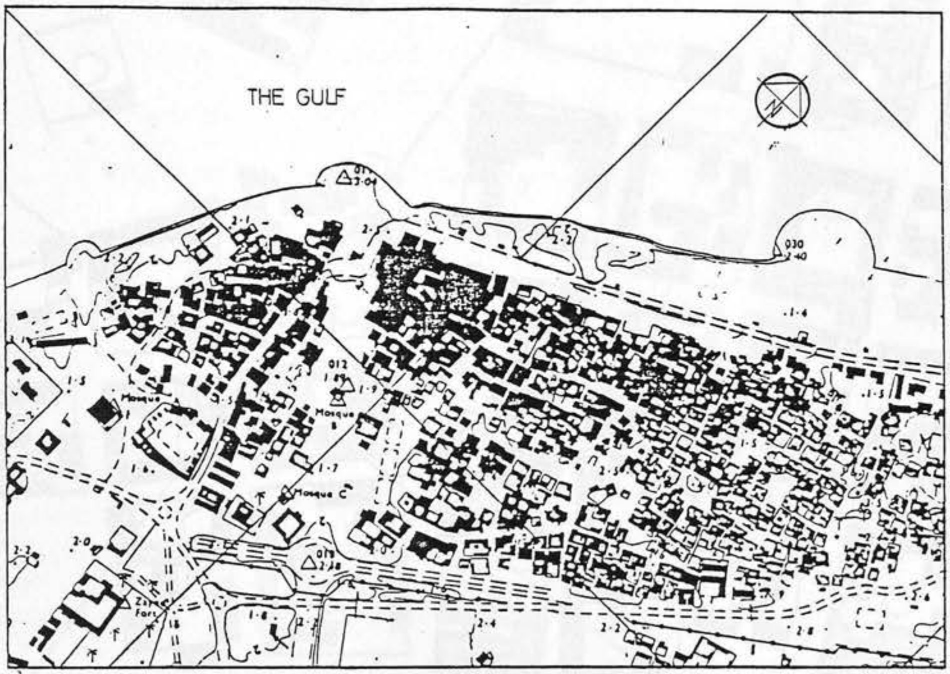


Figure 6 (a) part of Abu Dhabi map (1968)
(source: Hunting Surveys Ltd., 1968)

traditional buildings
palm trees
new roads
tracks

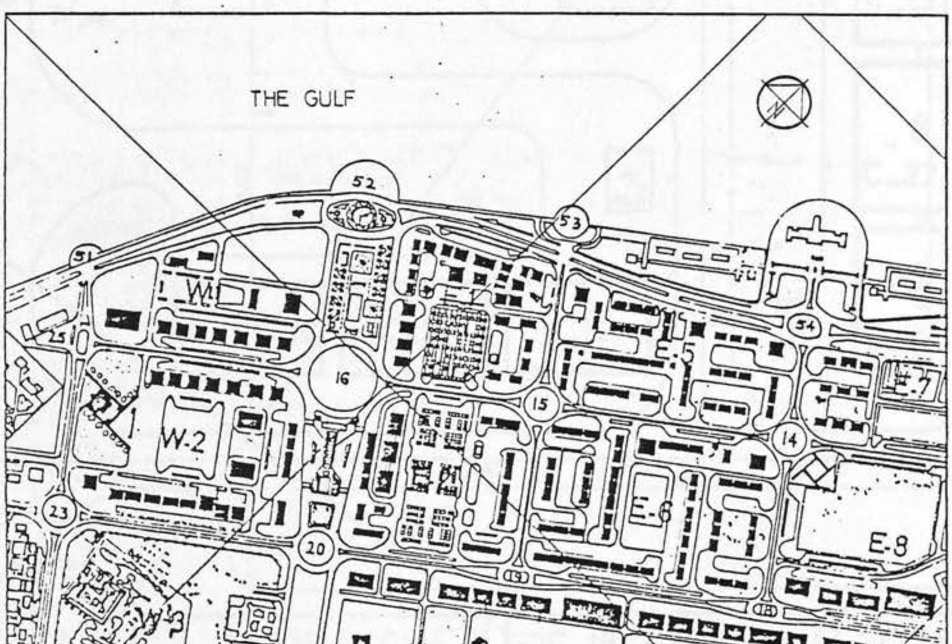


Figure 6 (b) the same part of Abu Dhabi after recent development (1978)
(source: Town Planning Dept., 1978)

high rise buildings
mosque
scrub
roads
0 200 400 Meters

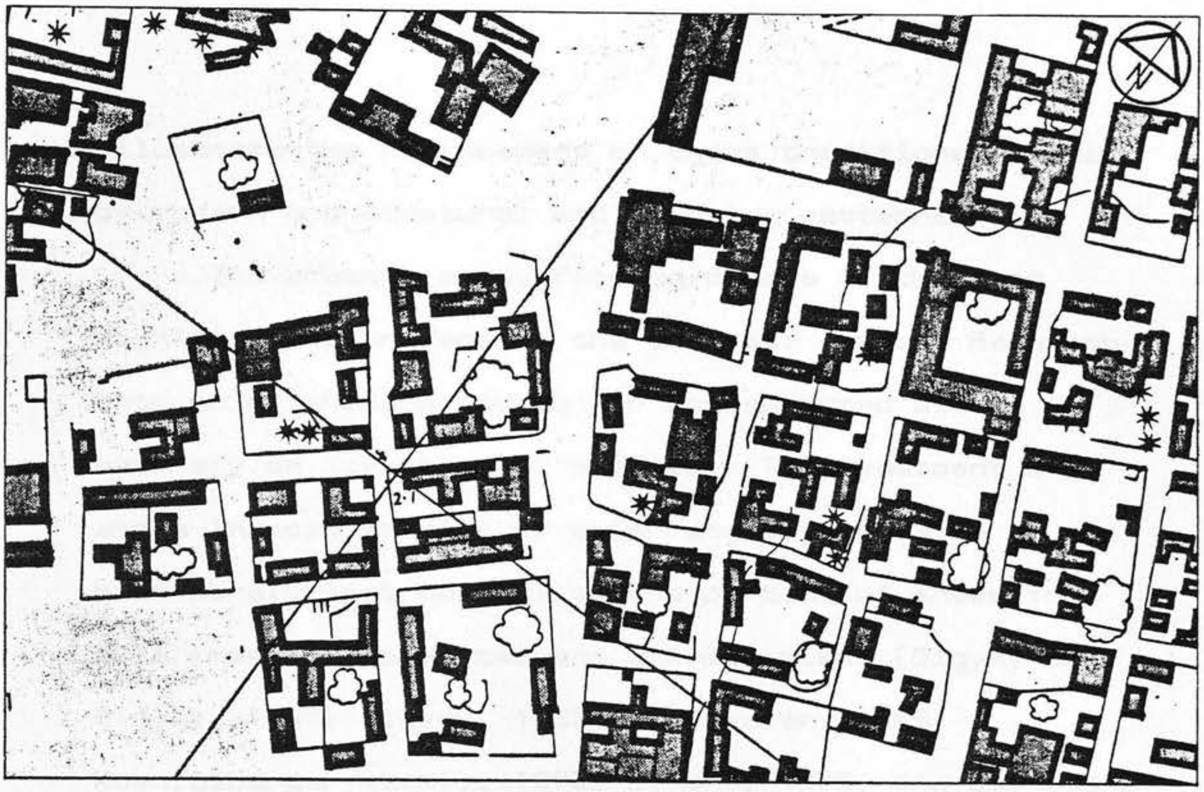


Figure 7(a) Traditional buildings with their intimate urban spaces (source: Hunting Surveys Ltd., 1968)

traditional buildings · palm trees · walls and fences · scrub

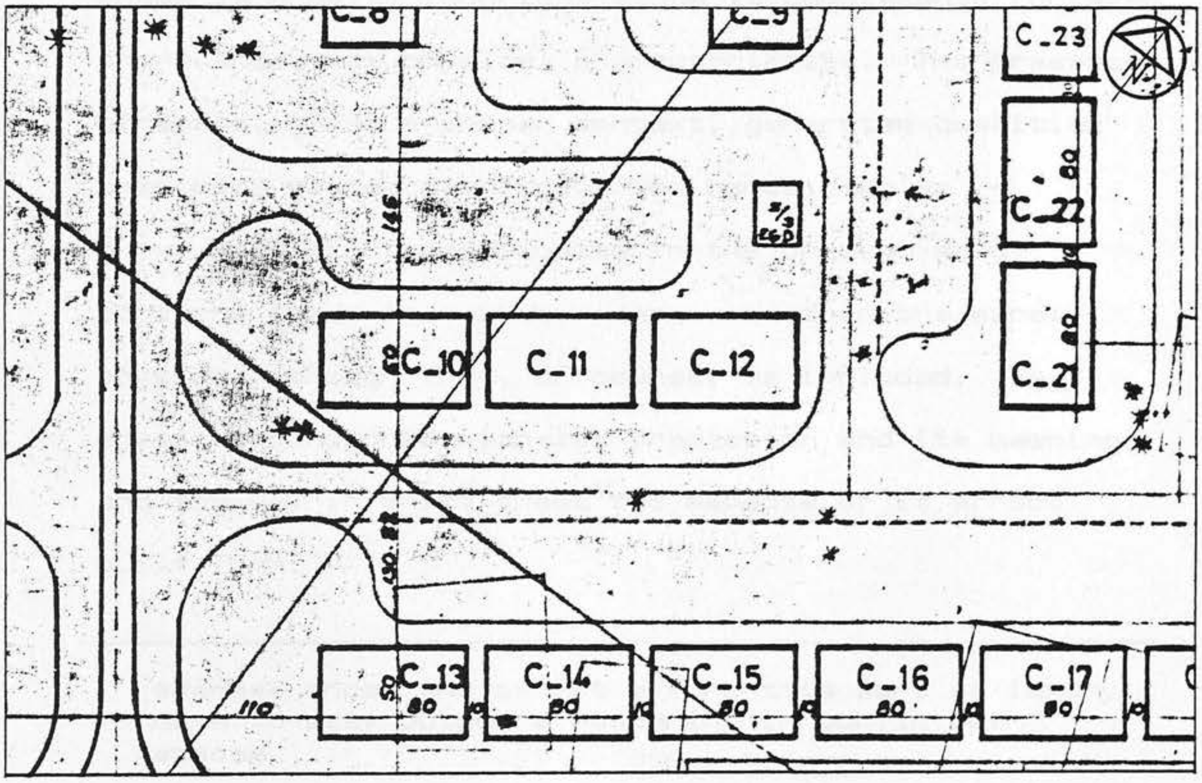


Figure 7(b) High-rise buildings with their parking areas and roads (source: Town Planning Dept., 1978)

high-rise buildings · palm trees

Figure 7 A comparison between traditional urban built forms and spaces and their modern replacements in Abu Dhabi

Scale 1:1250 (in feet)

illustrate the replacement of these traditional forms by modern architectural and planning patterns.

The present study focuses on one of the most significant phenomena in the tropics: shade. Research into solar shading has so far concentrated almost entirely on its physical aspects. The treatment of shade in most studies of solar shading seems to be at best purely instrumental to the purpose of answering some immediate physical and thermal needs (Olgyay and Olgyay, 1957; Olgyay, 1963; Lippsmeier, 1969; Koenigsberger et al., 1973; Givoni, 1976, and Smith and Wilson, 1976), and contains no reference to its broader phenomenal nature, in the sense that the meaning of shade is equally important since it complements (or even transcends) its physical characteristics. The presence of shade, given a proper context, generates qualities that make places meaningful and hence usable.

The main theme adopted in the present study concerns shade in a much wider sense than the merely physical, though that, of course, is included. We shall be concerned with its prediction and its meaning and the way in which these two aspects of it affect built form.

---

whereas those who cannot afford this sort of luxury have to stay outdoors wandering in public open spaces.

The factual, physical and geometrical nature of shade has, in the abstract sense, the character of exactitude [e.g., a percentage of a given area is predictably shaded for a given percentage of time]. In this way, the objectification and abstraction of shade distort its living concrete reality because the systematic quantitative handling of solar shading and the explication of the physical and geometrical laws embodied therein allow no subtlety in interpretation either as to form or as to the use of space.[1]

On the other hand, the meaning and value of shade, though subjective and scientifically inexact, can offer a new approach in which shade and place are interrelated in such a way that the resulting shady place is not merely a computed patch of shaded area for a known period but is also a real place with all that it gathers.

Moreover, this approach to the treatment of shade emphasizes the primacy of its qualitative nature while leaving room for its quantitative handling to play its proper part in the design process.

---

[1] The term "use of space" is intended here to refer to real places and the human behaviour associated with them. In real places in which man dwells naturally, human behaviour cannot be reduced or interpreted in terms of lower animals, nor is it possible to reduce man's behaviour to the physical laws controlling the behaviour of inanimate matter.

One of the central concerns in this study is directed towards simulating the interaction between solar shading and the geometrical parameters of a form. This is done by structuring a mathematical model based on the qualitative choice of the courtyard form with which a systematic quantitative investigation of shade on the ground can be carried out. In order to make the lengthy calculations inherent in the prediction of shade the model was implemented on a computer.

In addition to choosing the courtyard as a viable form both socio-culturally and climatically, this also limits the range of computer investigations, since there is, from a purely practical point of view, a real need to reduce complexity and to ease the routine and potentially excessive output associated with such techniques.

The thesis has eleven chapters. The first surveys the physical and geometrical nature of solar shading, particularly in the tropics, where shade is regarded as being a physical fact to which any tropical environment has to respond.[1] There are three components of solar shading that seem to be relevant to its factual nature. First, the characteristics of the

---

[1] In considering the factual nature of solar shading and its importance for the tropical urban environment the reader is referred to Egli's work [1951].

sun, shade and urban built forms at a given latitude. Second, the ways of providing shade in urban spaces and forms, particularly those methods of form and plan used in traditional settlements. And finally, techniques of predicting shade patterns, including a summary of prediction techniques and simulations, such as sun-path diagrams, heliodon, solarscope and computers.

Chapter II introduces the phenomenal nature of shade, especially in relation to some of the behavioural aspects which characterize tropical urban environments, where the phenomenon of shade is envisaged as a medium linking people's everyday urban activities and the places they live in. The argument in this chapter rests on two beliefs: [i] the supremacy of the qualitative aspects of the environment over its quantitative ones, and [ii] human behaviour in the environment is grounded on a sense of generalization. According to these beliefs an attempt is made to bring into the open the meaning of shade in relation to man's dwelling with reference to some spatial and temporal characteristics of the socio-cultural and physical environment.

Chapter III begins with an epistemological question dealing with the nature of the knowledge we pursue in the search for the meanings and values that the phenomenon of shade might produce in the tropical environment. Two different kinds of knowledge concerning shade are examined: [i] knowledge which deals with its physical and geometrical nature [its factual description], and [ii] knowledge which is needed to unfold its meanings and values [its phenomenal nature]. This chapter is also directed towards bringing into view the interplay between the factual description and the phenomenal nature of shade in such a way so as to make possible the gathering together of its quantitative and qualitative aspects in the design process. A discussion is also presented of the relationships between those two approaches to shade and similar phenomena and current attitudes towards man and his environment. In this respect three tasks are undertaken: [i] the customary positivistic idea of resorting to the establishment of purely physical or behavioural relationships as the only means of linking man and his environment is disputed, [ii] as an alternative, the general notion of man's existence, b e i n g - i n - a n - e n v i r o n - m e n t, is introduced as a viable replacement for positivism, and [iii] the importance is emphasized of combining the scientific representation and the phenomenological understanding of shade with the aim of getting closer to the environment in which man is as human being.

Chapter IV discusses quality and quantity in the design process. Here the aim is to achieve two things: [i] a reversal of the conventional order in which designers deal with shade by arguing for a process of design initiated upon the meanings and values of shade while, at the same time, allowing room for its factual description; and [ii] the development of certain characteristics of the spatial and temporal qualities of man and his environment for the purpose of arriving at a better understanding of a set of dimensions [space, time, shade and activity] considered as important in designing for the tropics.

Chapter V sums up the overall argument in the previous chapters to prepare the way for a discussion of the quantitative approaches to the prediction of solar shading. The main concern in this chapter is with the qualitative choice of the courtyard as a viable and relevant form [both socio-culturally and climatically] upon which a systematic quantitative investigation can be carried out. This is related to a more detailed discussion about the meaning of the qualitative choice of the courtyard form with reference to earlier and contemporary town planning practice in the Gulf region.

Chapter VI deals with the physics of solar shading. It begins with a survey of conventional techniques of simulating and predicting shading patterns, and then describes a computer-based technique for calculating the time-averaged distribution of shading of the ground from the sun by an ensemble of buildings. This chapter also shows that the effectiveness of the computer program SHADE [the simulation] and the potential benefit to the present study lies in its versatility and speed, without which it would be impracticable to carry out the necessary range of investigations of form and shade.

Chapter VII gives the structure of a mathematical model which represents the interaction between the courtyard form and the sun's geometry. A systematic quantitative investigation with the model is carried out through an analysis of the effect of plan proportion, orientation and configuration of the courtyard form on the time-averaged distribution of shade on the ground surface of the courtyard and urban space.

Chapter VIII presents individual results from the computer program SHADE, gives an account of the procedure needed to run it, and describes the nature of its input and output.

Chapter IX analyzes and discusses the investigations carried out with the model, and presents diagrams illustrating and explaining different interrelationships between the geometrical parameters of the chosen forms and their corresponding shading performances.

Chapter X reviews sequentially the different stages taken in the present study and discusses the question of how quality engages with quantity both in research and in design.

The last chapter gives a number of conclusions which may be drawn from the study, discusses the findings, and suggests further investigations.

The work is supplemented with an appendix which includes the main climatic features of the Gulf region with reference to the city of Abu Dhabi.

CHAPTER I

THE PHYSICAL AND GEOMETRICAL NATURE OF SOLAR SHADING

CHAPTER I

THE PHYSICAL AND GEOMETRICAL NATURE OF SOLAR SHADING

I.1 Introduction

In this chapter, solar shading in its physical and geometrical sense is introduced. This is done by considering briefly the characteristics of the geometry of the sun, solar shading and built forms in the tropical urban environment; by noticing some traditional ways of providing shade in urban spaces and forms; and by referring to techniques used in the prediction of shade.

Since the physical aspects of solar shading are more likely according to current practice to be taken as a basis for concern in design, an attempt is made in this chapter to make two things clear: [i] the principal problem facing the designer is not that of the prediction of shade, but is rather one of choosing the form, and [ii] shade in everyday life is not just physical because, in terms of design, we are more concerned with its meanings and values.

I.2 The Characteristics of the Sun, Shade and Urban Built Forms at the Latitude of Abu Dhabi

Shade is the result of the interaction between built forms and the sun's geometrical behaviour at any given locality on the earth's surface. Direct sunrays falling on a building or a group of buildings generate a wide variety of shade patterns both on the ground and on the external surfaces of these buildings [Figure I.1].

The magnitude and distribution of shade depends on three main factors: [i] the geometry of the built forms, [ii] their orientation with respect to the cardinal directions, and [iii] the daily and seasonal variations of the apparent motion of the sun.

Shade is conditional upon the geometrical configuration of the forms which cast it; however, the relationship between them becomes more complex when buildings are given different forms and arrangements. For a given period in time some forms may well cast more shade on the ground than others, though the opposite might be true for some other period. However, with all the varieties of urban built forms, the courtyard, with its characteristic qualities, is perhaps most suited to the generation of shade.

Shade also varies with the time of the day: it reaches a maximum in the early morning and before

Figure I.1 Patterns of shade generated by new buildings in the city of Abu Dhabi sunset, whereas a minimum is given at solar noon.

As the sun rises urban forms receive sunrays that make a small angle with the horizontal, and as a result, shade is at a maximum, and then begins to contract until the sun crosses the meridian and reaches its greatest altitude. The exposed ground receives minimum radiation in the early morning and late evening; it increases until solar noon when the process reverses.

Of the external surfaces, the roof is the major source of heat gain to the building because of the considerable amount of solar radiation received on its surface during the day. This accounts for its construction and surface treatment. Unlike walls, where a wide variety of shading devices can be used, the shading of the roof is, for practical and economical reasons, much more difficult to deal with.[1] However, variation in building heights can generate shade patterns by which one roof can be in the shade of other buildings [Figure I.2].

---

[1] The reader is referred to Saini's work [1973] and Koenigsberger et al. [1974] for general information on ways by which heat flow through the roof can be reduced.

1.3 The Ways of Providing Shade in Urban Spaces and Forms with Particular Reference to those Methods of Form and Plan in Traditional Settlements

Due to the extreme climatic conditions prevailing in the Gulf region, the provision of shade is of vital importance to people in their daily activities.

In order to generate as much shade as possible the traditional buildings of Abu Dhabi settlement are compactly laid out so as to minimize the urban spaces and to provide mutual protection and shading which help reduce the amount of heat gain on the external surfaces of buildings [Figure I.3]. Another way of generating shade can be found in the traditional market-place ['souk'], where much of the urban activity takes place during the day. In such a place shade is provided by demountable canopies and temporary roofs [Figures I.4 and I.5].

Shade is also provided in traditional forms in two ways:

1. By providing an enclosed space within the building whereby large areas of the inner surfaces surrounding the courtyard as well as that of the ground are shaded, which in turn helps to modify the thermal behaviour of the courtyard. Traditionally, vegetation and water together with shade are the most effective method of screening dust and sandstorms and providing a visual, physical and psychological relief [Figure I.6]. Here,

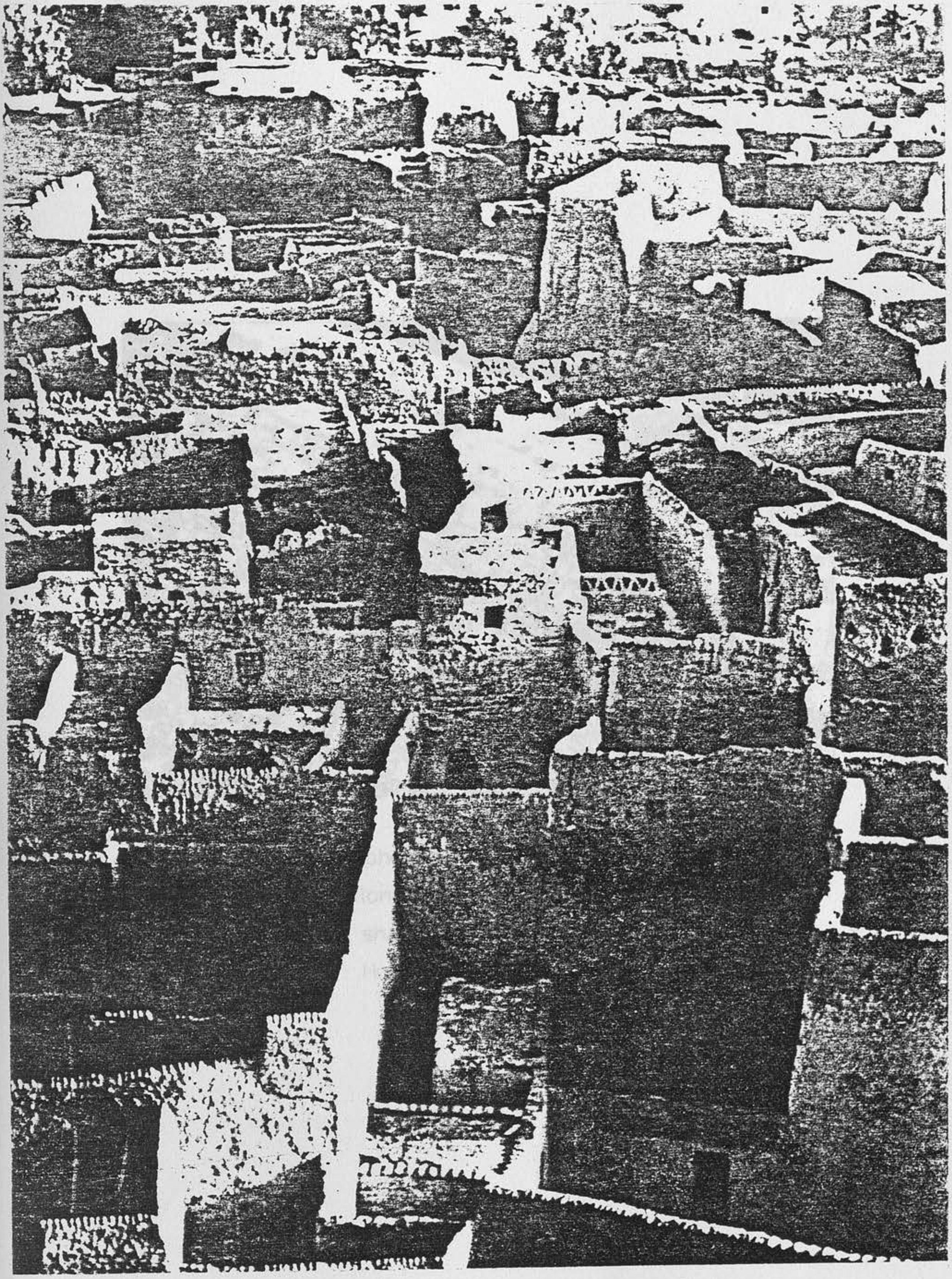


Figure I.2 Ghat, Libya (Sahara)

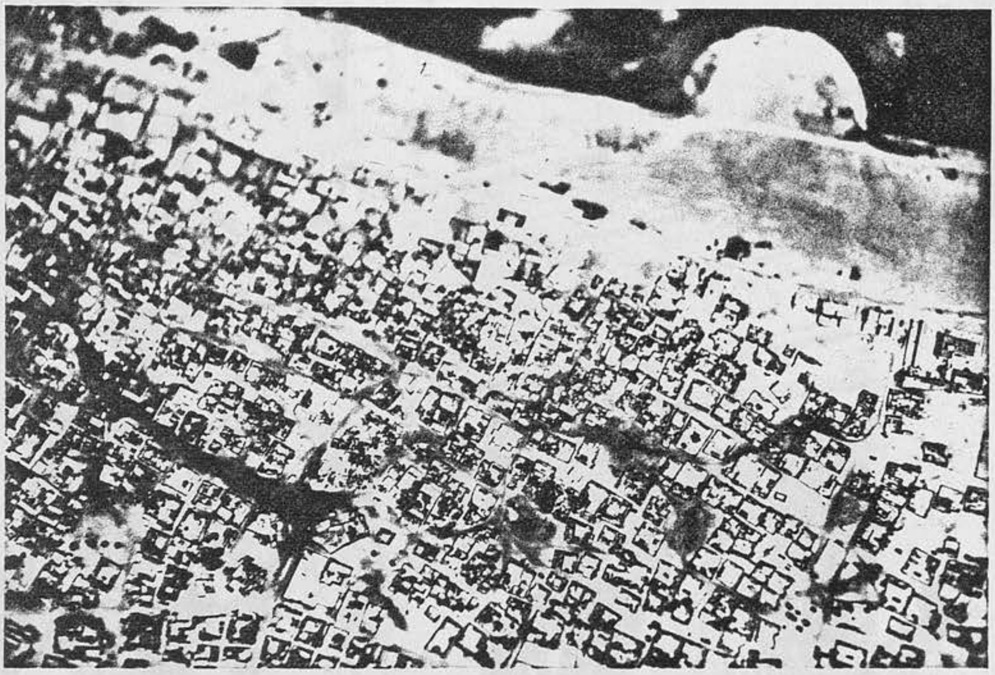


Figure I.3 An aerial photograph showing the compactedness of the traditional settlement of Abu Dhabi as a way of providing shade in urban spaces and forms
(source : Hunting Surveys Ltd., 1968)

Figure I.4 View of the traditional marketplace (souk) of Dubai with its wooden roof

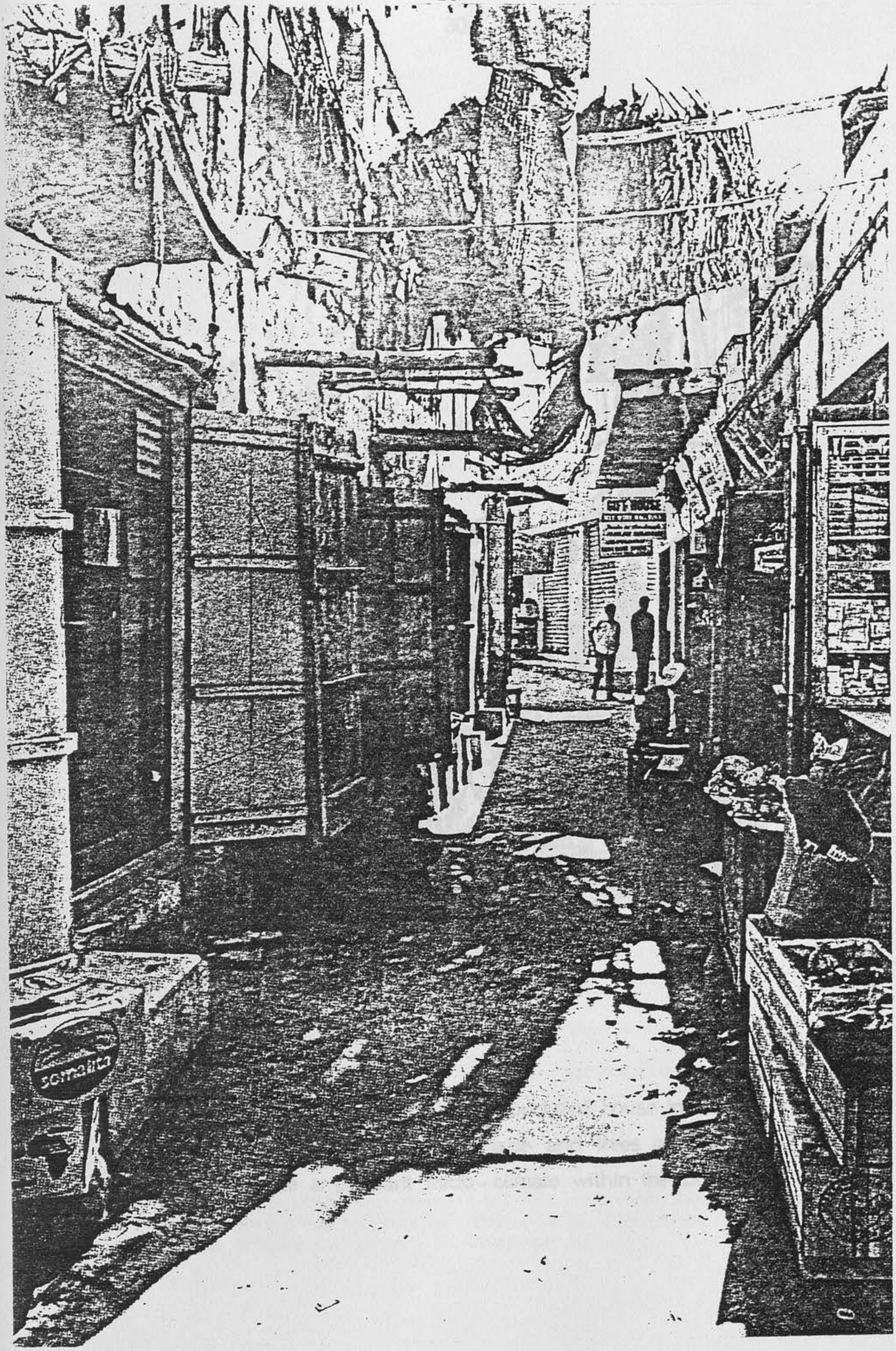


Figure I.5 The traditional marketplace of Sharjah

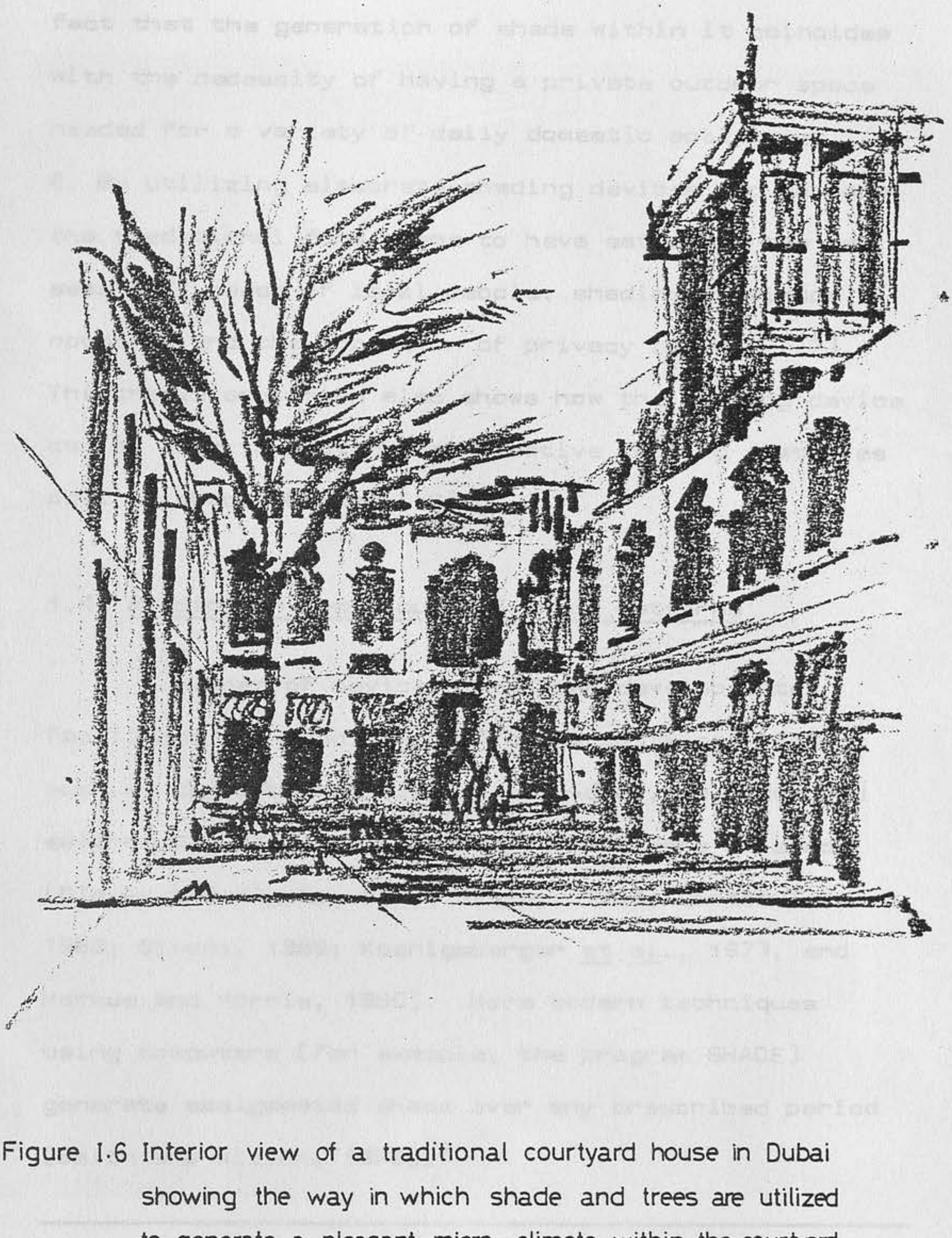


Figure I.6 Interior view of a traditional courtyard house in Dubai showing the way in which shade and trees are utilized to generate a pleasant micro-climate within the courtyard space the effectiveness of the courtyard house lies in the fact that the generation of shade within it coincides with the necessity of having a private outdoor space needed for a variety of daily domestic activities.

2. By utilizing elaborate shading devices and screens, the traditional form seems to have satisfied the two essential needs of local people: shading of window openings and the provision of privacy [Figure I.7]. The traditional form also shows how the shading device can be used to provide an effective cooling system as well as shade [Figure I.8].

1.4 Prediction Techniques of Shade Patterns

A number of devices have been developed to facilitate the prediction of shade patterns. Some, such as the sun-path diagram, sun-dial, heliodon and solarscope, produce instantaneous patterns of shade [Olgyay and Olgyay, 1957; Olgyay, 1963; Lippsmeier, 1969; Givoni, 1969; Koenigsberger et al., 1973, and Markus and Morris, 1980]. More modern techniques using computers [for example, the program SHADE] generate amalgamated shade over any prescribed period [Smith and Wilson, 1976].[1]

---

[1] A comparison between conventional methods currently used in the prediction of shade and the computer program SHADE is given in Chapter VI.

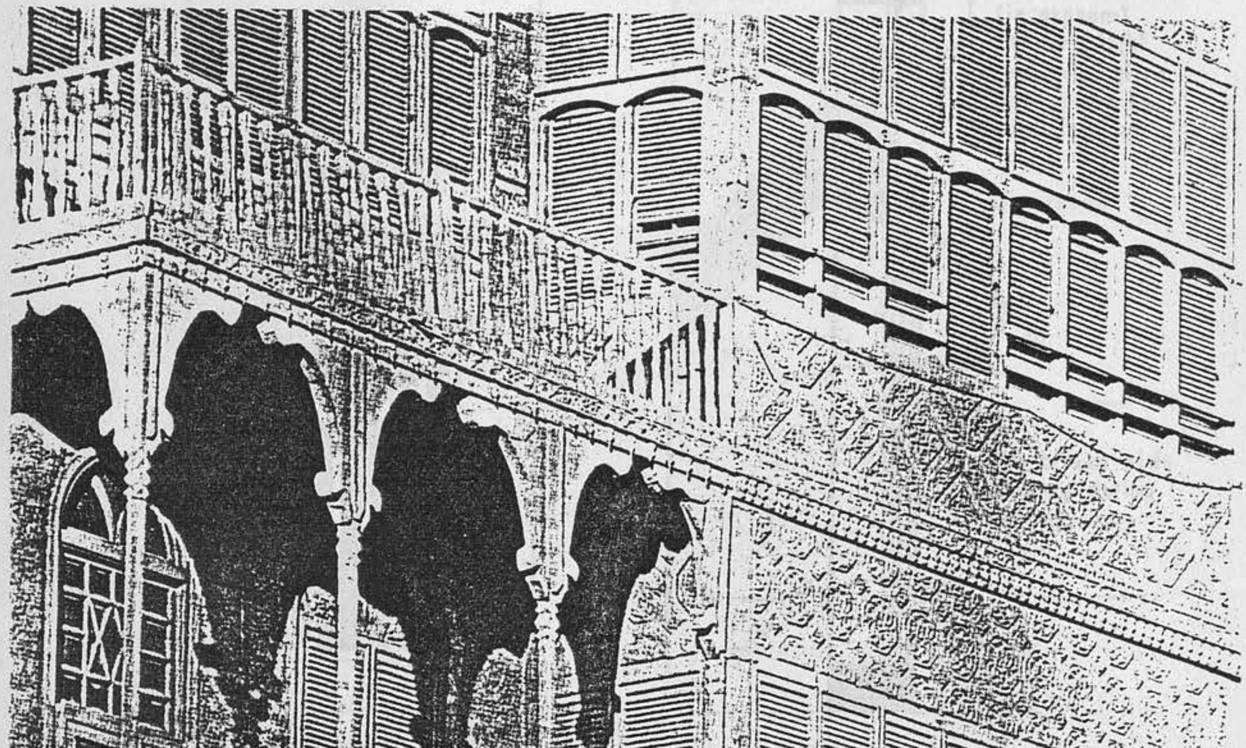


Figure I.7 A traditional building in Saudi Arabia responding to the need for shade and privacy

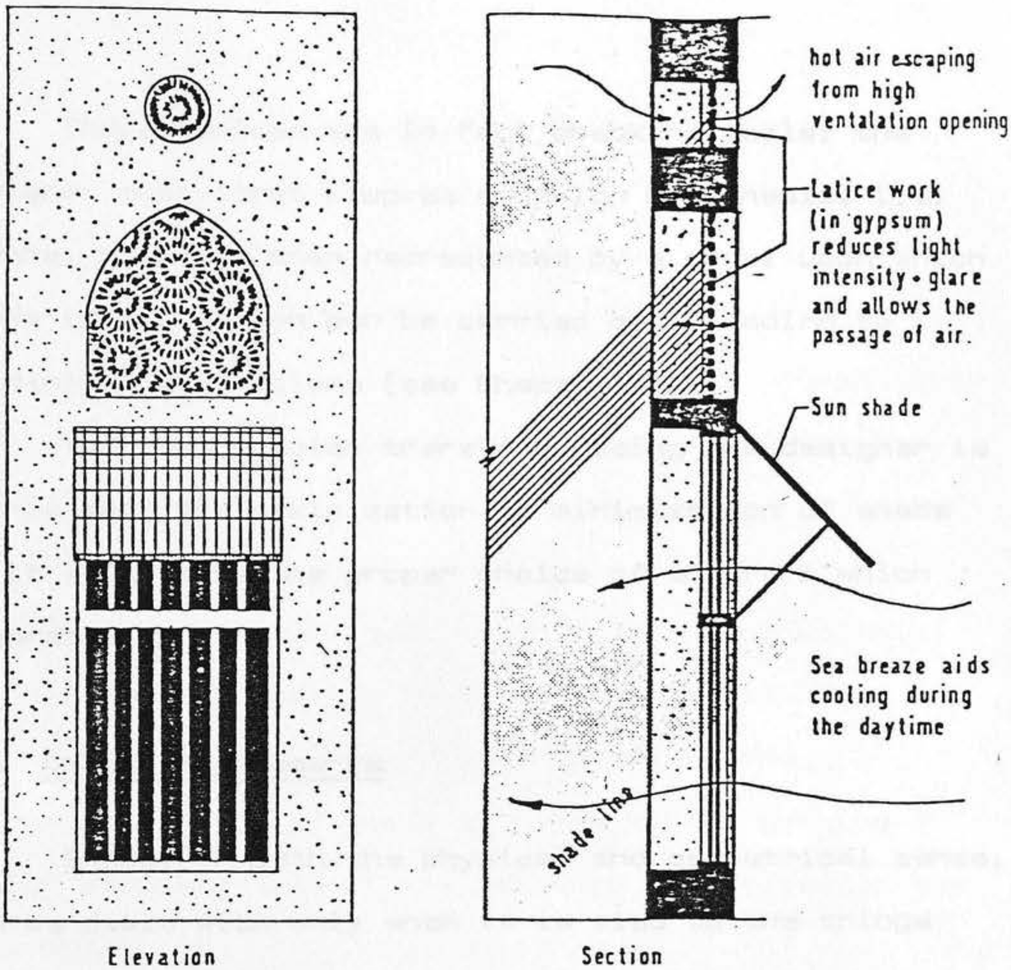


Figure I.8(a) a multi-level opening combining shade with ventilation system

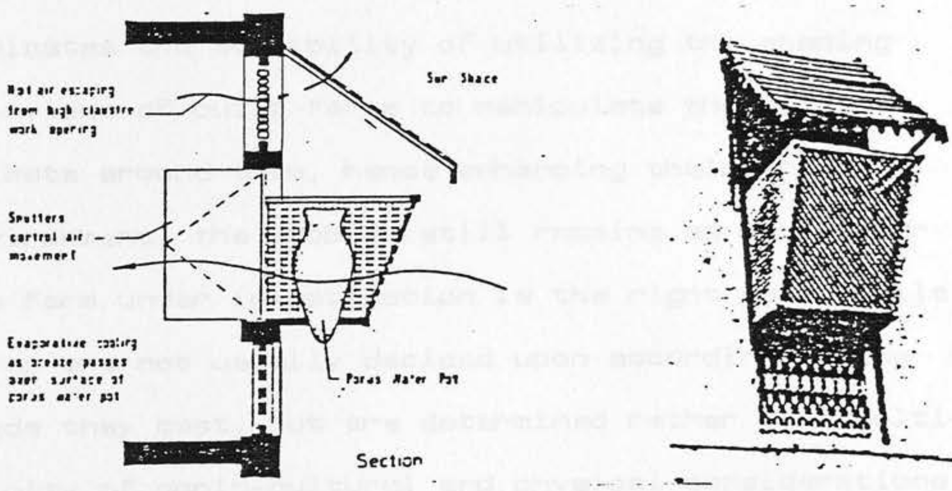


Figure I.8(b) a traditional shading device incorporating evaporative cooling system

Figure I.8 Two types of shading devices found in the traditional settlement of Muscat Oman (source: Cain et al., 1975)

Those devices are in fact checking tools: the designer must first propose a design hypothesis, i.e. a form, which is then represented by a model upon which shade investigation can be carried out, leading to possible modifications [see Chapter VII].

The main problem therefore facing the designer is not so much the maximization or minimization of shade as it is to make the proper choice of the form which generates it.

I.5 Concluding Remarks

Shade, in both the physical and geometrical sense, can be dealt with only when it is tied to the things which bring it into existence. In addition to the geometry of the sun and orientation, shade is primarily conditional upon the form that casts it. Although this indicates the possibility of utilizing the shading behaviour of built forms to manipulate the micro-climate around them, hence enhancing their internal environment, the problem still remains as to whether the form under investigation is the right one. Built forms are not usually decided upon according to the shade they cast, but are determined rather by a multiplicity of socio-cultural and physical considerations of which shade is just a part.

As mentioned in Section I.3 the provision of shade coincides with the communal and private behavioural patterns exhibited by people in the market-place and in the courtyard house. This means that shade is not just physical nor could it be brought into the living reality by the mere prediction of it [see Chapter III] because, in the tropical urban environment particularly, shade also embodies values and meanings.

In the present study we shall argue repeatedly for a process of design initiated by qualitative concerns. The following chapter examines the phenomenal nature of shade with the aim of gaining a better understanding of its meanings and values in the environment.

CHAPTER II

THE PHENOMENAL NATURE OF SOLAR SHADING

CHAPTER II

THE PHENOMENAL NATURE OF SOLAR SHADING

II.1 Introduction

In this chapter the phenomenal nature of solar shading is examined, and the relationship linking shade, place and human behaviour is established. The emphasis in the first section is upon the beliefs that in the living concrete reality the qualitative aspects of the environment preside over and transcend the quantitative ones, and that human behaviour in the environment is based upon a sense of generalization.

In the next section an attempt is made to bring out the meaning of shade in accordance with man's relationship to his environment discussed in the first section, and with reference to shade's physical and socio-cultural manifestations in the tropical urban environment.

It is believed that such an approach to dealing with both the quality generated by the presence of shade and the meaning inherent in it can be used as an "orientation" and as an attitude towards building and the built environment.

II.2 Shade, Place and Behaviour

In the first chapter shade was discussed in its purely physical sense: the provision and prediction of shade were understood purely quantitatively in terms of such measures as magnitude and distribution. However, shade in everyday experience is one phenomenon [a significant one for the tropics] among others that make a place what it is and as it is.

In this context, Heidegger's insight [1971] into the phenomenon of sound may well help us to obtain a deeper understanding of the phenomenal nature of shade. He argues that 'we hear the storm whistling in the chimney, we hear the three-motored plane, we hear the Mercedes in immediate distinction from the Volkswagen. Much closer to us than all our sensations are the things themselves. We hear the door shut in the house and we never hear acoustical sensations or mere sounds. In order to hear a bare sound we have to listen away from things, divert our ear from them, i.e., listen abstractly'.

In the everyday life-world natural phenomena such as sound and shade can never be experienced in isolation or be dealt with apart from things with which and by which man experiences any given situation as a qualitative and comprehensive phenomenon.

Therefore, unlike those abstract shade patterns, which can be quantitatively predicted and instrumentally generated, the phenomenon of shade in the living concrete reality must also be taken, like all natural phenomenon, in terms of qualities. Here, hot and cold, dry and humid, up and down, light and shade are 'things' to know with and by. This, of course, necessitates the existence of a locality in which shade can be experienced. It would be meaningless to imagine happenings or occurrences in the absence of a place.

However, in attempting to trace shade back into that place in which things that concern man are to be found we have to ask: In what way does shade belong to place?

The answer to this question begins with the word "place". Norberg-Schulz [1980] defines "place" as something more than abstract location. It is a locality made up of concrete things having material substance, shape, texture and colour; together these things determine an "environmental character", which is the essence of place. Any place has such a character or "atmosphere". A place is therefore a qualitative, "total" phenomenon, which we cannot reduce to any of its properties, such as spatial relationships, without losing its concrete nature. Accordingly, we may regard a place as a gathering of qualities in which shadiness may play a part [but only a part].

More important is the placeness of shade, since the presence of this significant phenomenon means something that is itself a place, i.e., shade comes into existence only by virtue of a place [Figure II.1]. There are, of course, many places in the environment that may be experienced through the things happening within them. However, in the tropics the presence of shade brings into being the place that is closely linked with people and their activities.

In fact, the environment in the Gulf region is far less diverse than those found in temperate or cool regions and this is largely because places can sharply be differentiated as sunny or shady. Due to this "crispness" which characterizes the tropical environment it is much easier to make up one's mind as whether to be in a place or not.

Being in shade implies the presence of people and places in which a wide variety of their urban activities <u>take</u> <u>place</u>. Here, we may suggest two things: [i] shade is, in the living reality, a place, and [ii] shade is the manner in which tropical places <u>are</u>. This, however, should not lead to the conclusion that non-shade [exposure to sun] is necessarily non-place, because in real urban situations shady places

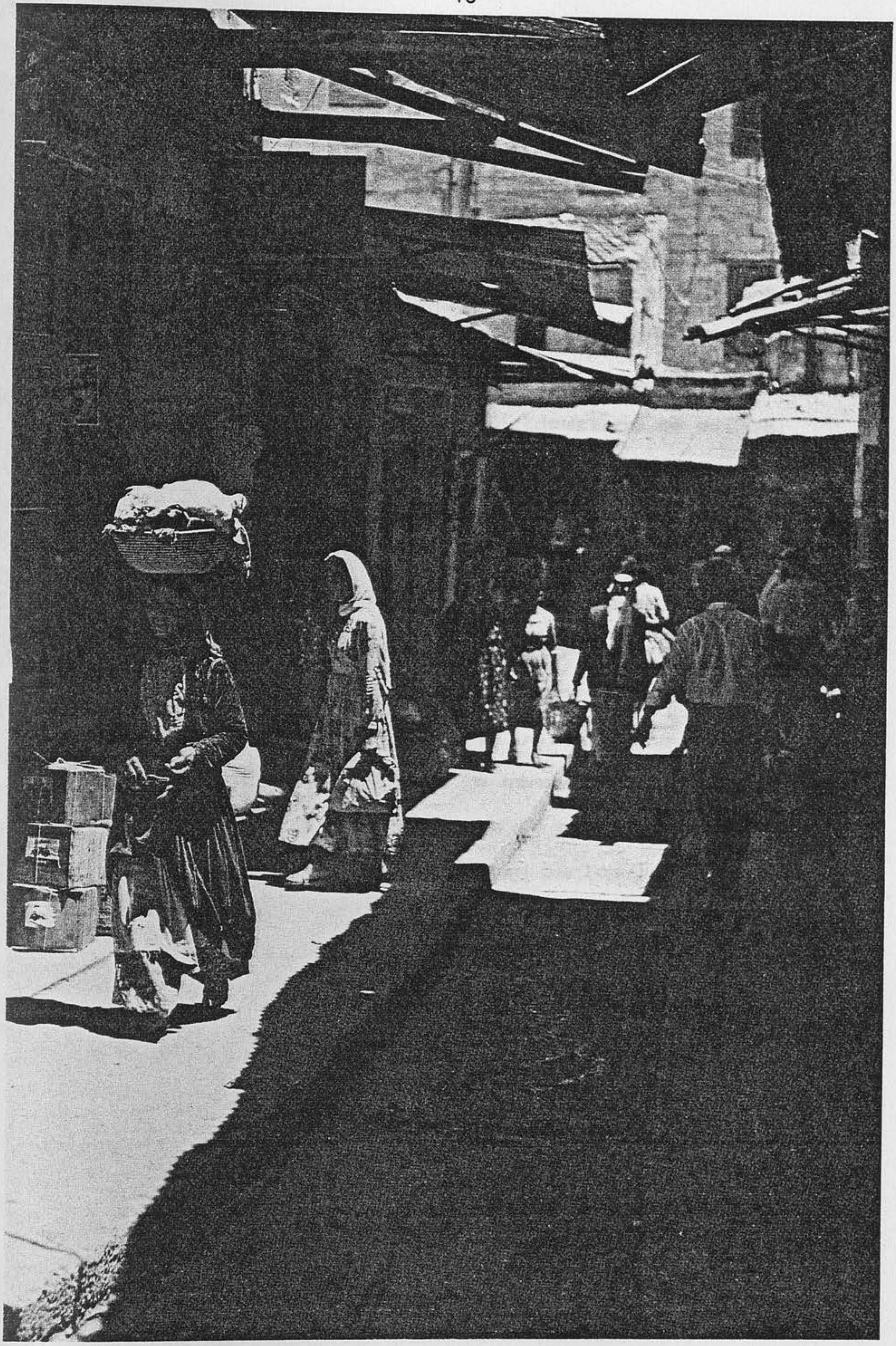


Figure II-1 The placeneess of shade

remain intact even when they are exposed to the sun [see Chapter V].

If we speak of human behaviour in relation to this simple unity of shade and place, we must think of the way in which man exists in a human manner. Heidegger [1971] argues that 'man's relation to locations [places], and through locations to spaces, inheres in his dwelling. The relationship between man and space is none other than dwelling, strictly thought and spoken'. Dwelling for him is 'an activity that man performs alongside many other activities. We work here and dwell there. The way in which you are and I am, the manner in which we humans are on the earth is dwelling' [1971, pp. 147, 157].

In limiting ourselves to behaviour in the sense of the potentiality of patterns of events [activities] generated by people for any given period in time, we find that those events are prompted by two things: [i] by a given situation which can be differentiated over space and time, and [ii] by the familiarity which characterizes man's behaviour in the environment. However, should the situation be changed, it may be expected that an entirely different behavioural pattern will be observed. An example of such interdependence is the relationship between the phenomenon of shade and different patterns of people's urban activities taking place throughout a typical summer's day in Abu Dhabi. Activities usually begin early in the morning while the day is relatively cool and urban spaces are shaded, and continue until shortly after midday. At that time shade cast by urban built forms is scarce and a break is taken so that people can rest during the unshaded period of the afternoon. When shade begins to spread throughout urban spaces people tend to resume their daily urban activities, spending a great deal of their time outdoors.

The habitual way in which people pattern their activities in accordance with shade brings into view the spatial and temporal characteristics of the tropical environment which can be expressed in terms of <u>where</u> and <u>when</u> a given pattern of events is likely to take place.

II.3 The Meaning of Shade

The meaning of shade in the tropical urban environment is not an abstract notion that can arbitrarily be added to the physical existence of shade, but rather something that is inherent in daily life and embedded in the relationship between man and his environment.

What, then, is this relationship? And by what means could it be defined?

Although such a relationship can abstractly be defined in spatial and temporal terms, the real meaning of shade is, in fact, something that goes beyond those abstract concepts. In everyday life this relation is brought to the fore through dwelling which is deeply rooted in man's very nature. In this context, Heidegger [1971] argues that 'we attain to dwelling, so it seems, by means of building. Dwelling and building are related as end and means. However, as long as this is what we have in mind, we take dwelling and building as two separate activities, an idea that has something correct in it. Yet at the same time by the means-end schema we block our view of the essential relations. For building is not merely a means and a way towards dwelling - to build is in itself already to dwell'. He concludes that 'to dwell, to be set at peace, means to remain at peace within the free, the preserve, the free sphere that safeguards each thing in its nature' [1971, pp. 145-49].

Staying, relaxing or even taking a refuge in a shady place means, on that account, 'dwelling' which extends over every act of building, whether it is of a simple shed, or that needed for a house. Moreover, the sense of 'togetherness' generated by being in shade with one another is, in the true sense of the word, dwelling [Figures II.2 and II.3]. In this respect man's everyday-interaction with his environment is nothing other than 'dwelling'.

With the relationship between man and his environment now clearer, one might ask: In what way can we come to know the meaning of shade? And how does the meaning manifest itself in the tropical urban environment?

The starting point to answering these two questions seems to be hidden in language. Heidegger [1971] argues that 'among all appeals that we human beings, on our part, can help to be voiced, language is the highest and everywhere the first. Language belongs to the closest neighborhood of man's being'. For him, and for us, 'Language speaks'.

The Arabic word for shade, zalla, means 'to be'. The word 'zalla' in its original sense also means to continue to do, to remain in a place and to stick to it, e.g., zalla yaskunu l-makan, he continues to stay [to remain or to live] in the place. The sense of belonging hidden in this word indicates that in man's everyday experience there is something "habitual", namely dwelling.

To shade, 'zalla', also means to screen, to shelter, and to protect in the sense of preserving, maintaining and keeping up. To protect from the sun

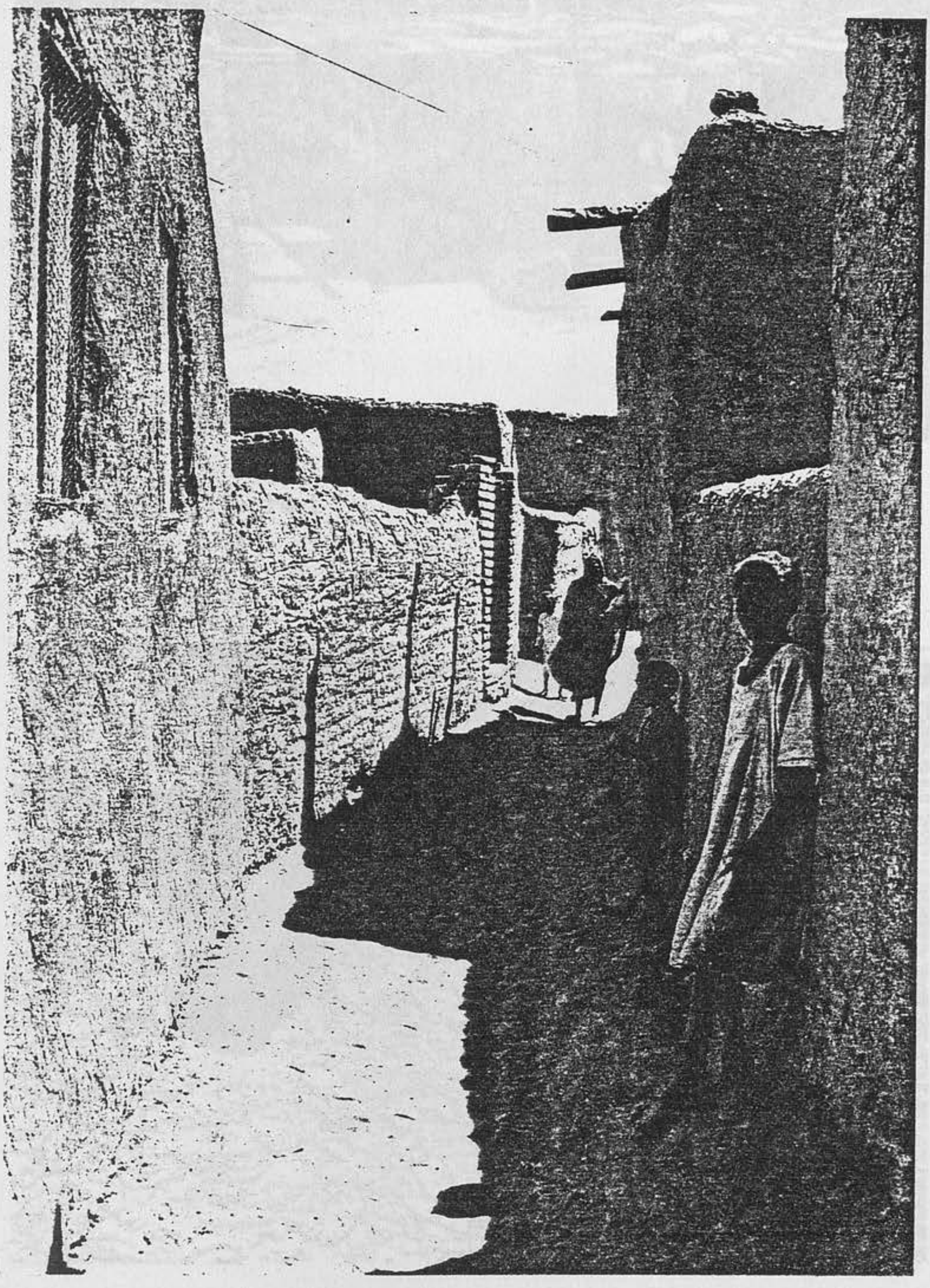


Figure II·2 Dwelling being materialized through staying in shade
(from Norberg-Schulz 1980)

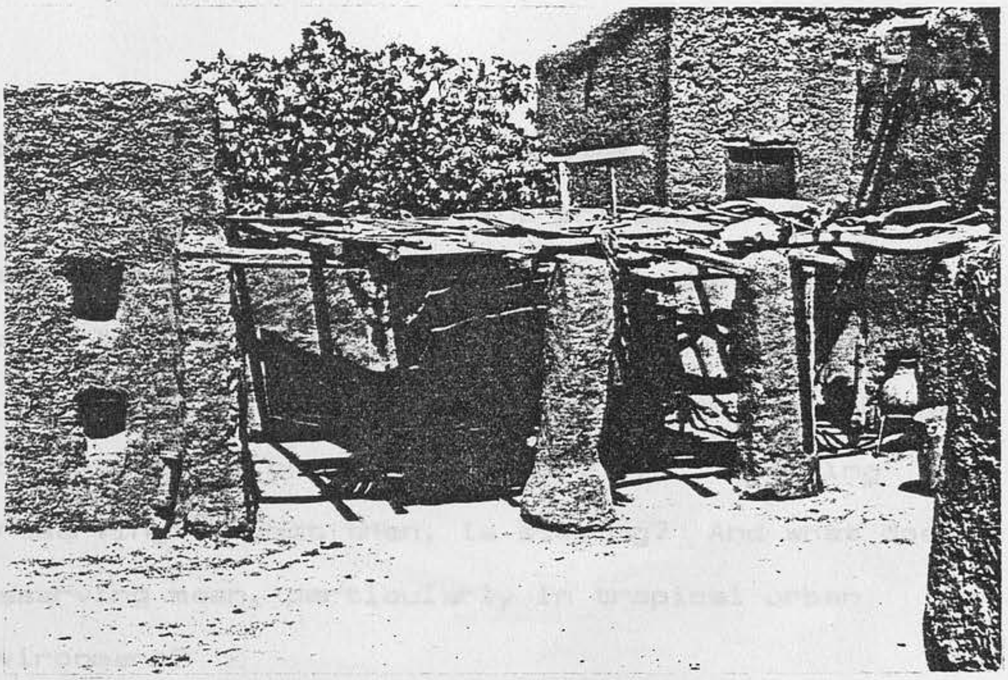


Figure II.3 (a) a shed

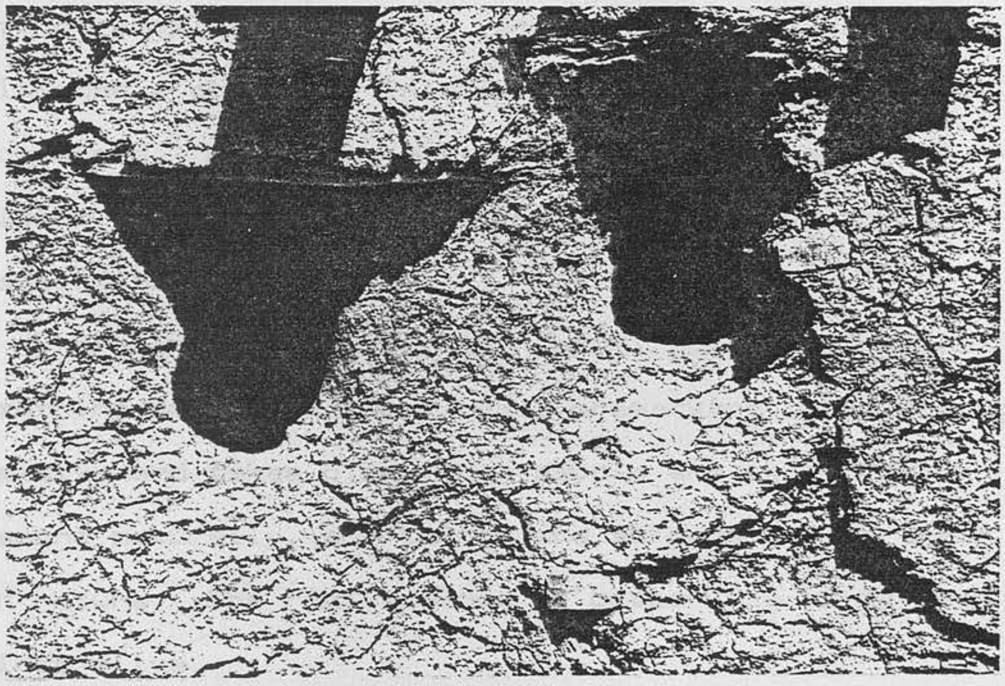


Figure II.3 (b) openings

Figure II.3 A simple shed and recessed openings brought into existence through a conscious act of building embodying dwelling (from Norberg-Schulz 1980) also means at the same time to seek the shade and hide in it. To be placed under the protection of 'God' means to be in the shade of 'Allah', that is, to be under His sovereignty.

Language here speaks of two fundamental things inherent in the meaning of shade, i.e., 'staying' and 'preserving'. What, then, is staying? And what does preserving mean, particularly in tropical urban environment?

Staying signifies something more than the mere existence of man in a place. To stay in the shade of a tree or that of a building means being 'with' and 'among' people and things. Staying, in this sense, initiates a gathering in which man's being-in-shade is pronounced. Here, the essential quality of shade belongs to the gathering nature of the phenomenon of shade [Figure II.4].

Preserving, on the other hand, goes beyond keeping something safe from harm. Real preserving is something positive and takes place when people are left free to respond naturally, and things are safeguarded in their own nature. The real essence of preserving is to keep things alive.

Some physical expressions of preserving in a tropical urban environment, such as that of the Gulf region, can be seen in man's behaviour as well as in

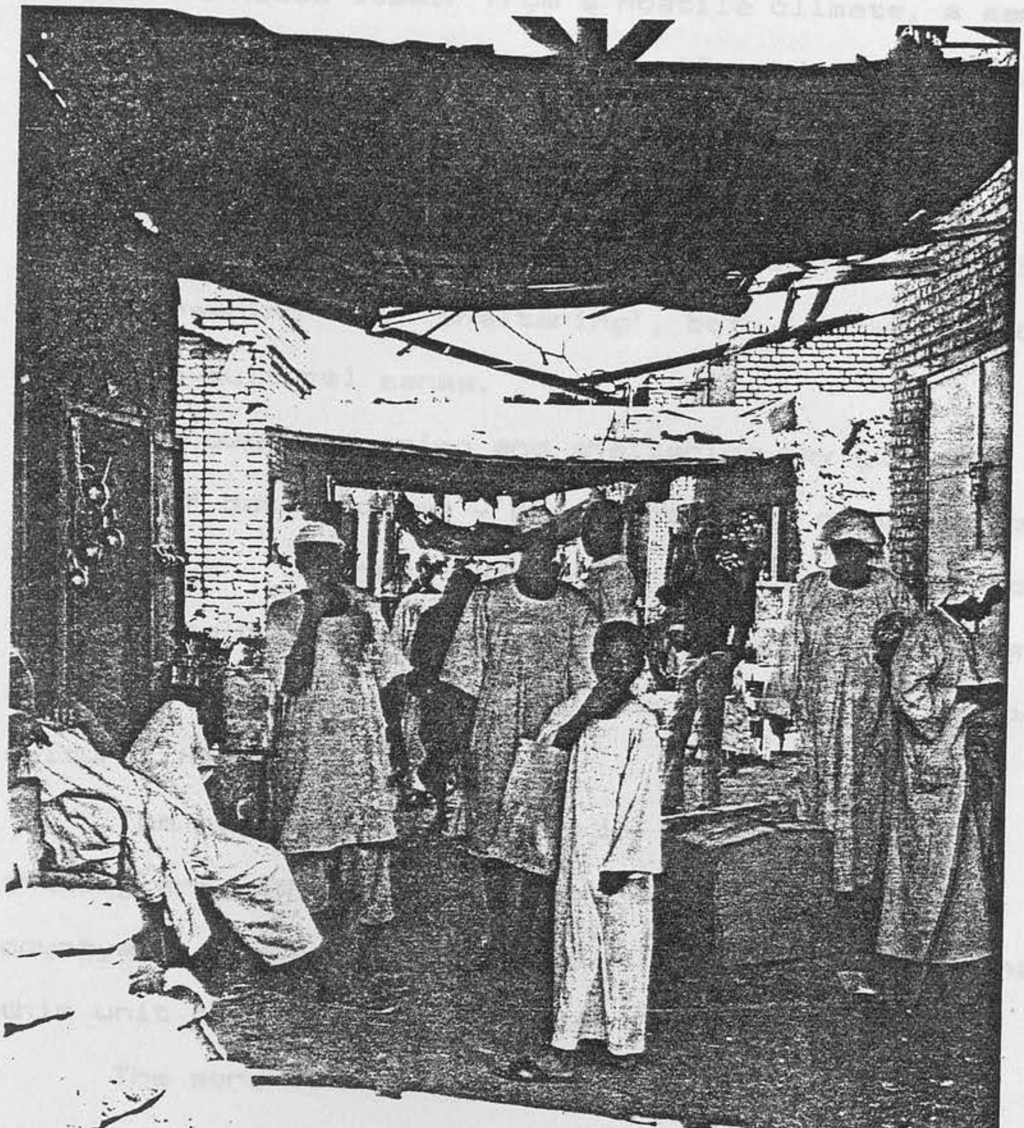


Figure II.4 The gathering nature of the phenomenon of shade
(from Norberg-Schulz 1980)

settlement forms. As man seeks shade and the urban settlement hides itself from a hostile climate, a sense of protection emerges which is manifested in the denseness of people's activities and in the compactedness of traditional settlements and forms.

Preserving, in the sense of protecting, signifies also 'screening' and 'sheltering', both in the climatic and socio-cultural sense.

Although screening and sheltering may give the feeling of detachedness - of a separation or isolation from things - the real meaning of them is hidden in the sense of belonging through which man dwells in places and builds places that satisfy his physical and socio-cultural needs.

The meanings originating in the true nature of shading are gathered in the form of the traditional courtyard. Once more language helps us understand what this unit of dwelling really is.

The word courtyard, <u>hauš</u>, means 'to round up', 'to drive into place'. The spatial interpretation of this meaning is something that gives us a sense of enclosure which suggests holding something in and together. The socio-cultural implication of this enclosure signifies 'privacy' which withdraws man to a protected core or a place that safeguards his life.

Language speaks of courtyard, 'hauš', as a thing that gathers and saves, both in the sense of bringing together parts into a whole and in the sense of safe-guarding things in their own nature.

Within this courtyard we find two things: first, a gathering of meanings signifying man's very nature and existence; second, a gathering of qualities generated by the presence of shade, trees and water, all of which assist man in his everyday activities. Here, the simple unity of shade and the traditional courtyard is inherent in their 'gathering' nature [Figure II.5].

II.4 Concluding Remarks

In this chapter, we started with the phenomenal nature of shade, defining it in qualitative terms with bearing on man's everyday experience, and in relation to the places in which he finds himself.

Out of the relationship linking shade, place and behaviour we brought forward three things: [i] shade, in the living concrete reality, is a place, [ii] the sense of generalization which characterizes human behaviour in the environment stems from man's famili-arity with things around him, and [iii] man's true relationship to a place is none other than dwelling in the essential sense of the word.

Figure II·5

The meaning of dwelling was made more explicit in the discussion of the meaning of shade, as the essential basis upon which the authentic relationship linking tropical man and his environment is founded.

The physical interpretation of this meaning in the urban environment began with Heidegger's idea that dwelling is in itself building. With the help of language we were able to: [i] bring out the hidden meaning of shade by tracing it back into man's being, [ii] generate the essential qualities in this hidden meaning, and [iii] bring forward a physical expression exemplified in the traditional courtyard through which those qualities are brought into existence. In this context, the traditional courtyard is not seen as a simple built form that has a void within it, but rather is understood as a gathering of qualities generated by the meaning of shade.

Although the phenomenal nature of shade has been dealt with in contrast to both the physical and geometrical nature of it, the intention was not directed towards replacing one by the other. The gap, which seems to exist between "solar shading" <u>seen</u> objectively as a fact and "shade" <u>conceived</u> subjectively as a phenomenon, can be bridged through a deeper examination of the nature of the knowledge needed by the designer in his search for a better understanding of the need for shade and the physical provision of it. In the next chapter, therefore, attention is given to the epistemological question dealing with the sort of physical and behavioural conceptualization of shade which is appropriate to the tropical urban environment.

CHAPTER III

THE PHENOMENOLOGY OF SHADE

CHAPTER III

THE PHENOMENOLOGY OF SHADE

III.1 Introduction

The first section in this chapter examines the difference between two kinds of knowledge concerning shade. On the one hand, shade may be considered as being determined by its physical and geometrical nature [its factual description]; on the other, it may be seen through its use by man for his convenience and purposes [its phenomenal nature]. This is aimed at bringing to the fore the essential interplay between the factual description and the phenomenal nature of shade in such a way so as to make possible the gathering together of its quantitative and qualitative aspects.

The following section then contains a discussion of the relationships between those two approaches to shade and similar phenomena, and current attitudes towards man and his environment.

Three tasks are undertaken in this section: [i] disputing the idea of linking man and his environment by simply establishing purely physical or behavioural relationships, [ii] replacing this idea by the notion of man's existence, that is, b e i n g - i n - a n - e n v i r o n m e n t, and [iii] showing the necessity of combining the scientific representation and the phenomenological understanding of shade with the aim of getting closer to <u>this</u> environment in which man is as a human being.

III.2 The Epistemological Question Concerning Shade

In dealing with the phenomenon of shade in the first two chapters we encountered two forms of knowledge: [i] the physical and geometrical nature of solar shading, which has the character of exactitude, and [ii] its phenomenal nature which is imprecise but comprehensive. The former is more "objective" than the latter since it relies on number and calculation; whereas the latter is relatively "subjective" since it depends on our immediate sensory experience and the meanings and values we attach to it.

The epistemological problem arises from the fact that the physical and geometrical nature of solar shading can only be grasped in terms of magnitude and distribution over space and time. But it is equally true that in man's everyday life shade is experienced as something more than a mere percentage of area unexposed to direct solar radiation for a given period of time. As we mentioned in Chapter II, shade is the fulfilment of socio-cultural demands essential to securing man's dwelling in his world.

The problem here is not one of objectivity versus subjectivity, nor is it one of choosing certainty in preference to uncertainty; it is rather a problem of different attitudes taken when we act or are acted upon.

It is the exactness of the knowledge of shade's physical and geometrical nature that makes us think of the knowledge needed for dealing with its wider human dimensions as being imprecise, and hence, in essence, inferior.

Heidegger [1977] does not regard the inexactitude of life as a deficiency, but rather as a realization of a demand fundamental to this type of research. He argues:

> Mathematical research into nature is not exact because it calculates with precision; rather it must calculate in this way because its adherence to its object-sphere has the character of exactitude. The humanistic sciences, in contrast, indeed all the sciences concerned with life, must necessarily be inexact just in order to remain rigorous.
>
> [Heidegger 1977, pp. 119-120]

Accordingly, the use of the words "exact" and "inexact" may not necessarily coincide with our customary way of regarding everything that is scientific as "objective" and the things that make up our everyday life as "subjective". In this context, man's life has never been exact and need not be so. Hence, there is no point in supposing that the exactness of shade's physical and geometrical nature is more objective than its phenomenal one. The important point here is the inevitable interplay between objectivity and subjectivity; it is this reciprocal conditioning of one by the other that makes the realization of man's subjective experience more objective.

In dealing with the prediction of shade patterns the designer requires exact knowledge of the sun's geometry and of built forms on which man's personal judgment has no bearing. However, before shade can be materialized in a real urban situation, according to the designer's wishes, there comes the need for its representation. Here, since predicted shade patterns, particularly in architectural and environmental design, are concerned with built forms and their arrangements in three-dimensional space, the representation of space and things in it will necessarily be an essential component in shaping the design. In this way the "abstract shade patterns" inside a computer or in the designer's mind have very different properties from the ones experienced in our everyday life.

Here, we find that the two aspects of shade (as a fact (physical and geometrical) and as a phenomenon (quality, meaning and value)) simultaneously establishing and differentiating themselves in their projection of a specific sphere of characteristics which can be brought into view by means of an appropriate representation which secures the necessary interplay between the two.

In this context, quantity and quality, meaning and value, reciprocally needing one another, constitute the very nature of shade; therefore the representation of it must count on fact and take account of value in order to be able to transform abstract shade patterns into living shaded places.

An understanding of shade in its entirety consists in an interweaving of knowledge, procedure and attitude with respect to the representation of it, through which shade can both be calculated and predicted in advance and be an object of reflection through its meaning and value.

The act of design (a process through which something concrete is brought into existence) offers the context in which quantity and quality, meaning and value may be linked in a significant way.[1]

---

[1] With a great deal of precision, a courtyard house can quantitatively be dealt with as a mere object, with a void within it, in a three-dimensional Euclidean

The process of bringing something into being, such as a shed, a house or a neighbourhood, depends mainly on two things: [i] the designer's attitudes towards finding the appropriate physical solution to the sum of the true needs of a particular set of socio-cultural and climatic circumstances, and [ii] the knowledge available to him.

The materialization of shade begins first with a representation that aims at bringing each particular aspect of it into the fore in such a way that the designer who calculates it and unfolds its meaning and value can be certain of his design [Figure III.1].

The function of the representation, as a way through which explanation takes place, lies in letting shade be what it is. Only in this way can the representation shape the design in a satisfactory manner with the minimum of distortion. Here, the

---

space with implications such as number of persons per unit floor area, area of the sheltered house space, and area of the open space of the courtyard. But with man's very nature in mind, the courtyard could also be conceived qualitatively as a living <u>thing</u> whose characteristic qualities go beyond distinguishing it from other forms to become a reflection or interpretation of the meaning and value of social and cultural environments in which man finds himself. The idea of a courtyard house seen qualitatively as a living <u>thing</u>, though it might perhaps be rejected by a positive realistic mind, is intended here to express the distinction more concretely. In this sense, Bachelard [1969] argues that 'the house itself, when it starts to live humanly, does not lose all its "objectivity"'.

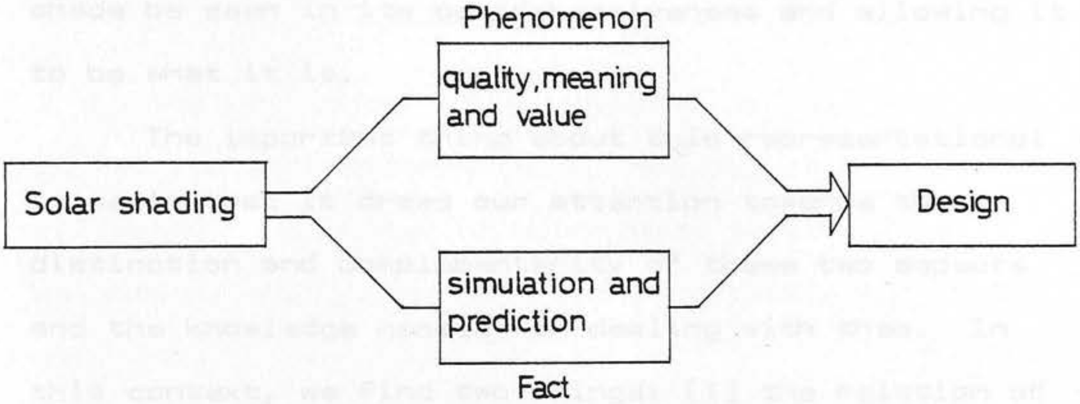

Phenomenon
quality, meaning and value
Solar shading
Design
simulation and prediction
Fact

Figure III·1

consideration of shade in its totality does not only mean a binding of its two aspects, but also signifies a manifestation of factual data and phenomenal experience. The binding problem then arises as to how these aspects, as something in the designer's mind, agree with the real.[1] Here, the authentic representation depends on how the designer succeeds in letting shade be seen in its comprehensiveness and allowing it to be what it is.

The important thing about this representational issue is that it draws our attention towards the distinction and complementarity of these two aspects and the knowledge needed for dealing with them. In this context, we find two things: [i] the relation of the two aspects in respect of reality; they are

---

[1] Heidegger [1977] argues that 'the word "factual" today connotes assurance, and means the same as "certain" and "sure". Instead of "it is certainly so", we say "it is in fact so" and "it is really so". Nevertheless, it is neither an accident nor a harmless caprice in the change in meaning of mere terms that, since the beginning of the modern period in the seventeenth century, the word "real" has meant the same thing as "certain". However, the "real", in the sense of what is factual, now constitutes the opposite of that which does not stand firm as guaranteed and which is represented as mere appearance or as something that is only believed to be so. He concludes that 'throughout these various changes in meaning the real still retains the more primordially fundamental characteristic, which comes less often and differently to the fore, of something that presences, which sets itself forth from out of itself' [1977, p.162].

unequally real, the one independent of man's subjective experience, and the other dependent on him, and [ii] their relative status: though they must be considered simultaneously in the design process, the qualitative aspect of shade lies, in fact, at a much higher level than that of its quantitative one [see Chapter V].

III.3 Man and Environment

The influences of objectivity and subjectivity, as two modes of understanding reality, have been reflected in a number of approaches to conceptualizing aspects of the environment and its relationships to man.

In some of these approaches the use of physics [for instance in Givoni's Man, Climate and Architecture, 1976 and Markus and Morris' Building, Climate and Energy, 1980], natural sciences [Olgyay's Design with Climate, 1963 and Knowles' Energy and Form, 1974], and geometry [March and Steadman's Geometry of Environment, 1971], are regarded as an objective means of describing and hence controlling the environment in which man is seen either as a biological entity, whose physiological and sensory responses to the changing conditions of his surroundings are both predictable and measurable, or is represented as a mere point moving isotropically in a two or three-dimensional Euclidean space.[1]

Other approaches concentrate on theories of human nature, personality and behavioural organization derived from psychology, anthropology and sociology (Hall's Hidden Dimension, 1966 and Rapoport's House Form and Culture, 1969 and Human Aspects of Urban Form, 1977), where the environment is envisaged as the consequence of a whole range of physical and socio-cultural forces in their broadest sense.

All of these approaches, though different in their treatment of various aspects of the environment, seem to have one thing in common, that is, their emphasis on establishing, either in physical or behavioural terms, some relationships between man and

---

1 Based largely upon an underlying assumption that a good thermal environment never needs to be "subjectively" experienced, and once an "objectively" thermal equilibrium between the human body and its environment has been provided and maintained all our requirements for health, well-being and comfort will have been met; a great deal of research has been carried out to control man's thermal environment, and to determine the "comfort zone" within which man is assumed to be able to function efficiently. In this context, there are two points that need to be made clear; the first is to do with indoor environments, such as houses, offices, factories etc., where thermal conditions are effectively prescribed by activity (in this particular area a 'factual' ergonomic approach to design related not only to prediction but also to regulation); the second is related to the outdoor environment, where activity (especially leisure activity) responds to the prevailing conditions (Figure II.2).

Figure III·2(a) Swimming in a clearing in the ice in frozen Finland
(from Nickels et al., 1973)

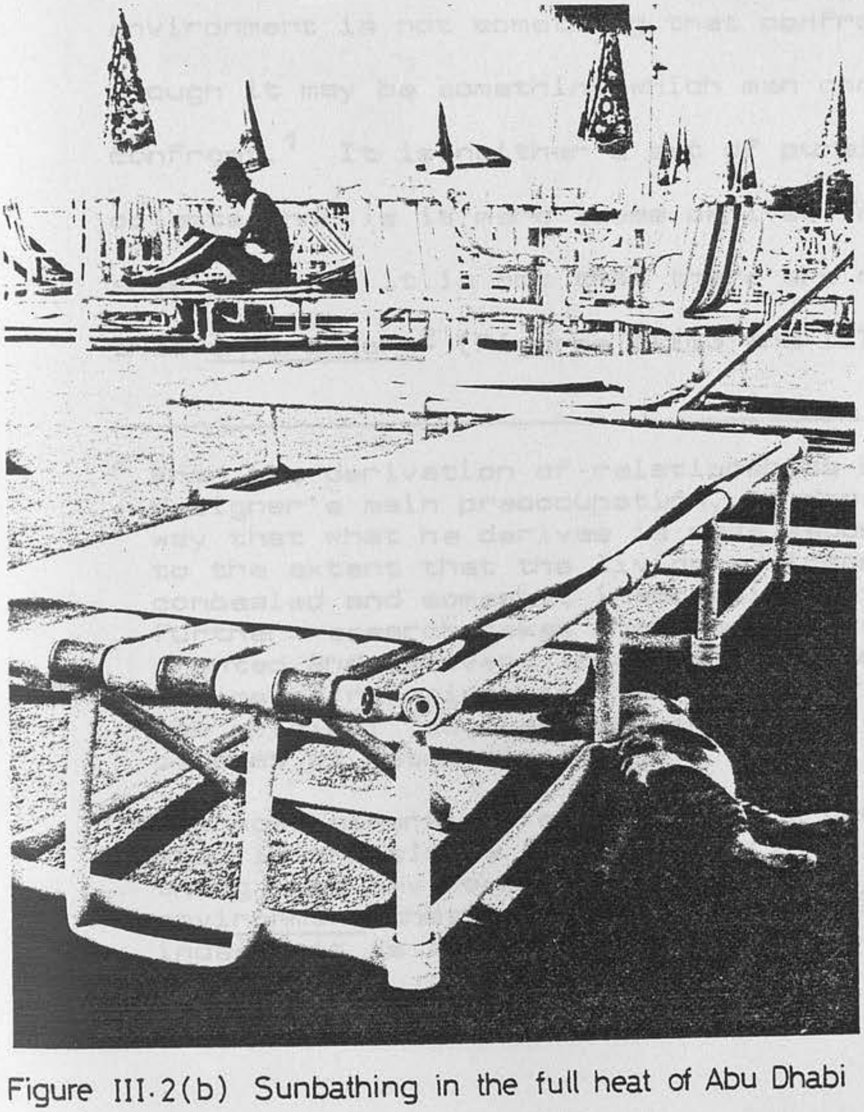


Figure III·2
Two extreme environments showing how people can relish the very coldness and hotness of these places

Figure III·2(b) Sunbathing in the full heat of Abu Dhabi his environment, seen from the beginning as two separate entities.

The habit of looking at the environment as something to which physical properties may be attached, and against which man finds himself placed, led to the generation of many of these ideas about the ways in which man is assumed to be able to respond and adapt to, or even to control and dominate his surroundings.

Whenever we speak of a relationship between man and his environment, it sounds as though man stood on one side, and the environment on the other. Yet the environment is not something that confronts man, even though it may be something which man chooses to confront.[1] It is neither a set of purely physical objects, nor is it mere ideas derived from our experience of them; it is not that there are men and "around" them environment[2] [Figures III.3 and III.4]. Rather,

---

[1] When the derivation of relationships becomes the designer's main preoccupation, it does so in such a way that what he derives is made secure and objective to the extent that the living environment becomes concealed and somewhat inaccessible. Consequently, further research takes what has been arrived at for granted and delivers it as self-evident; in this way layers of relationships tend to block our access to the original "source" from which the environment can be what it naturally is.

[2] The most general of concepts about our existence is seen in the simple fact that I find myself in something - an environment. It is this being-in-an environment that is prior to our experiences, and, indeed, it is that which makes them possible.

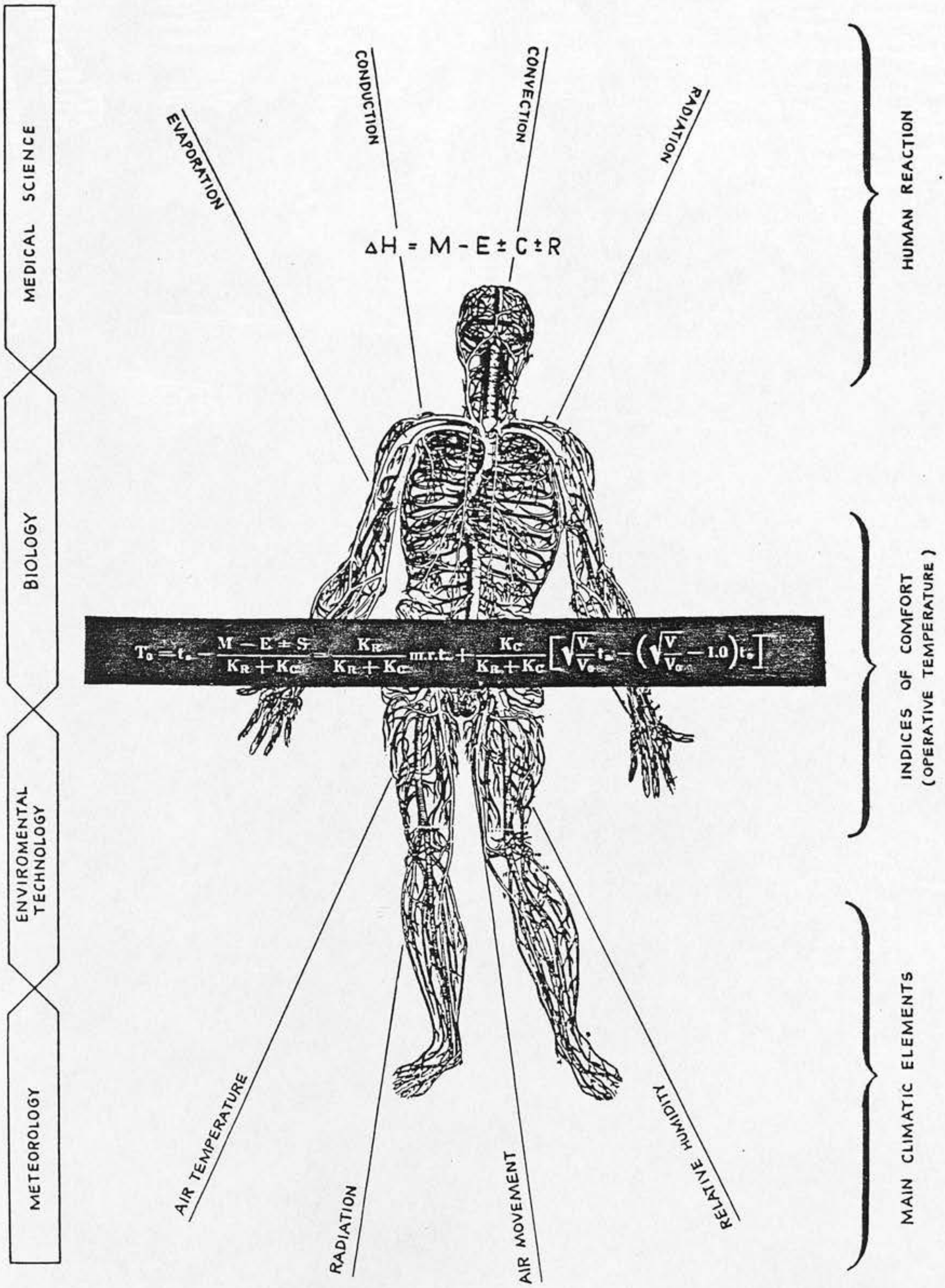


Figure III.3 Relation of human body to the environment

(from Olgyay, 1963)

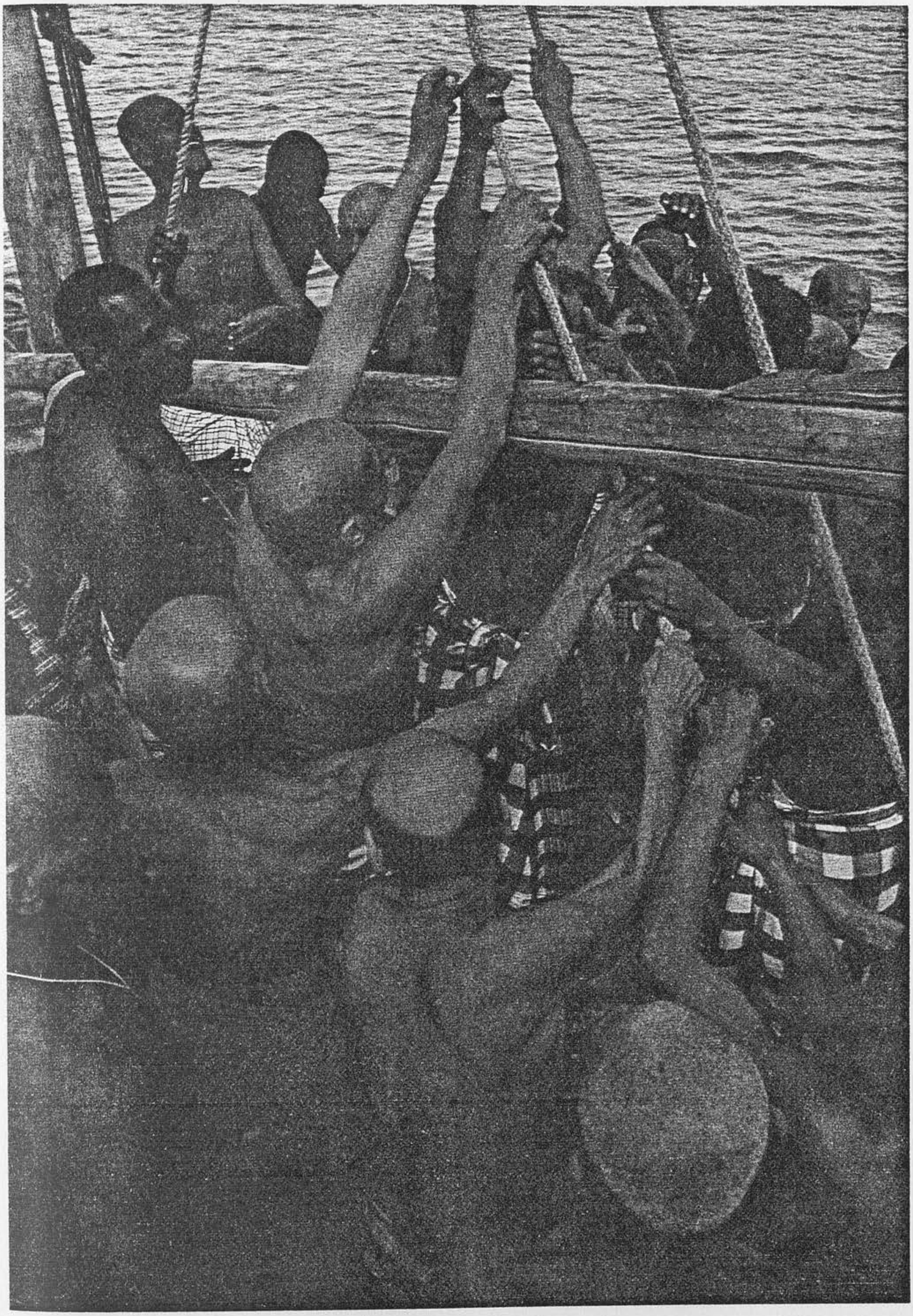


Figure III.4 'Being-in-the-environment'

the environment is the place in which man is. For when we utter the word "man" we simultaneously think of a human being whose dwelling is a resting-place that materializes his very existence [Figure III.5]. Whether in the sun or in shade, man's dwelling, which is rooted in his being, tells him how to live, act or behave without requiring a conscious choice. In the mosque we worship and in shade we relax [Figure III.6].

In discussing the relationship between man and his environment two points need to be made clear: [i] our argument does not imply that we should do away with all these relationships, and [ii] the argument is intended, rather, to help to "break the ice", so to speak, that research has frozen around the environment so that we might be better able to understand what the environment really is. In order to make clear what the word "environment" means we must free ourselves from this relational representation that still continues to dominate both architectural and environmental research. The designer needs to realize that such relational representation can only grasp the environment as an object wherein happenings and occurrence can be predicted or controlled.

A phenomenological interpretation of man's everyday environment shows how deeply it penetrates all the organizational forms of our everyday life: in a

Figure III.5 A mudbrick post which once marked a courtyard's gate and is now man's resting-place

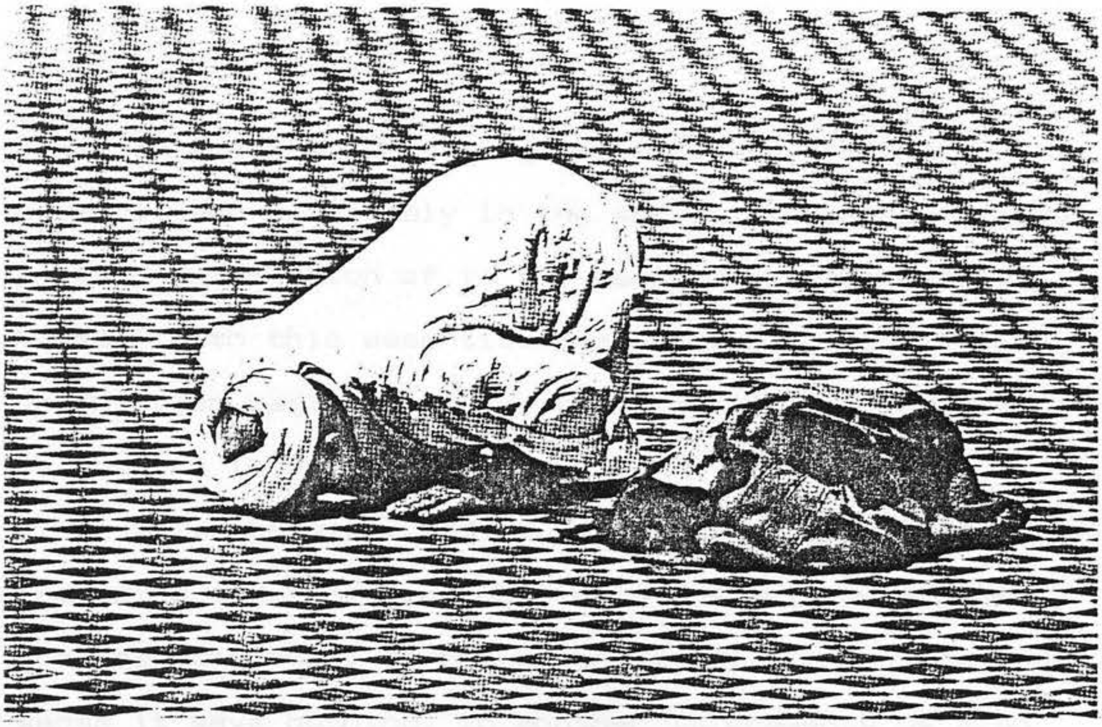


Figure III·6(a) Worshipping in the sun
(from Burckhardt, 1976)

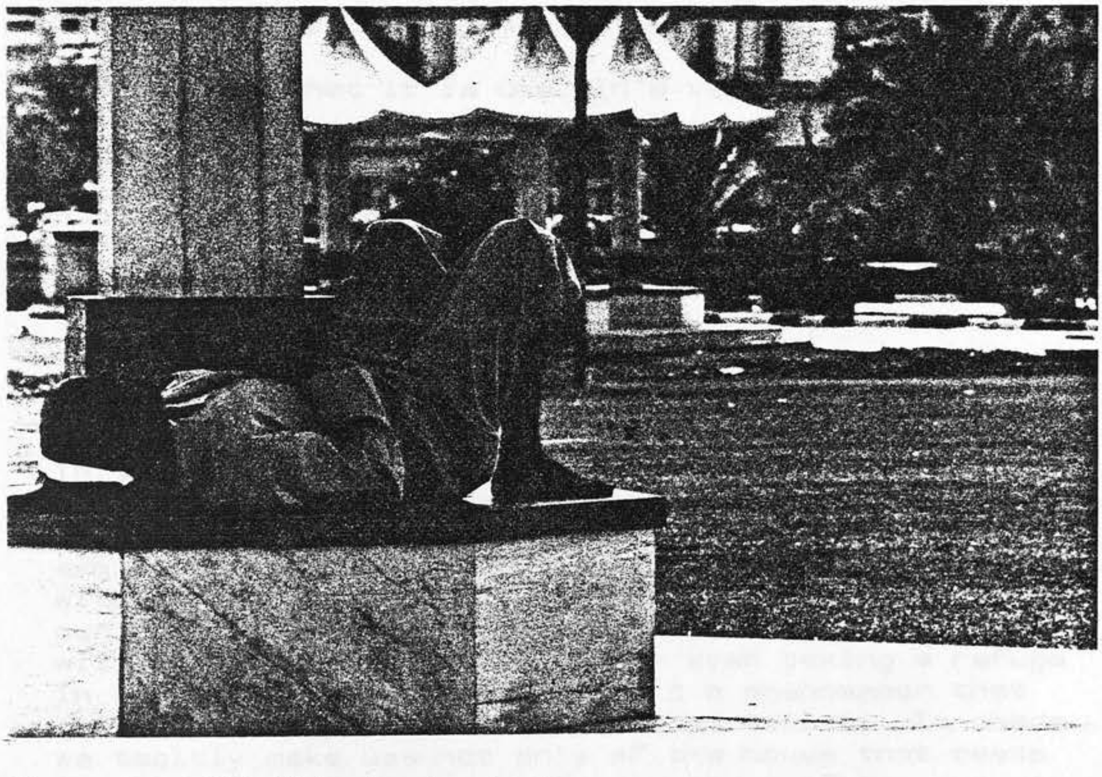


Figure III·6(b) Relaxing in shade

Figure III·6 Two behavioural patterns of dwelling in the sun and shade room, in a house, in a neighbourhood, in a city, in a country, and ultimately in the world. In order to give a vivid description of it the designer must acquaint himself with this essential penetration. This description begins with the statement "the environment is what it is".

This statement, of course, goes nowhere to providing a definition, nor is it a simple substitute for the complexity of the environment. In an immediate sense it says nothing, in another it presents us with nothing but questions. These questions emerge only when the environment is phenomenologically clarified.

The discussion of the word "environment", and the frequent and indiscriminate use of it, have made it so general that it is used in a very wide variety of ways. The question of the meaning of the environment can be worked out concretely by indicating the different kinds of phenomena that make up the environment, and the way in which they are interconnected.[1]

---

[1] This point can be made clearer by the following example: shade which we encounter as the closest thing to us in the tropical environment can be exhibited phenomenologically, in its interpenetration with other phenomena, if we take <u>being-in-shade</u> as our point of departure. The nature of our dealings with shade [working, relaxing or even taking a refuge in it] is the thing that makes it a phenomenon that differentiates places and puts them to use. In shade we tacitly make use not only of the house that casts it, but also of the sun. Only because of the sun can

It is true that the environment is, in its prime reality, visible, tangible and made up of physical objects, which we may be tempted to describe and analyze objectively, so that they are amenable to mathematical and geometrical treatment. In this way, the objectification of the environment is then accomplished in a simplified representation aiming at bringing each particular phenomenon before the designer in such a scientific manner so that he [who gives the measure and draws the guidelines for everything that is] can make secure his representation of it as something in space and time that is calculable and predictable in some way or other in advance.

When phenomena are transformed into the certainty of scientific representation we fall into the trap of acting as though the environment were in reality this simplified representation of them.[1] Hence, we impose a model for some reason or other and act as though the model were the reality. In consequence, the environment as what it is, in its

---

the house have its shady and sunny sides. Allowing the sun in or screening it out is thus found in the arrangement of the rooms and in the form and orientation of the house.

[1] In this context, Heidegger [1977] argues that 'scientific representation is never able to encompass the coming to presence of nature. Nature remains for the science of physics that which cannot be gotten around'.

entirety and reality, gets passed over.

Just as the scientific representation of the environment misleads us into the conviction that what we generate as a physico-mathematical construct is a true representation of it, and also makes us overlook it as a field of meanings and values, so the environment, seen only as a phenomenon, hides the fact that it is its physical reality that makes the meanings and values we attach to it possible.

In this context, two points need to be made clear: [i] scientific representations are useful and secure even though they deny shade its reality as a human experience, and [ii] phenomenology holds the comprehensiveness [and in Heidegger's sense the exactness] of reality but is vague and somewhat imprecise for certain kinds of action or decision. This leads us towards the argument that phenomena determine qualitative design decisions while computational tasks should be confined to testing and tuning them.

Thus what the phenomenological approach does is not to hide the physical reality of shade but rather to obscure its scientific description and hence its secure predictability. The two approaches are not in opposition or contradictory; it is just that their internal values and emphases are so different as to suggest, sometimes, that they have no point of contact, but of course the point of contact exists, and that is shade as it is.

This suggests that by combining the two together we might perhaps get closer to acting as though the environment were what it really is. However, this combining must not be taken as a mere adding together of one particular kind of investigation to the other; rather it should be understood in terms of allowing them both to speak in the design process.

III.4 Concluding Remarks

This chapter began with the epistemological question concerning the phenomenon of shade, where we encountered the two different forms of knowledge needed for dealing with it, and went on to argue that the necessity of considering them both stems from the very nature of shade.

In bringing the two together we referred to the act of design by which the designer is able to materialize his own attitudes towards man and the environment.

In dealing with the environment as what it is, we disputed [without totally rejecting] the common way of establishing relationships between man and his environment. Instead, we began with one of the broadest notions of man's very existence, i.e., being-in-an-environment. This was brought forward by emphasizing the fact that neither scientific representation nor phenomenological description is ever capable, by itself, of encompassing the environment in its entirety. Therefore, it was argued that by combining these two we might get nearer to dealing with those things that make the environment what it is.

We shall next question the environment as to what it is by working through a phenomenological interpretation of those things within it which we encounter as closest to us, with emphasis on shade and with the aim of placing quality and quantity properly in the design process.

CHAPTER IV

QUALITY AND QUANTITY IN THE DESIGN PROCESS

CHAPTER IV

QUALITY AND QUANTITY IN THE DESIGN PROCESS

IV.1 Introduction

It has been shown that there are two levels at which shade must be dealt with. At one level there is its mathematical and physical representation; at a higher level we find living shade with its meanings and values.

Since the consideration of both aspects is necessary in arriving at an adequate operational understanding of this phenomenon an attempt was made in Chapter III to show how they can be combined through the design process.

The present chapter moves towards achieving two things: [i] overturning the conventional order in which designers usually think about shade by arguing that the design process should be initiated with the meanings and values of shade left intact whilst leaving room for its subsequent factual prescription, and [ii] developing certain characteristics of the spatial and temporal qualities of man and his environment, with the aim of bringing out a better understanding of a set of dimensions [space, time, shade and activity] regarded as significant in designing for the tropics.

There are two reasons for choosing this limited set of dimensions: [i] it avoids the formidable task of taking the total environment into account, and [ii] together they deepen the designer's awareness of the environment as a place [not as space] and form the basis for the inevitable abstraction needed by the designer so as to quantify his proposals on the drawing board.

It is of great importance to emphasize that none of these dimensions can be seen in isolation, since in the living reality they are all interconnected and, along with other things, they make the total situation.

Our phenomenological analysis can be carried out most effectively by beginning with real situations found in the tropical environment in which shade is taken as a primary theme against which the other dimensions can exhibit their characteristics.

IV.2 The Settings of Shade

The settings in which shade occurs in the tropics and manifests its meanings may range from a settlement situated in a desert to a tree planted in a courtyard house. Among these we find, as an example, the marketplace, souk, generating one of those places peculiar to the tropics in which various patterns of living are interwoven spatially and temporally with the phenomenon of shade [Figure IV.1].

Trees, narrow alleys and courtyard houses are also familiar settings which people use in their every-day lives and which gain meaning and value from the shade they provide [Figures IV.2, IV.3 and IV.4].

Within these settings there are many places that might be differentiated as sunny or shady. Here, the spatial interpretations of things found in the tropical environment are prompted by the dialectics of 'inside' and 'outside' through which the traditional settlement and the courtyard house emerge as two dominant physical expressions.

From the study of these phenomenal situations and according to our earlier discussion [see sec. 2, Chapter II] shade can be experienced and spatially be dealt with only when it is tied with things by which and with which man experiences any given situation as a qualitative and comprehensive phenomenon.

As we pointed out earlier [sec. 3, Chapter II] the meanings and values of shade in a tropical urban environment are not mere abstract notions that can arbitrarily be added to the physical existence of shade but rather something inherent in daily life and embedded in man's <u>being-in-the-environment</u>.

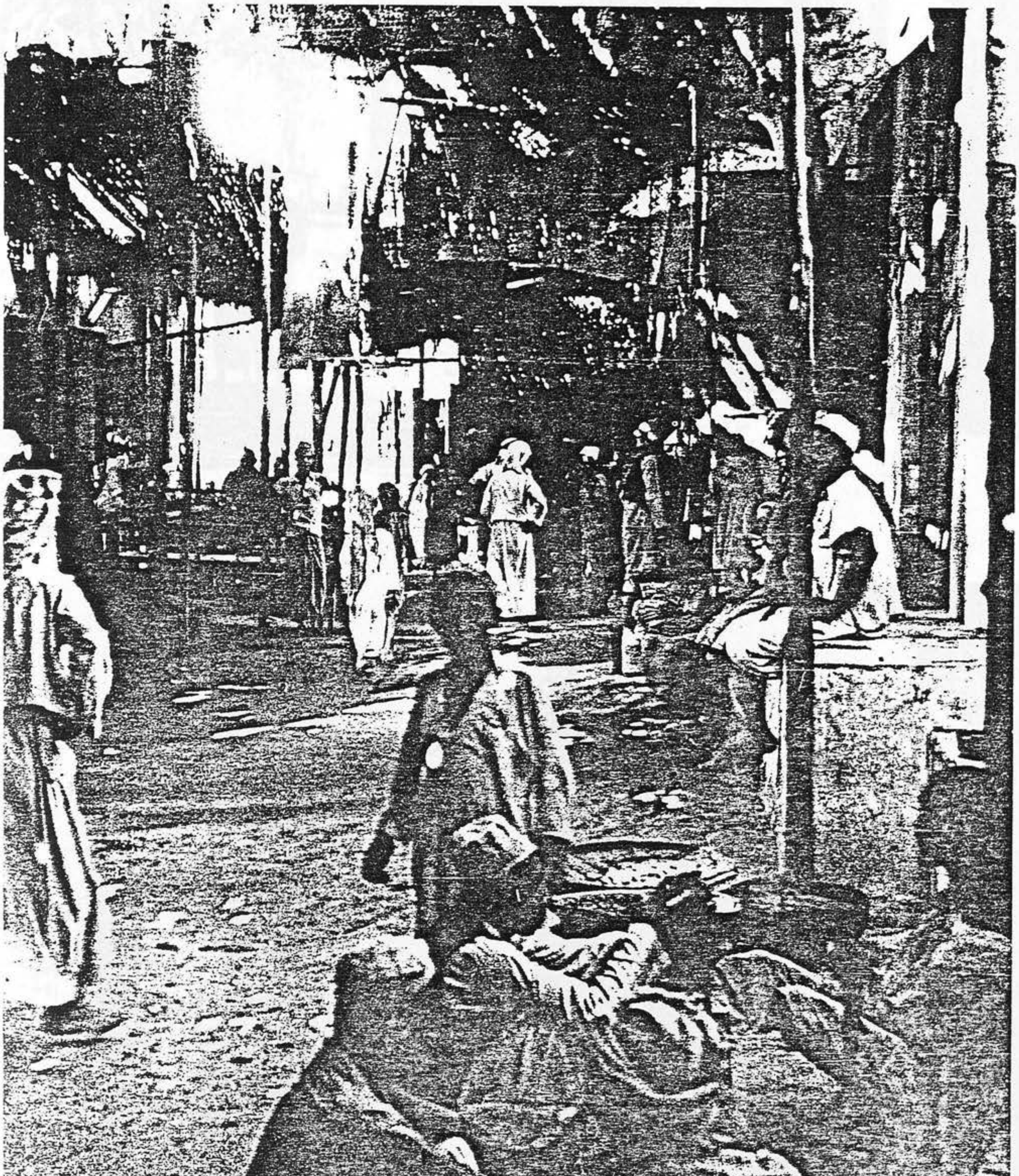


Figure IV.1 The traditional marketplace of Dubai generating a setting for people's urban activities and shade

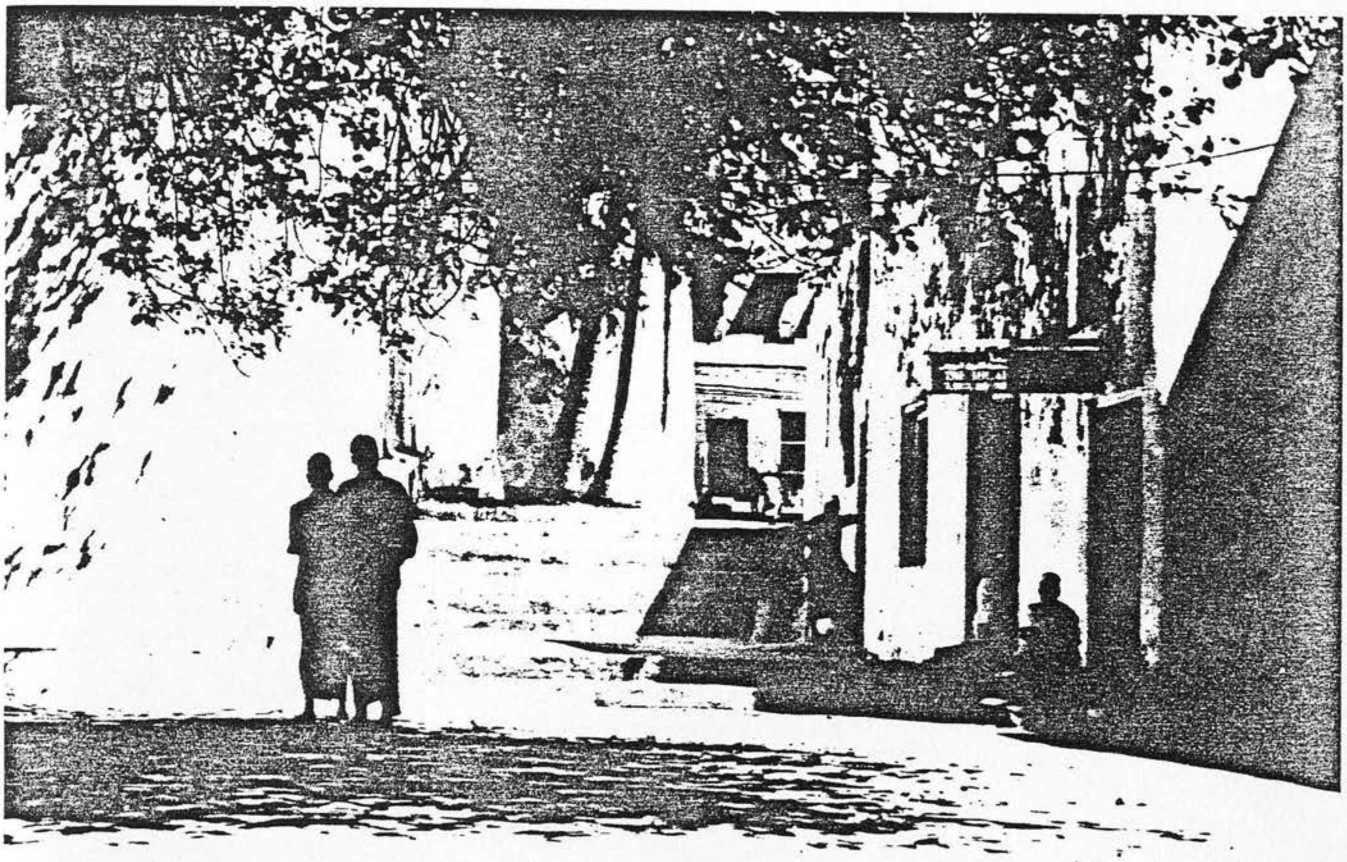


Figure IV.2 A tree

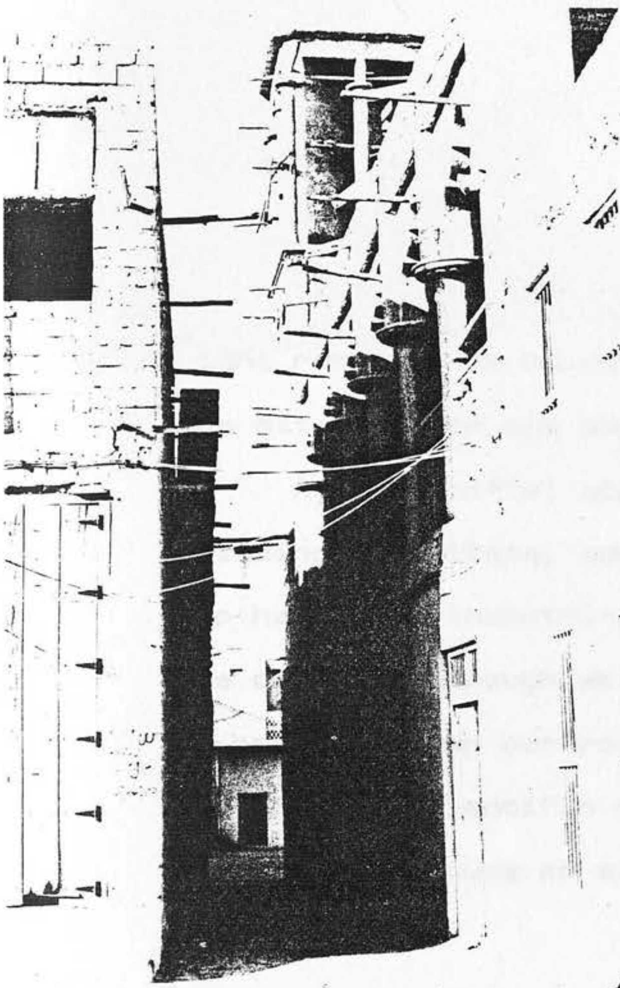


Figure IV.3 A narrow alley

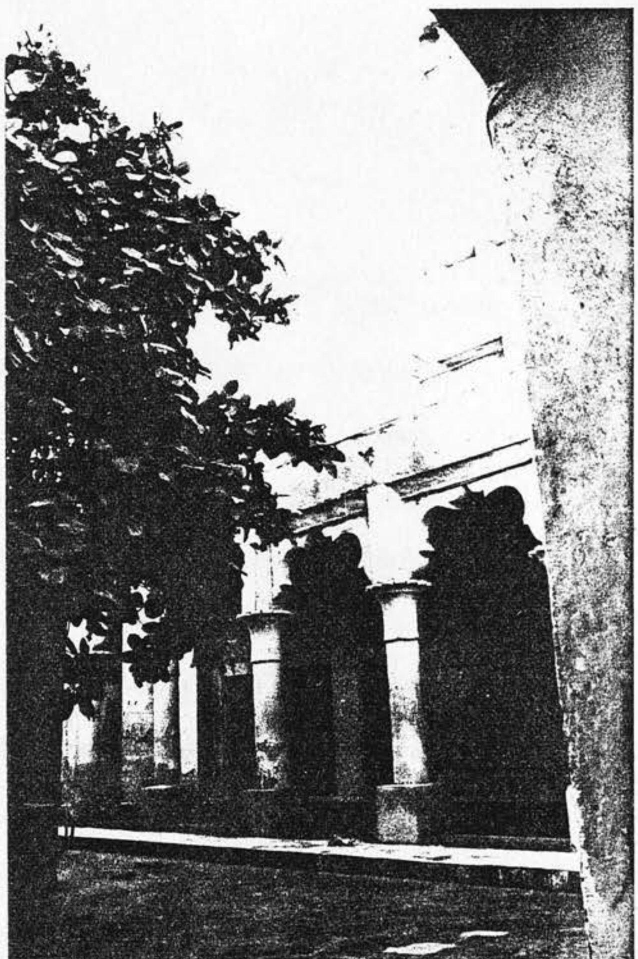


Figure IV.4 A courtyard

Having glimpsed how shade manifests itself in real urban settings, one could hardly think that the mere simulation and prediction of its physical properties could possibly substitute for the diversity with which shade gets used or the subtlety with which it evokes meanings. Unless the designer has a thorough understanding of what this living shade really is, it would be difficult to expect the scientific handling of it to go anywhere. This, of course, must not lead to the conclusion that a consideration of the meaning and value of shade should lead to the abandonment of its mathematical and physical nature. On the contrary, a better understanding can be arrived at only when the designer realizes that the two levels at which shade manifests itself though different in character, are in fact complementary [see Chapter III].

The problem then becomes one of establishing the right ranking and balance rather than concentrating the attention on one aspect and ignoring the other.

A 'scientific' approach to design, argued for by building scientists, has been adopted by many designers who have been indoctrinated to believe that science is the only way through which man and his environment can be brought under control. The result of this may be seen in the scientific handling of solar shading where various techniques of simulating and prdicting shade patterns are now being used as a means of providing people with 'good' micro-climatic conditions.

Although it is legitimate, and indeed necessary, to think of solar shading in this scientific way, this does not answer many questions about the way in which the abstract shading patterns simulated and predicted might correspond to the living ones found in real urban settings.

Such correspondance can only be partial since the abstraction of shade is nothing more than a simplification of the complexity with which the actual phenomenon exists in reality. To represent reality by what has been abstracted from it simply leads to the generation of arrangements of buildings with shading patterns far removed from the living reality. Of course, these patterns can represent a part of reality.

The main objective, therefore, in the present chapter is to show that while science has a necessary place in design, it should not be the dominant one. This means that the phenomenon of shade as a field of meanings and values must be given precedence over its mathematical and physical nature, and in the next section our phenomenological analysis shows that the spatial expressions that man encounters and generates receive their real existence from those hidden meanings which make the tropical environment what it is.

The discussion in section IV.4 is an attempt to arrive at a better understanding of that essential dimension in our existence, space, by considering the spatiality of man and his environment in terms of three components: [i] the spatiality of shade within the environment, [ii] the spatiality of being-in-shade, and [iii] the spatiality of man.

In section IV.5 an account of time is given briefly in terms of man's temporality as it is rooted in his everyday concerns.

IV.3 Meaning and Spatial Expressions

The argument for the 'crispness' of the tropical environment [Chapter II], in which 'to be in shade' or 'not to be' form a dialectic of exclusiveness, can be paralleled by another argument based on the dialectic of 'inside' and 'outside' prompted by the contrast between the vastness of the desert landscape and the compactness of the traditional settlement[1] [Figures IV.5[a] and IV.5[b]].

---

[1] Only by virtue of the settlement can the dialectic of inside and outside be made possible. The sharpness of this dialectic begins to fade as man leaves his settlement behind and gets absorbed by the infinite expanse of the desert and the all-embracing sky vault where his 'being-in' approaches its cosmic domain [Figure IV.6].

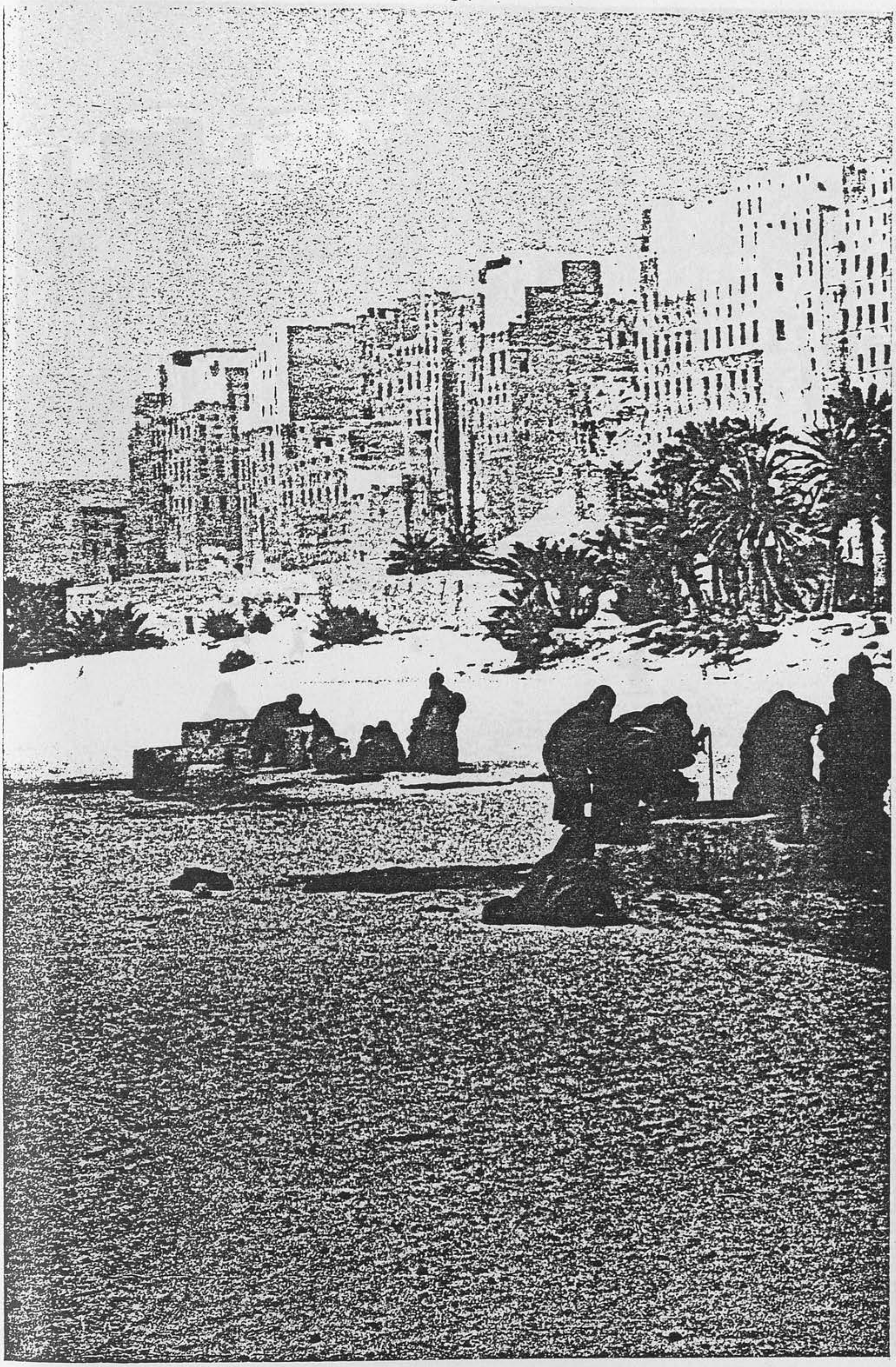


Figure IV.5(a)

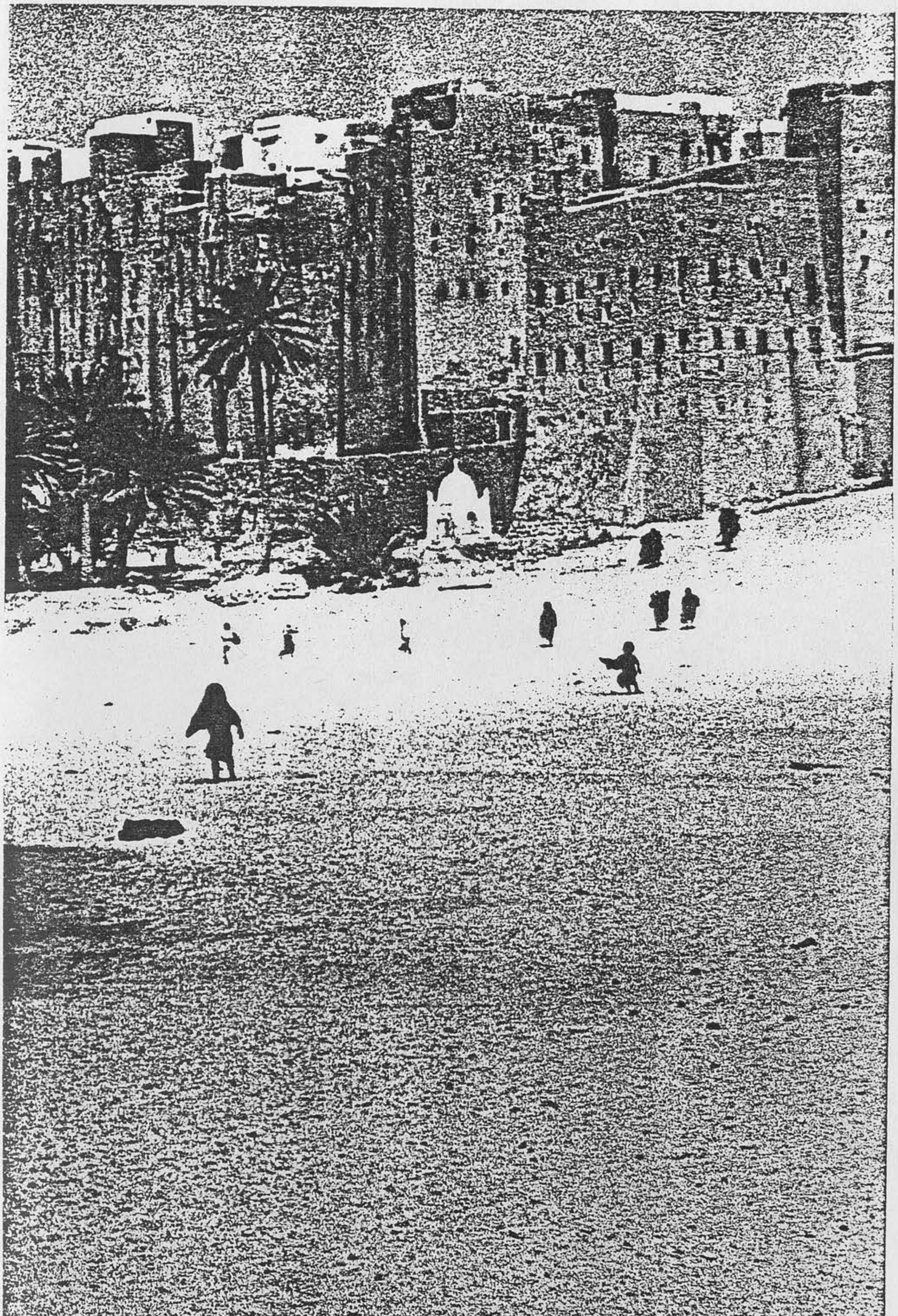


Figure IV-5 (b)

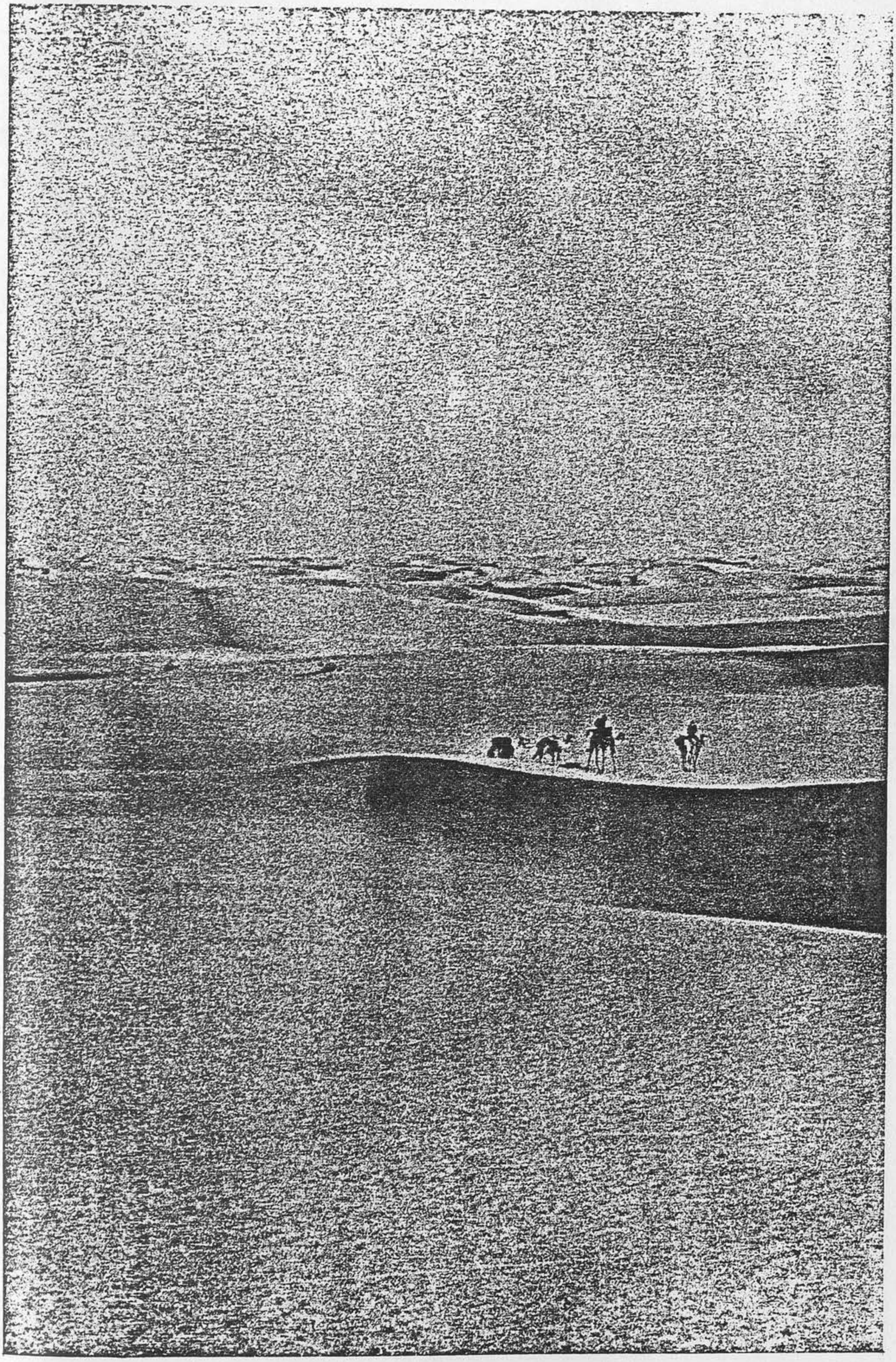


Figure IV-6

Inside the settlement a sense of security is accentuated by the shaded narrow alleys linking, or separating, the settlement's dwelling units. On the other hand, outside entails exposure to the threatening, burning sun, and hence creates a sense of insecurity.

We should not be misled by the simplicity with which inside and outside exclude each other, since in the living reality 'inside' may well be 'outside' when viewed from a different standpoint: the shaded narrow alleys are inside the settlements but outside the courtyards [Figure IV.7]. However, the dialectic of inside and outside is deeply rooted in the courtyard's geometry which confers spatiality upon meanings and values. In this context, and from the point of view of geometrical expression, the courtyard with its four sides brings out clearly a dialectic of division, in which the intimacy and privacy of inside is secluded from the communal life outside [Figure IV.8].

When the dialectics of inside and outside are understood in terms of places we find that phenomena vary in their capacity for differentiation; for instance, with the phenomenon of shade, places come into being in their simple identification as sunny or shady, whereas they might multiply, exchange or even blend with one another when taken in the domain of solar radiation.

Figure IV-7

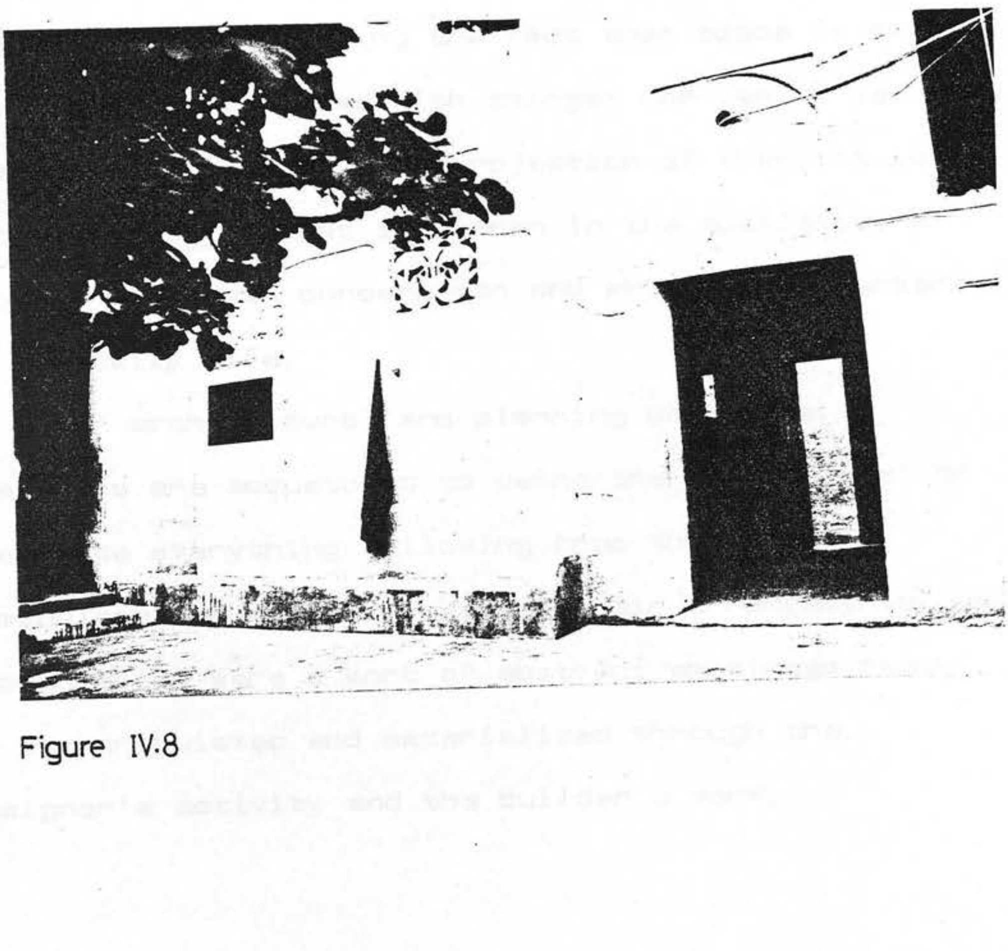


Figure IV.8

IV.4 The Spatiality of Man and his Environment

The discussion here is not intended to review the whole literature on concepts of space, nor is it aimed at analyzing their wider implications in architectural and environmental design;[1] the emphasis is rather placed upon bringing a better understanding of this dimension by emphasizing the fact that space is not that which gets filled with things; nor can it be created or formed by mere projection of them; it is rather something that is hidden in the spatiality of those things that concern man and which he encounters in his daily life.

In architectural and planning processes designers are accustomed to using the word 'space' to designate everything following from the three-dimensionality of buildings and their arrangements, as though space were a sort of abstract emptiness ready to be manipulated and materialized through the designer's activity and the builder's work.

---

[1] For detailed analysis of various concepts of space the reader is referred to Norberg-Schulz's Existence, Space and Architecture [1971] and Giedion's Space, Time and Architecture [1941].

IV.4.1 The spatiality of shade within the environment

In Chapter II we pointed out that shade is a thing that 'gathers'. This means that in shade we not only encounter things that concern us, but also 'this place' which is 'close by'. It follows that what is 'used' in our everyday concern with the environment has the character of 'closeness' or 'nearness'.

This 'closeness' is not to be determined by a mere average distribution of shade over space and time, but rather is accentuated through the way in which it is bound up with things encountered and used within the whole environment.

This process of 'binding up' begins with the 'placeness' of shade [Chapter II]. In this respect, what is close to us in this way is initiated by our concern to find places in which shade is usable. When the closeness of shade has been given a place, this signifies not only that shade has its position in space as a phenomenon occurring somewhere, but also that as shade, it has been concretely set up and put to work.

The mere presence of shade as something 'lying around' has nothing to do with our everyday concern with the environment. Here, living concrete shade embodies that kind of 'concern' which manipulates places and puts them to use [Figure IV.9].

We should not, however, take for granted that

Figure IV.9(a) The presence of unused shade seen as something 'lying around'

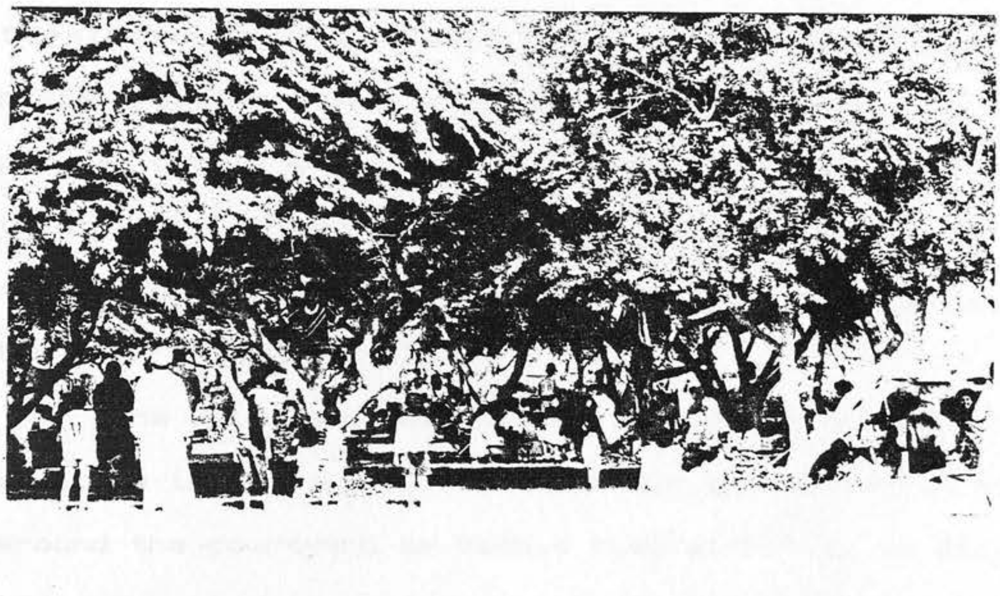


Figure IV.9(b) Usable shade embodying a kind of 'concern' which puts place to work every presence of shade is an initiator of 'this place' which concerns us: for instance, shade cast by an acacia arabica growing naturally in the desert would surely have different implications from that of trees consciously planted in a parking area [Figures IV.10 and IV.11].

This indicates that along with shade the place also needs other things, in particular activities, to be materialized. In the tropics the conscious act of building, as one of these activities, shows how shade is bound up with walls and buildings, through which places are brought into existence [Figure IV.12].

In the Gulf region the courtyard embodies a gathering of places, each of which defines itself by the kind of activity taking place in it - gathering place, resting place, cooking place and so on. As we pointed out in Chapter II, it gathers together the things that concern us and the meaning and value we assign to them in 'such' a way that it allows 'places' for them [Figure IV.13].

The daily and seasonal variations in the sun's position in the sky vault have their own places in and around the courtyard as people move within it in daily and seasonal patterns of living to take advantage of the alternating sunny and shady places. In the Gulf region, for example, the traditional house encloses a

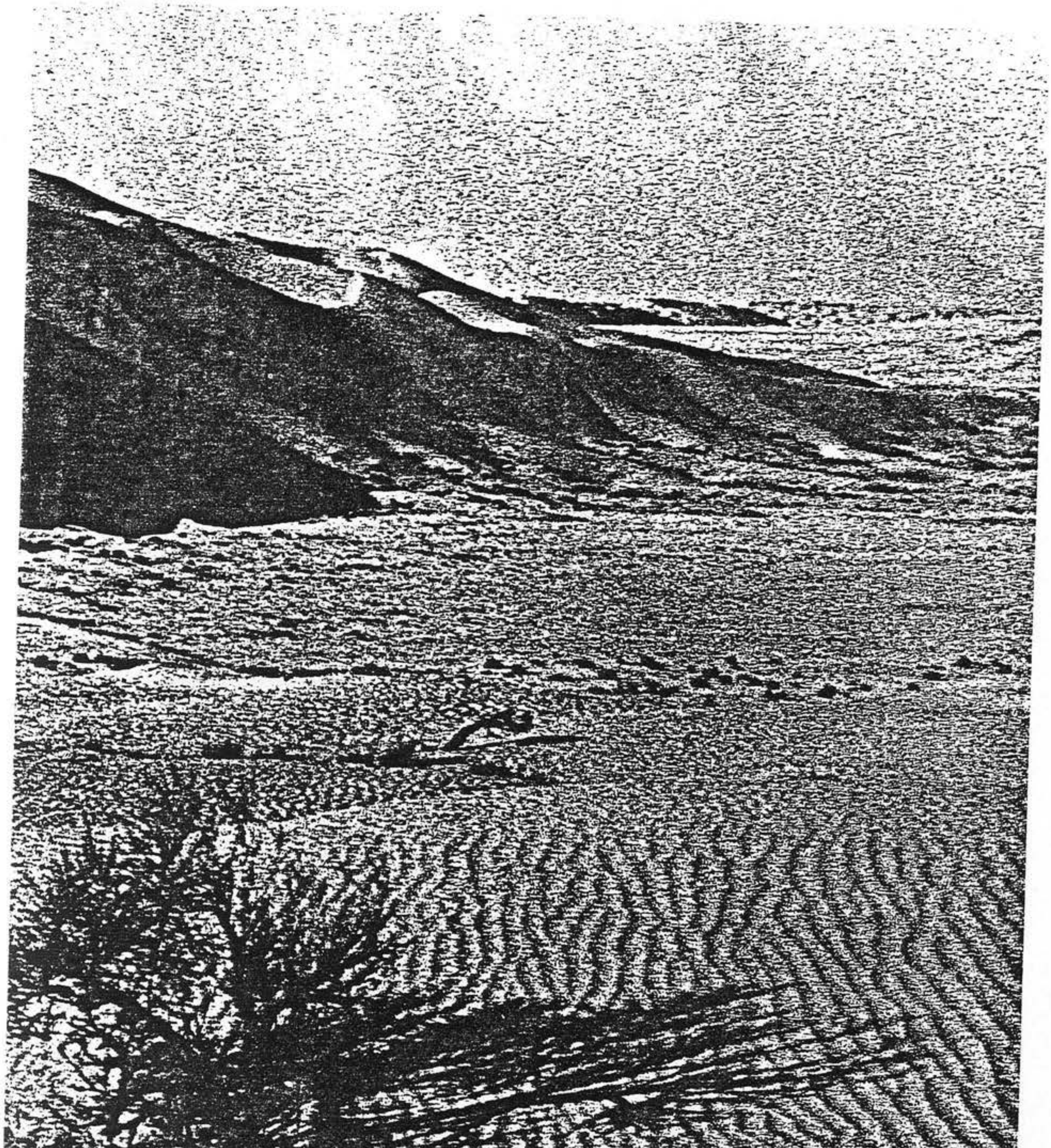


Figure IV.10

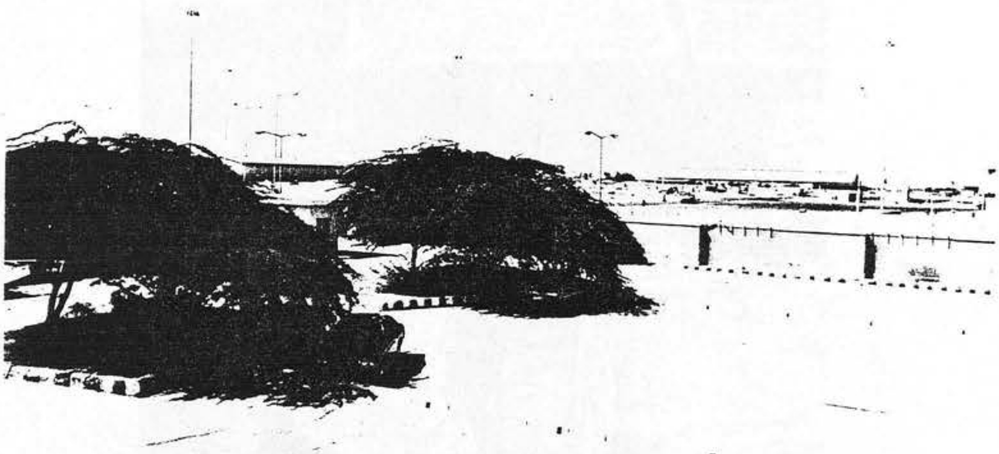


Figure IV.11

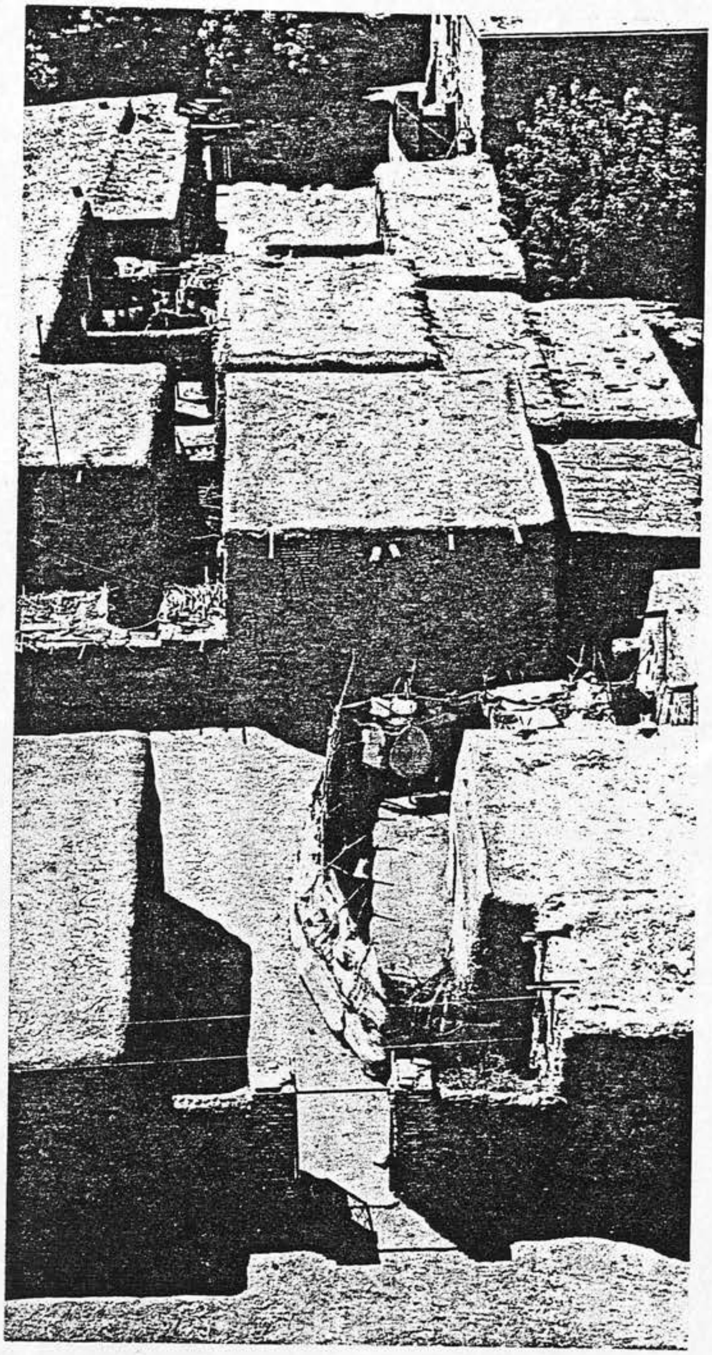


Figure IV·12

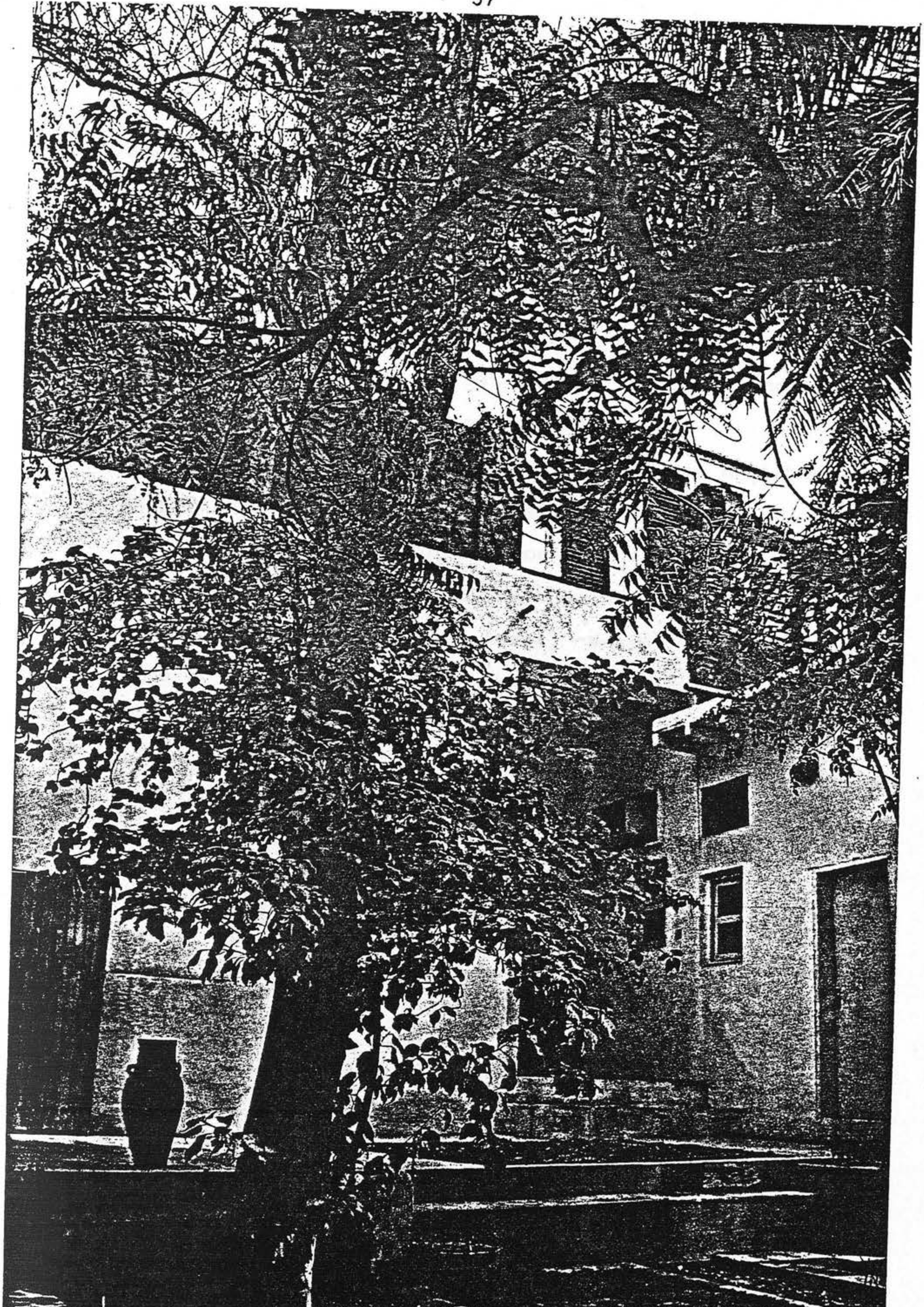


Figure IV.13

central courtyard with colonades [see Figure IV.14]. During summer when the sun is high, the colonades provide a deep shade. The family avoids the sun's heat by spending the day in the courtyard and interior rooms of the ground floor. In winter the pattern is reversed and the family spends a great deal of their time on the roof where the winter sun can reach them.

As soon as the courtyard with its sunny and shady places is put to work through daily activities, it reveals the spatiality of the space which belongs to it; however, the bare space, as the designer might think of it in the abstract sense, remains hidden. [And so of course, do the naked geometrical patterns of sun and shade].

IV.4.2 The spatiality of being-in-shade

Due to the 'crisp' differentiation of sunny and shady places in the tropical environment [see sec. 2, Chapter II], the expression being-in-shade indicates just one of the diversified modes in which man is 'in' his environment.

A brief mention of 'being-in' was made in Chapter III, but now we have come to the point where there is a need to grasp more explicitly this general notion of man's existence in order to arrive at a better understanding of 'being-in-shade' through meanings and

Figure IV-14

spatial expressions found in the tropical environment.

A preliminary comprehension of this being-in can be obtained by distinguishing and contrasting its two different modes.

On the one hand there is the being-in of things encountered in the environment, such as, "a tree is 'in' the courtyard". By this 'in' we mean the manner in which these two things are placed 'in' space with regard to their location 'in' it. This particular mode of 'being-in' can also be expanded to encompass the totality of the environment. This is of course a purely spatial or geometric meaning of 'in' which is concerned with enclosure within which all things occurring in the environment may be described in terms of a definite relationship of locations.

But the expression 'being-in' may, on the other hand, be used to designate the mode of existence in which man concerns himself with activities. In this context, the expression means much more than just being physically located in space and time; that is to say, being-in is not to be interpreted only as the "wheres" of something occurring in a spatial relation to something else, but also as the concrete "there" where man's concern belongs.

Etymologically, the Arabic word for 'in', <u>fī</u>, means to be in the company of something in the sense of being concerned with it. Thus the word has an implicit meaning of involvement which, for instance, characterizes the familiarity with which man carries out his daily urban activities. Here, the very meaning of 'in' is not very different from 'dwelling' [see Chapter II]; to say that man is [being] in shade would then signify a kind of dwelling in which his 'concern' is embedded.

The word 'concern' is thus used here to refer to the complexity and diversity designated by this 'in' of being-in-shade. 'Concern' in Arabic is ināya which has the meaning of care, solicitude and providence; for example, ināya tibbiya [medical care] and ināya ilāhiya [divine providence]. In this context, planting a palm tree in the courtyard or even setting up carpets in the marketplace are in fact spatial manifestations of 'care', ināya, which bring to the fore man's being-in [Figures IV.15 and IV.16].

Although the tree has a definite place in the courtyard by way of planting, it receives its true 'being-in' from growing [shade too grows with the tree!]; also the courtyard gets built in the settlement, but it earns its real 'being-in' from screening; and the settlement densifies itself in the desert, but its authentic 'being-in' is rooted in sheltering.

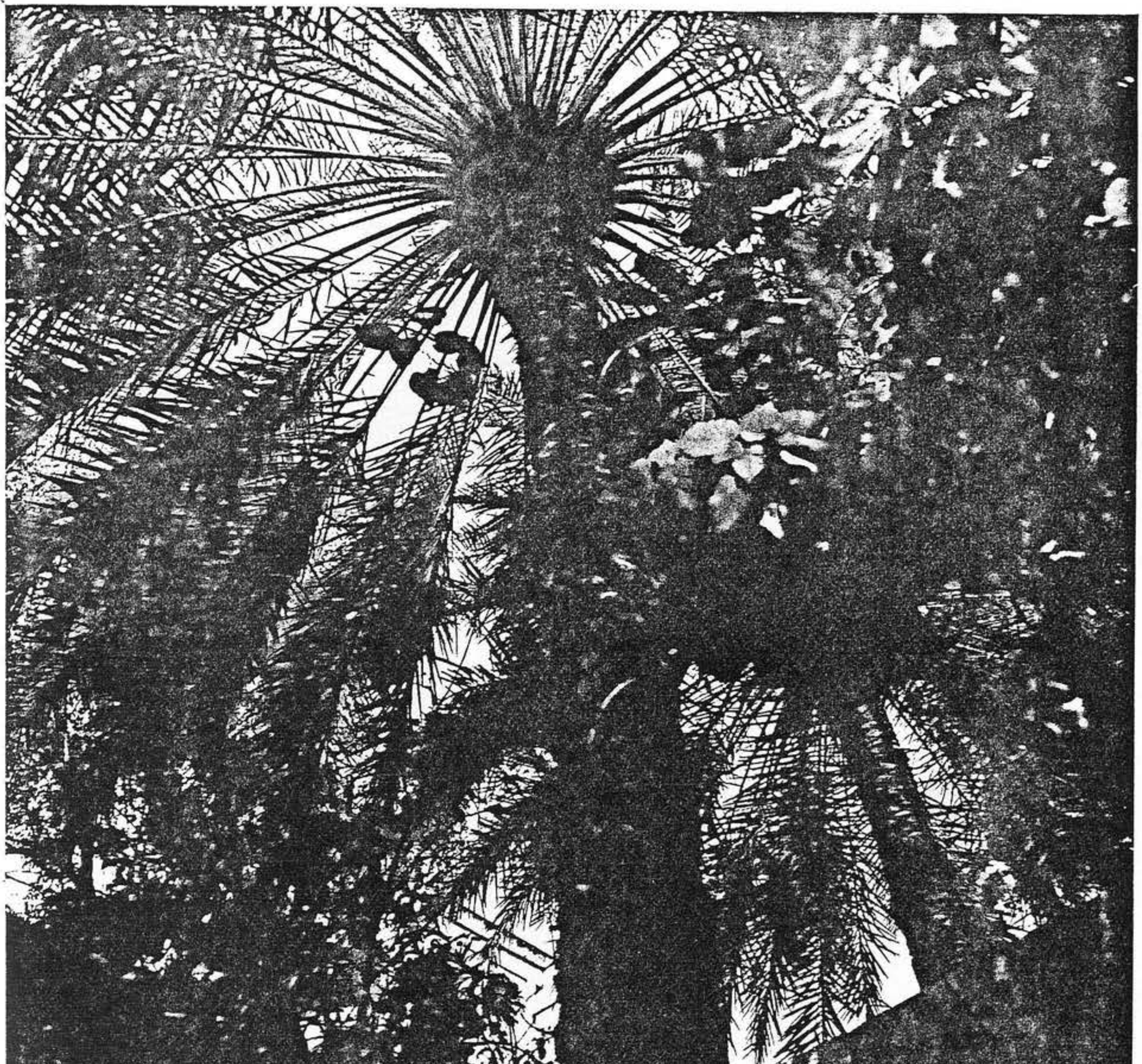


Figure IV.15

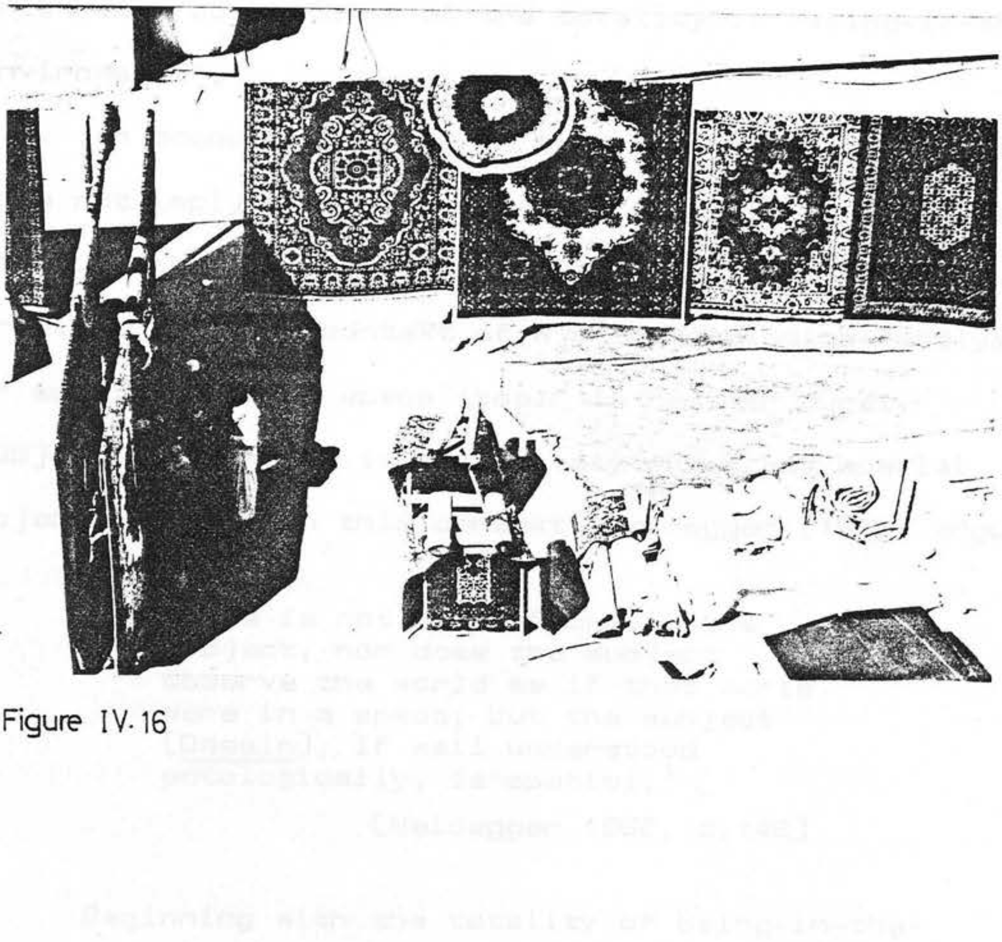


Figure IV.16

IV.4.3 The spatiality of man

Although we have made a preliminary distinction between two modes of 'being-in', we need to discuss more closely the spatiality of man for two reasons: [i] because his 'being-in' arises from his spatiality, and [ii] to round out this expression to 'being-in-shade', which is a constituent of the totality of 'being-in-the environment'.

An account of space in terms of man's "spatiality" does not imply a subjectivizing of space. The notions of 'subjectivity' and 'objectivity' of space are irrelevant in the context of a phenomenological analysis of spatiality; for space itself is neither purely subjective nor does it objectively exist, as spatial objects exist. In this context, Heidegger [1962] argues:

> Space is not to be found in the subject, nor does the subject observe the world as if that world were in a space; but the subject [Dasein], if well understood ontologically, is spatial.[1]
>
> [Heidegger 1962, p.146]

Beginning with the totality of being-in-the-environment, of which being-in-shade is a significant mode, we find man dealing with and encountering things which

---

[1] We may note that Heidegger prefers to say that space is in the world, rather than the world is in space.

accentuate his spatiality, and in which his understanding of space arises from the way in which he sees things as "close by" and "far away". In this way man's spatiality shows two things.

First the character of closeness. Things can be brought close by through man's concern which is founded upon his unique way of being-in. But bringing something close by, or else being close to it, in the sense of putting it into use, is not to be seen in terms of a measurable spatial distance between man and the thing that concerns him. As a significant phenomenon in the tropical environment, man's familiar dwelling in shade remains unnoticed for most of the time. Perhaps he becomes aware of it when it is lacking: shade, which people have always taken for granted in the traditional settlement, has suddenly come to the fore because it ceases to be available in modern towns [Figure IV.17].

'Closeness', therefore, is not taken here as a distance, it is rather estimated through the way in which man, with his inherent spatiality, is able to discover 'space' in its 'nearness' and 'farness'. This implies that the streets people take in the course of their everyday journeys may well vary from time to time in their apparent length. The shaded street seems [subjectively] shorter than the sunny one which has [objectively] the same length but appears 'hard going'

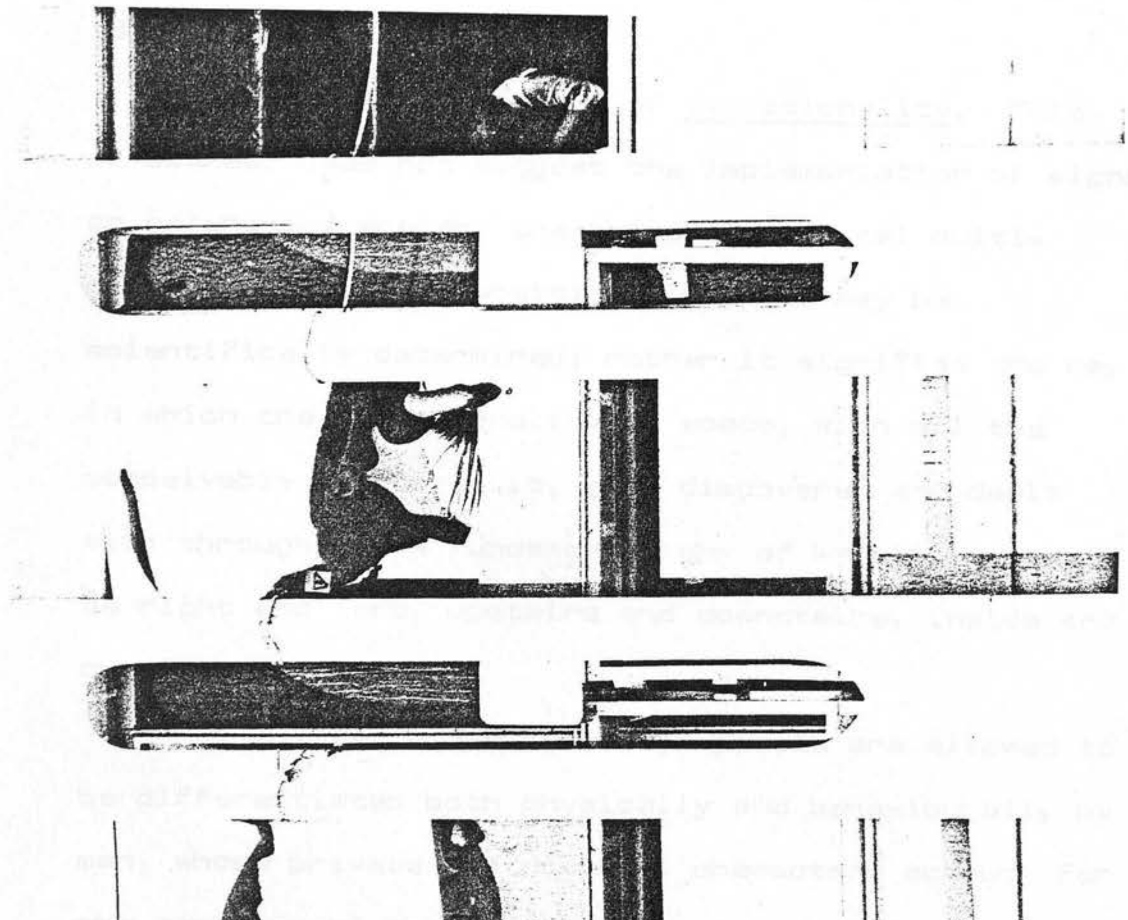


Figure IV.17

and comes before people as tediously long [Figure IV. 18].

Second, the character of directionality. This, of course, does not suggest the implementation of signs or references whereby the three-dimensional multiplicity of possible positions in space may be scientifically determined; rather it signifies the way in which the dimensionality of space, with all the conceivable places in it, gets discovered and dealt with through man's fundamental way of knowing places as right and left, upstairs and downstairs, inside and outside.

With this 'directionality' places are allowed to be differentiated both physically and behaviourally by man, whose private and communal characters account for the geometry of the courtyard house in which 'upstairs' and 'downstairs' go beyond calling attention to a location to spell out the meaning and value of man's dwelling.

The Arabic word for upstairs, haramlik, means all the things that are forbidden to you; in the case of the courtyard the expression indicates the 'direction' of an inviolable place in which female members of the family [harem] dwell [Figure IV.19]. On the other hand, the word for downstairs is salamlik, which means: to be at peace in a place shared with others; a sitting

Figure IV-18

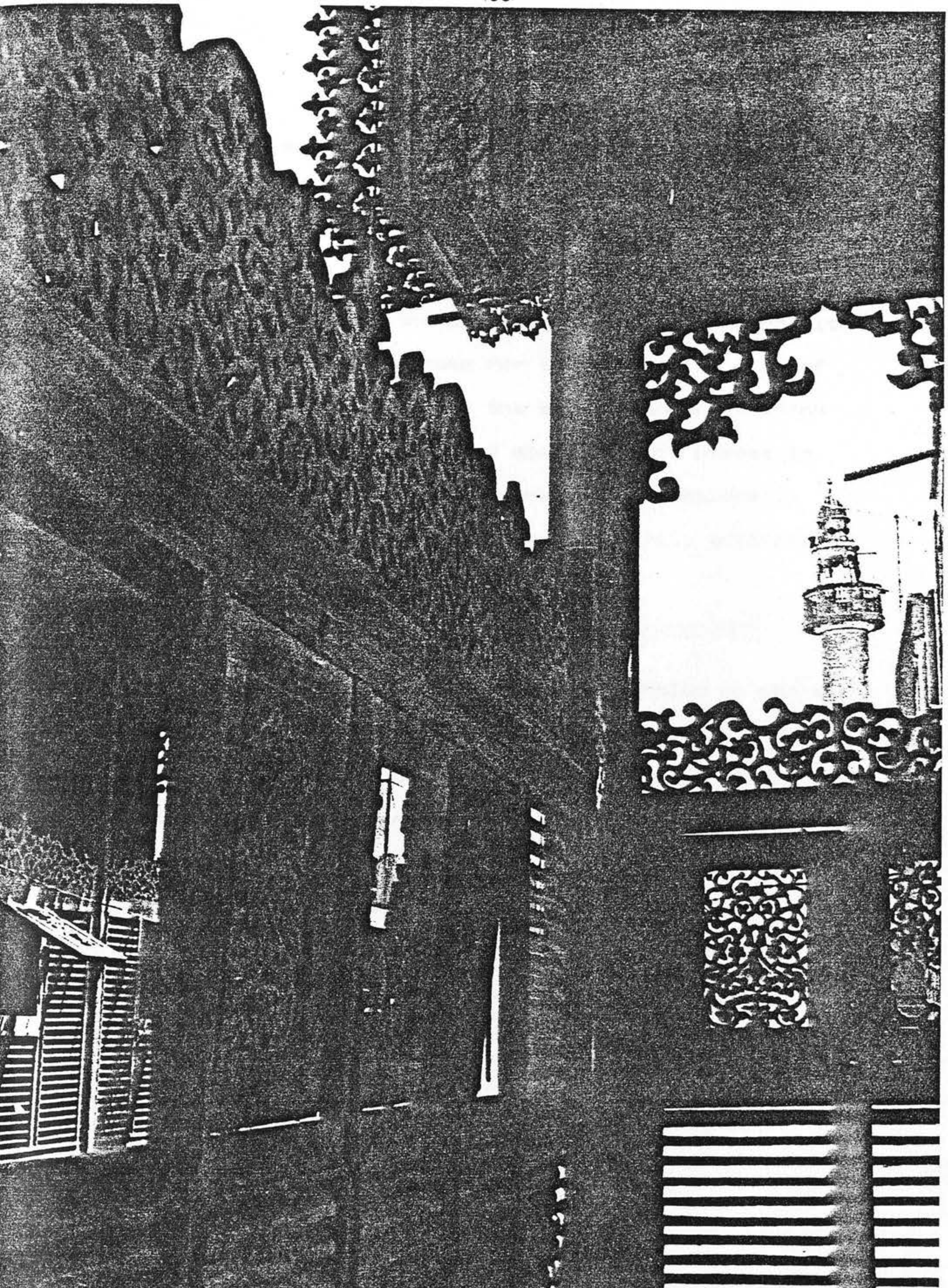


Figure IV.19

room is an example [Figure IV.20].

The courtyard holds 'closeness' and 'directionality' together. Here, the four sides of it explain people's concern to have something 'close by', namely, the inner place; at the same time, another concern with the provision of more room for the increasing size of the family shows itself in the spiral manner in which the courtyard gets built and split up into places in which all "theres" are discovered and directionally interpreted as people carry out their daily activities.

IV.5 The Temporality of Man and his Environment

As the last argument focused attention on man's spatiality rather than space itself, we now wish to place the emphasis upon man's temporality without introducing any abstract idea of time.[1]

---

[1] Time as man knows it in his life is different from that abstract time measured by the clock. In this respect Meyerhoff [1955] argued that the logical notion of abstract time - that infinite, empty medium, flowing evenly, perhaps even reversible, in which moments are identical dimensionless points, and lengths of time are precise, and exactly measurable against each other - opposes and eliminates the very sense of being alive.

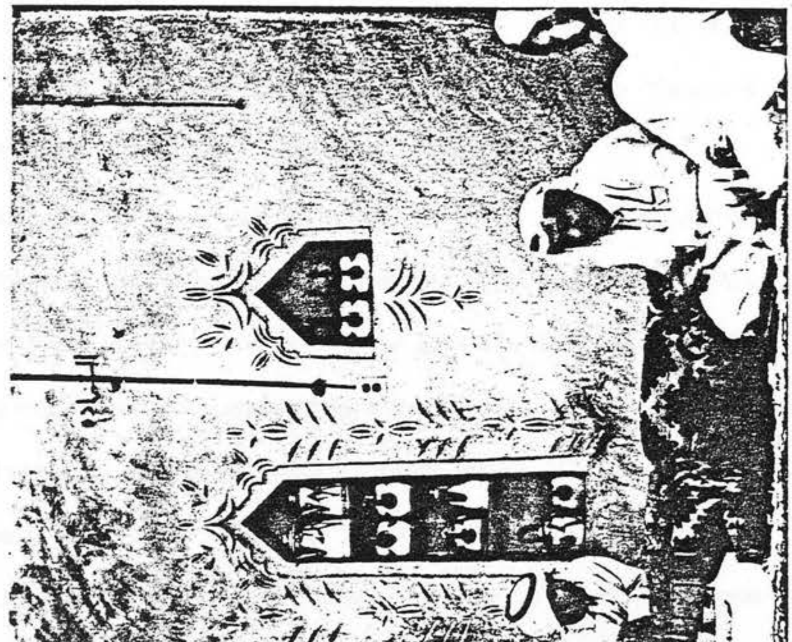


Figure IV.20

When we turn from the spatiality to the temporality of man and the things around him we notice that time also gets organized in terms of man's everyday concern with his environment. There is a time to wake up, a time to go to work, a time to have a break, a time to go to bed, and so on.

Man experiences time through the fundamental alternations of light and dark, of heat and cold, of sound and silence. With the daily course of the sun the environment pulses rhythmically and man responds to these changes before his urban activities get co-ordinated and correlated with a 'clock time'.

Although the rhythms within the environment have diverse periods, the 24-hour cycle is the dominant one not only because of day and night but also because man's internal biological rhythms are closely connected with the earth's rotation. However, this period can be influenced by shifts in the cycle of light and darkness or be affected behaviourally by social clues.[1]

---

[1] For man time may well pass quickly or slowly; accordingly we must be aware of the fact that the 24-hour cycle is not intended as an absolute measure of the temporality of both man and his environment; rather, it must be conceived in terms of estimates, which - though they may be imprecise and variable when compared with objectively measured time - have a sort of 'definiteness' when understood through man's everyday concern with the environment. In this context, Heidegger [1962] argues that "even when we avail ourselves of a fixed measure and say 'it is

In the tropical urban environment shade subjects people to a potent rhythm constitutive [but not determinative] of their urban activities. From the daily projection of the phenomenon of shade people become aware of their environment through a set of expectations about a chain of places, sunny or shady, in which their dealings with things around them are spatially materialized and temporally coordinated.

IV.6 Value and Fact in the Design Process

The argument in this chapter has been that in the living reality shade and activity, space and time are a gathering of interwoven spatial and temporal qualities which characterize the tropical urban environment whose existence and nature depend as much on meanings and values as on physical facts.

It has often been considered rational to begin the design process with physical facts in the belief that they secure, through their quantitative nature, the designer's findings on the drawing board. Then,

---

half an hour to the house', this measure must be taken as an estimate. 'Half an hour' is not thirty minutes, but a duration which has no 'length' at all in the sense of a quantitative stretch. Such a duration is always interpreted in terms of well-accustomed everyday ways in which we 'make provision'".

when the design process approaches its closing stages, physical facts begin to appear in their spatiality to which some meanings and values are added or concluded. This of course means that the certainty of facts is prior to the uncertainty of meanings and values.

But in everyday life this order is reversed as the meanings of things found in the tropical environment give rise to physical facts which man encounters and generates in his everyday activities. For example, spatial expressions, such as the traditional settlement, the courtyard house, and man's behaviour and costume, flow from the very meaning of protection and privacy, which may sometimes go against climatic good sense as the case with veiled women or the black costume of the Bedouin [Figure IV.21].

Within the tropical urban environment shade manifests itself at two different levels, i.e., as a fact and as a field of meanings and values. As we pointed out in Chapter I the problem is not so much one of the generation of shade as it is of finding the appropriate built form that brings it into being. This means that shade as a physical fact needs to be brought into existence through the building that stems from the very meaning of man's dwelling. Accordingly, the simulation and prediction of shade can only be carried out after its meanings and values have been fully

Figure IV.21

understood and within a context of design activity based initially and predominantly upon that understanding.

CHAPTER V

THE QUALITATIVE CHOICE OF THE COURTYARD

CHAPTER V

THE QUALITATIVE CHOICE OF THE COURTYARD

V.1 Introduction

At this point in the thesis, where we are about to move into an exploration of quantitative approaches to the prediction of solar shading, it may be helpful to summarize the argument so far. Additionally, the discussion which follows in section V.2 provides a qualitative background against which the choice of the form, which has been chosen for quantitative analysis, is to be made. In design, shade is just one of many factors which have to be taken into account and the overall form of the building is a response to a unique set of requirements and concerns. In order to pursue the quantitative considerations of shade at a research level, we are forced, partly by practical necessity (we cannot explore every conceivable form) and partly by the argument of this thesis (that form should be determined primarily on qualitative grounds) to choose a particular form for investigation.

Section V.3 contrasts the handling of shade in design and in research, and then introduces the courtyard as a viable and relevant form (both socio-culturally and climatically] upon which a systematic quantitative investigation can be carried out.

V.2 Summary of the Overall Argument

The present study concerned as it is with one of the most significant phenomena affecting man and his environment in tropical conditions, has as its main objective the provision of a better understanding of shade as a design objective by emphasizing the primacy of its qualitative aspects whilst putting its quantitative ones in their proper place.

Through the discussion of the physical and geometrical nature of solar shading [Chapter I] we were able to make two points clear: [i] the problem is not one of the prediction of shade, but rather of choosing the proper form, and [ii] shade is not merely physical and, in terms of design, there is a need to place the emphasis first on its meanings and values.

In Chapter II we discussed the phenomenal nature of shade by defining it in qualitative terms through its bearing on man's everyday experiences. Out of the relationship linking shade, place and behaviour three things were arrived at: [i] shade, in everyday life, is a place, [ii] human behaviour in the environment is mainly founded upon a sense of generalization, and

[iii] man's true relationship to a place is none other than dwelling in the essential sense of the word. The phenomenological analysis of the nature of dwelling brought together meaning and physical expression exemplified in the form of the traditional courtyard house.

We raised in Chapter III the epistemological question concerning the phenomenon of shade, and encountered the two different forms of knowledge needed for dealing with it. The necessity was shown of considering these two in the design process where the designer's task would then be to bring to the fore the interplay between factual description and phenomenal nature in such a way so as to make possible the gathering together of its quantitative and qualitative aspects. This was carried out in three stages: [i] disputing the customary idea of linking man and his environment by mere relationships, [ii] replacing it by the general notion of man's existence, i.e., <u>being-in-an-environment</u>, and [iii] showing the necessity of combining the scientific representation and the phenomenological understanding of shade with the aim of getting closer to <u>this</u> environment in which man <u>is</u> as a human being.

The main objective in Chapter IV was to explore relevant ideas about shade and the tropical urban environment in greater depth and in a way which emphasizes the primacy of quality. By developing certain characteristics of the spatial and temporal qualities of man and his environment we were able to arrive at a better understanding of a set of dimensions [space, time, shade and activity] considered essential in design. Out of a phenomenological analysis of living urban situations in the tropical environment two main points were made clear: [i] the scientific handling of shade [simulation and prediction] must be preceded by a deeper understanding of the meanings and values which give rise to built forms in the tropics [as we shall explain in the following section, when the choice of the courtyard form is made for further quantitative analysis, the part that science might play in the design process would then be limited to checking and assessing the shading performance of this particular form], and [ii] in the process of design, space, time, shade and activity are in fact determinative dimensions resulting from the way in which designers usually get into things by abstracting from the living reality in which those dimensions are constitutive. The important thing about such abstractions is that they make the scientific representation of shade possible.

V.3 The Treatment of Shade in Design and in Research

Shade may or may not be a concern of a designer. This of course depends on the nature of the design problem and on the designer's knowledge and attitude towards finding a proper solution to it.

However, if shade were to be taken account of, it is perhaps more likely to be linked to the internal environment of the building; and this is because the designer usually focuses his attention on the provision of artificially controlled indoor spaces rather than on the generation of desirable outdoor conditions.

In the Gulf region where the prevailing climatic conditions are mostly adverse and where people tend to spend a great deal of their time outdoors, there are strong arguments for making use of building shapes and arrangements to produce satisfactory outdoor micro-climatic conditions.

If it should happen that a designer is convinced by this argument for utilizing shade to improve the micro-climate around buildings, he seems most likely to turn first to the available quantitative techniques of simulating and predicting shading patterns rather than to acquiring a qualitative grasp of its living nature in the tropical environment.

The question then arises not only of how the qualitatively based determination of form is to be achieved, a matter which has been dealt with at length, at least implicitly, in the preceding chapters, but also how, within a process of design initiated by qualitative concerns, the best use is to be made of quantitative methods of prediction and evaluation.

There is no doubt that such quantitative methods have a real value when used as a means of analyzing and assessing the shading behaviour of form. However, uncertainty begins to rise when their role extends to the determination of form.

The quantitative handling of shade either produces instantaneous shadow patterns, when using conventional techniques such as the heliodon, solarscope etc., or generates amalgamated patterns of shade averaged over a prescribed period of time, when use is made of computers; for instance using the program SHADE.

In the living reality a shady place can be found within the shadows cast by a building. But such a place is not only determined by the presence of this shadow but also by man's everyday activity. As shadow moves, places can be either in shade or out of it. But, the shady place, in which man dwells, stays even when it is exposed to the sun [Figures V.1[a] and V.1[b]].

Dealing with shade on a purely quantitative basis we find that shadow is conditional upon the building

Figure V.1(a) Shadow

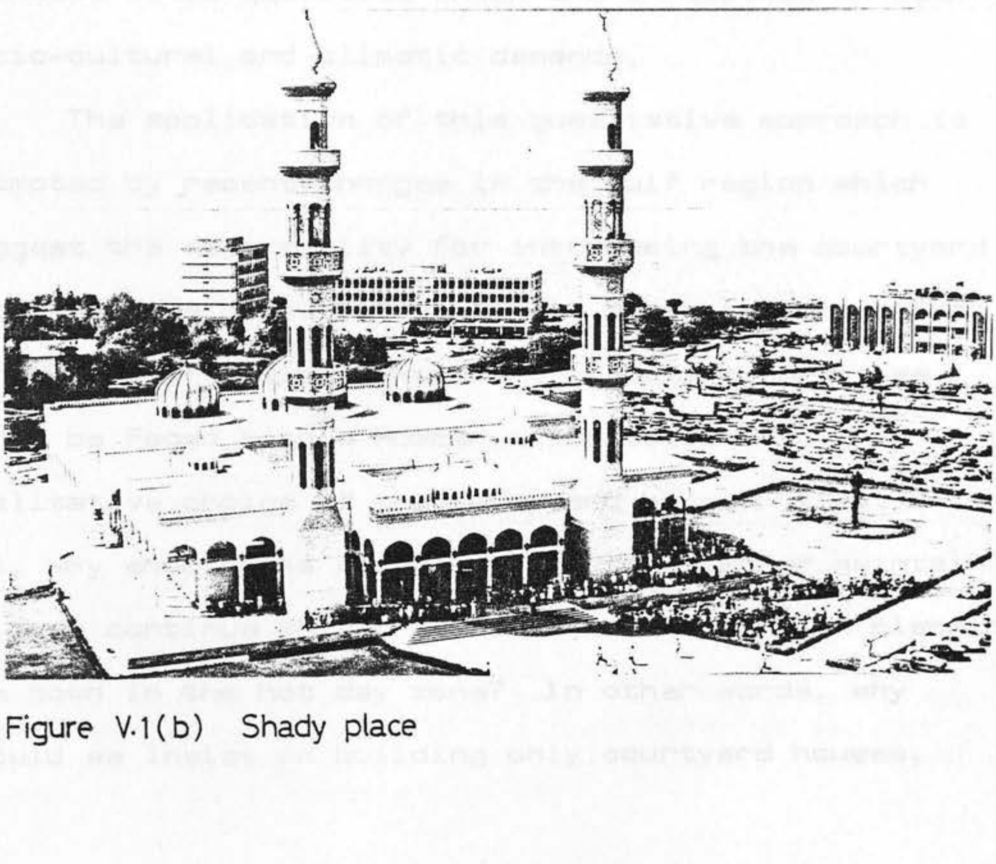


Figure V.1(b) Shady place

that casts it. Apart from casting shadow, the building signifies in the first place a dwelling unit responsive to a unique set of values and considerations which gives rise to its form. This of course means that this shady place cannot be brought into existence unless the built form is qualitatively chosen. Here, we encounter again the circling argument which repeatedly calls for a process of design initiated by qualitative considerations.

The qualitative choice of the courtyard satisfies, at research level, the need for picking out a form upon which shade investigation can be carried out. Moreover, the suitability of this particular form stems from its characteristic qualities which are a response to both socio-cultural and climatic demands.

The application of this qualitative approach is prompted by recent changes in the Gulf region which suggest the desirability for introducing the courtyard not only as a house but also as a basis for urban form on a range of scales. However, in design terms, we might be faced with a number of objections to the qualitative choice of the courtyard house. First of all, why should the architect and the planner maintain or even continue this traditional built form in planning the town in the hot day zone? In other words, why should we insist on building only courtyard houses, and as a result, screening the entire town from its immediate surroundings? Moreover, why should we keep the present situation as it is, filling towns with just courtyard houses instead of finding a way in which the characteristic qualities, which distinguish this particular form, may reasonably be manipulated in such a way so as to enable both the architect and the planner to generate the proper form of their town, which responds to physical and socio-cultural demands, and be in accordance with the principles of its basic structure, such as individual houses, private and public open spaces, as well as community and public buildings etc.

It is evident that under the present circumstances gnerated by recent changes in the Gulf region, no courtyard house or a settlement can possibly become independent of its immediate surroundings, nor can it be isolated from the impact of today's modern technical means.[1]

The development of the traditional courtyard house towards a 'new form'[2] depends mainly on two

---

1 We are referring here to all modern technology products, in particular those used in today's building industry.

2 Admittedly, the use of the term 'new form' seems to generate a sense of unease, since forms do exist, but just wanting to be looked at sensibly, and hence, used in a more imaginative way.

things: [i] an understanding of the basic structure of today's town, which must respond to the prevailing physical conditions, and should satisfy people's socio-cultural demands, and [ii] a recognition of both the importance and existence of the modern technical means, which had been dictated by recent economical and technological transformation in this area, and can hardly be ignored.[1]

It might be useful to continue the discussion by analyzing the spatial and behavioural patterns of the traditional settlement that may influence the planning and design of the tropical town.

The most dominant of these patterns is the courtyard house, which is built around shaded private space, and shielded against dust and sandstorms. This particular pattern is basically determined by the inducing climate and happily coincides with social and cultural demands.

The idea of maintaining and continuing the courtyard house in today's tropical towns might seem

---

[1] It is worth mentioning here that because of the increasing availability of electricity, many omni-directional wind-towers, which characterize the traditional settlement in the Gulf region, have been sealed, and are now fully equipped with air conditioners!

sensible for climatic and socio-cultural reasons; but the pattern in its traditional form cannot be introduced without modifications needed to cope with the recent imposition of modern technical means, which seem at the present time indispensible. Such modifications should allow new building materials to be used wisely,[1] since it is meaningless to insist, under the present circumstances, on building our towns out of mere mudbricks, for the reason that it is a noble building material,[2] or perhaps because it is much cheaper and more efficient than the new ones.

As we look back into the past with affection, we must also realize the fact that the present situation requires new patterns of urbanization different from those used in the traditional settlement. In the

---

[1] In the Gulf region, many new building materials are now being used in building industry with complete disregard to climatic consideration. Some of these materials proved to be entirely inappropriate, whereas others were fairly successful (trial and error!). However, there was a case in which a multi-storey appartment building had to be repainted three times because the plaster used could not sustain the extreme climatic conditions, and eventually the whole building was covered with ceramic tiles, usually used in bathrooms and kitchens; the building now stands like a huge bathroom turned inside out!!

[2] The expression 'noble building material' reflects the belief held by Moslems that man (God's masterpiece) was created out of mud.

decade following the first exports of oil, the entire region has completely transformed. Due to these changes many new businesses were introduced, e.g., banking and building industry. These businesses have contributed to the transformation of this region by generating new activities, and consequently, providing new opportunities of employment offered to people from Arab neighbouring countries, as well as to other people from quite different social and cultural backgrounds.

Under these circumstances, the traditional courtyard house, though 'culturally rich' and undoubtedly usable, seems to offer an inadequate solution to the problem of dealing with new activities which need new accommodation and circulation patterns, which are entirely different from those found in the old settlements. It is not surprising then that urban patterns such as streets and parking areas will become more important for both the local and expatriate people than the delightful shaded alleys of the traditional settlement.

In looking for new basic principles of planning the tropical town, the wide variety of existing forms might tempt us to get involved, or even lost, in technical details. To avoid this the emphasis here is placed only upon the establishment of patterns and relations of practical implications.

Anyone who has visited the Gulf must have recognized the importance and necessity of having shaded spaces not only for individual houses but also for the town as a whole. Here, we may imagine the town as a group of large shaded courtyards sheltered and enclosed by either offices or dwelling units. Such patterns may reasonably be referred to as 'courtyard forms', which are distinct from the old traditional courtyard houses.

In this context, we may also assume that public services and utilities as well as parking areas could be situated within these large courtyard forms. It may be even more interesting to bring some patterns found in the traditional settlement into these forms. Here, the most important of these patterns is the market-place [souk] which is always dominated by the mosque. However, it must be taken into account that unlike the traditional settlement, this particular pattern in its new form requires shaded urban spaces for different purposes such as streets, footpaths and parking areas.

At this point, and from an architectural point of view, one might reasonably argue against the use of the courtyard form: "Why should people and their urban activities as well as public services and facilities be surrounded and shut in from all sides?"

This objection seems to be justifiable only when all the courtyard forms are directly placed on the ground. But let us imagine an urban situation in which the ground floors of these forms are penetrable and free, i.e., the courtyard forms are raised on columns. Undoubtedly, the spatial and behavioural qualities generated from such an idea may produce a pattern in which both enclosure and accessibility work in combination with one another through the town of tropics. An image of such a town is illustrated by the sketch shown in Figure V.2.

Though the geometrical character of both the courtyard house and form is exactly the same, they have quite distinct spatial and behavioural qualities. Perhaps the most important factor in generating those qualities is that of size. Here, the traditional courtyard space is generally used for private and domestic purposes, and surrounded by an 'introvert' dwelling unit looking inwards, whereas the large inner space provided by the courtyard form may be used for public purposes which are encompassed by 'extrovert' units of dwelling looking outwards. The diagram shown in Figure V.3 illustrates these two concepts.

Although several studies related to the effect of climatic forces on built forms have recommended

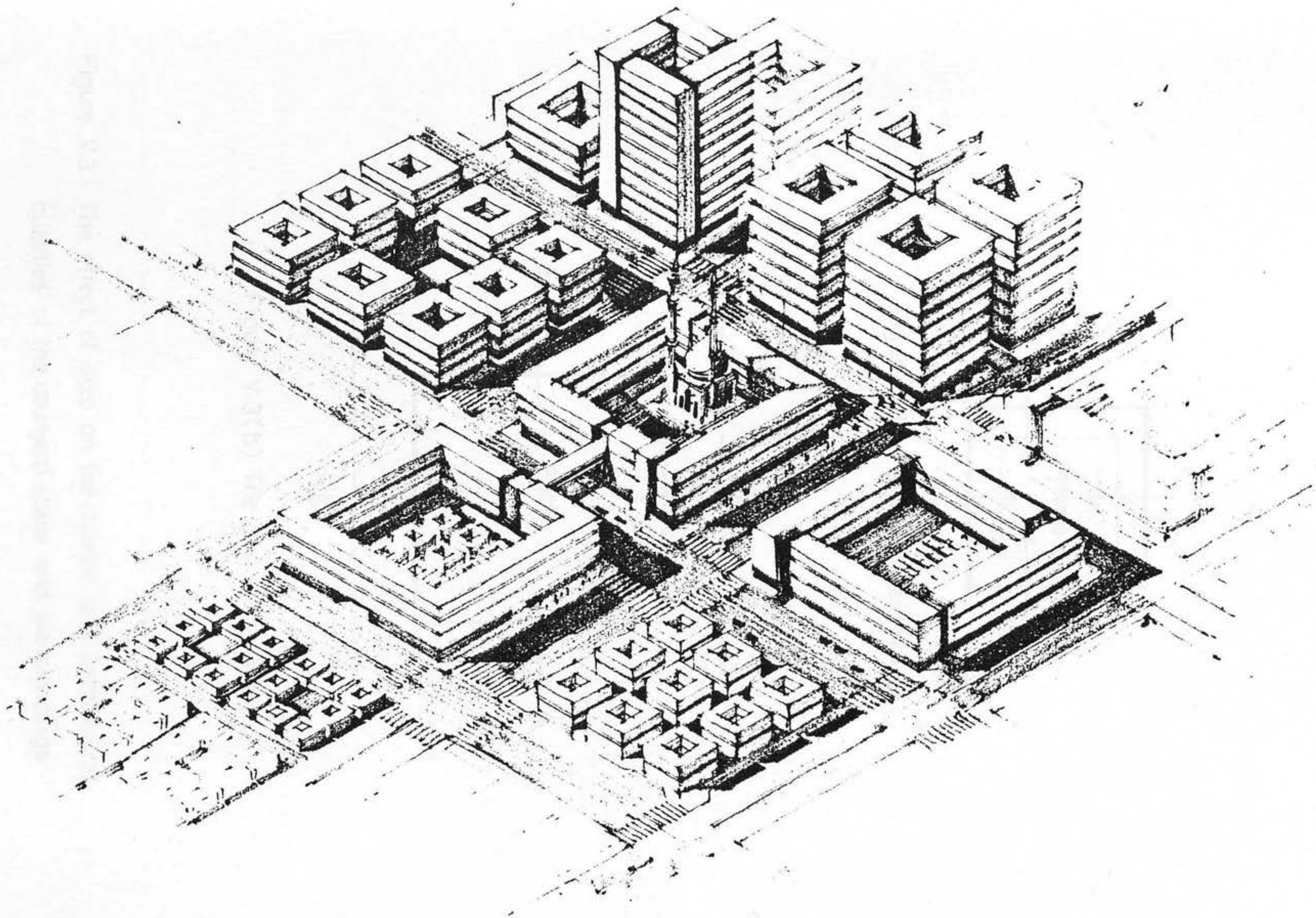


Figure V.2 An image of a town in the tropics based on courtyard forms at different scales

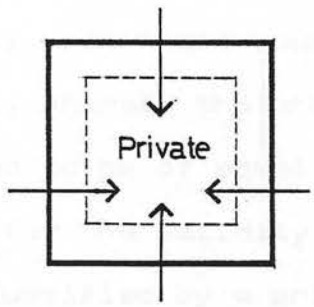


Figure V.3 (a) The courtyard house

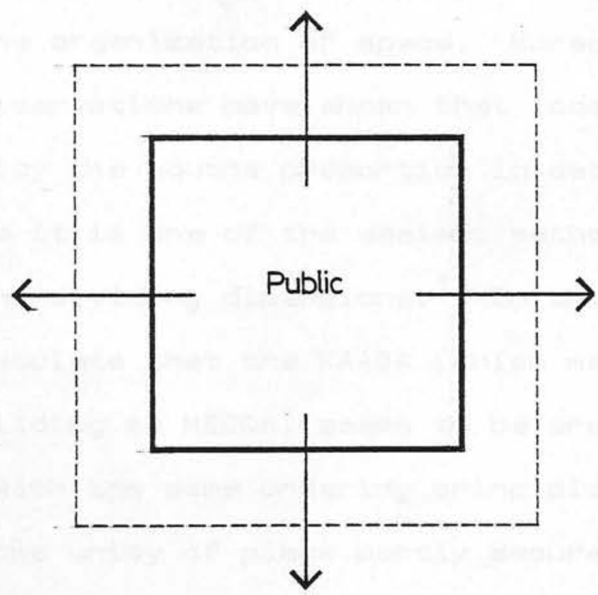


Figure V.3 (b) The courtyard form

Figure V.3 The effect of size on the spatial and behavioural qualities of the courtyard space and surroundings different plan shapes [Olgyay, 1963, and Tropical Advisory Services, 1966], the emphasis in the present study is placed only upon those courtyard forms with square shaped plans, whereas the urban spaces separating them are assumed to be of equal dimension.

The argument for the validity of this particular plan shape may be justified by a brief examination into geometric concepts in the traditional settlements in the Gulf region which shows the square shape as a dominant ordering principle or <u>mīzān</u> [balance and order] in the organization of space. Moreover, empirical observations have shown that local people tend to employ the square proportion in determining areas, since it is one of the easiest methods in measuring and dividing dimensions.[1] In this context, we might speculate that the KAABA [which means 'cube'], the holy building at MECCA, seems to be erected in accordance with the same ordering principle!

With the unity of place partly secured by the qualitative choice of the courtyard as a viable form for our systematic quantitative investigation, it is

---

[1] The use of the square shape by town planning authorities in laying out buildings in the city of Abu Dhabi was first initiated by local pressure groups [Figure V.4].

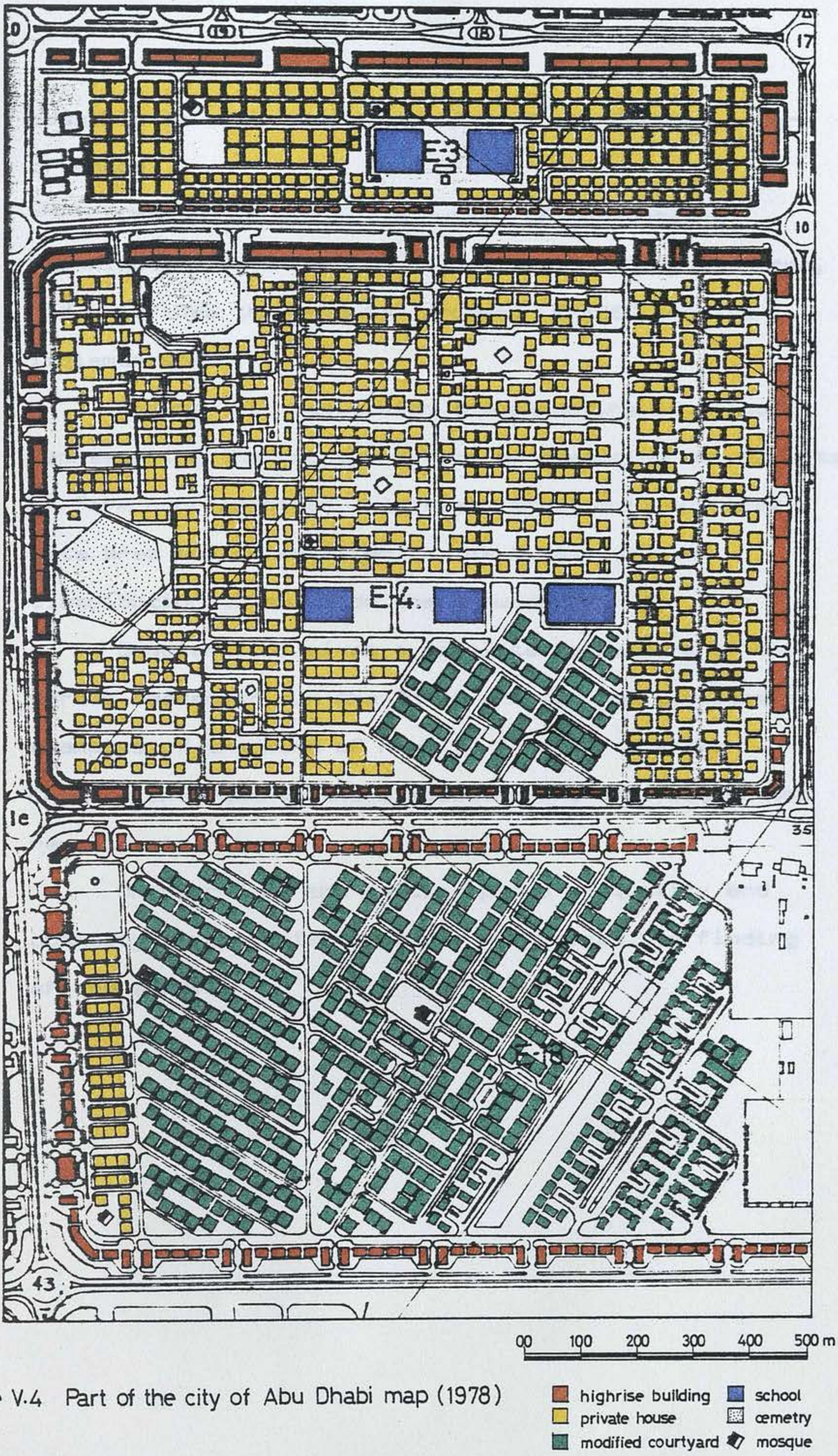


Figure V.4 Part of the city of Abu Dhabi map (1978) possible to begin the discussion of the factual nature of shade.

Chapter VI surveys a number of conventional techniques of simulating and predicting shade patterns, and describes the computer program [SHADE] and its implementation.

Chapter VII deals with the structure of a model representing the courtyard form by assessing the effects of form configuration, courtyard area, built-up area, site area and orientation on the time-averaged distribution of shade on the ground.

Chapter VIII gives a complete assessment of the effort needed to run the SHADE program and illustrates examples of the kind of results from it; whereas Chapter IX presents the discussion and analysis of the results.

Chapter X is the meeting place of quality and quantity, and the last chapter summarizes the finding of the study.

CHAPTER VI

THE CHOICE OF THE COMPUTER PROGRAM (SHADE)

CHAPTER VI

THE CHOICE OF THE COMPUTER PROGRAM (SHADE)

VI.1 Introduction

Having arrived at a qualitative choice exemplified in the geometry of the courtyard house, we can now turn our attention towards finding the appropriate technique with which the factual and physical nature of shade may be examined.

The first section, therefore, surveys some of the conventional techniques currently used in simulating and predicting shade patterns, with the emphasis placed upon their unsuitability for exacting the kind of investigation where the treatment of shade is not that of providing just mere patches of shade patterned for instants of time, but rather one in which the distribution of it is calculated between any prescribed hours of day and averaged over any period of time.

The second section describes the computer program SHADE which is considered in the present study as a checking tool capable of providing us with a rapid means by which the task of assessing the courtyard's shading performance can easily be carried out.

VI.2 Techniques of Predicting Shade Patterns

VI.2.1 Sun-path diagram

The graphic representation of the stereographic sun-path diagram [solar charts] and associated protractors and overlays are commonly used to specify and predict the performance of shading devices. With this method the sun's position on the sky hemisphere is determined by two angles: [i] the solar azimuth angle, i.e., the angle between the northerly direction and any given point on the horizon circle, measured clockwise, and [ii] the solar altitude angle, i.e., the angle made by a line connecting the sun with the point of observation [the site] and the plane of the horizon. The horizontal and vertical shadow angles [see Figure VI.1] can be determined for any time on the day throughout the year by using prepared solar charts. The prediction of shade patterns can be worked out using the shadow angle protractor. The diagram shown in Figure VI.2 illustrates the solar chart for the city of Abu Dhabi and the shadow angle protractor.[1] The shortcoming of this method is that the shade cast is depicted for only a particular

---

[1] The reader is referred to Lippsmeier's work [1969] for a more detailed analysis of the procedure by which the designer may check, design or select shading devices.

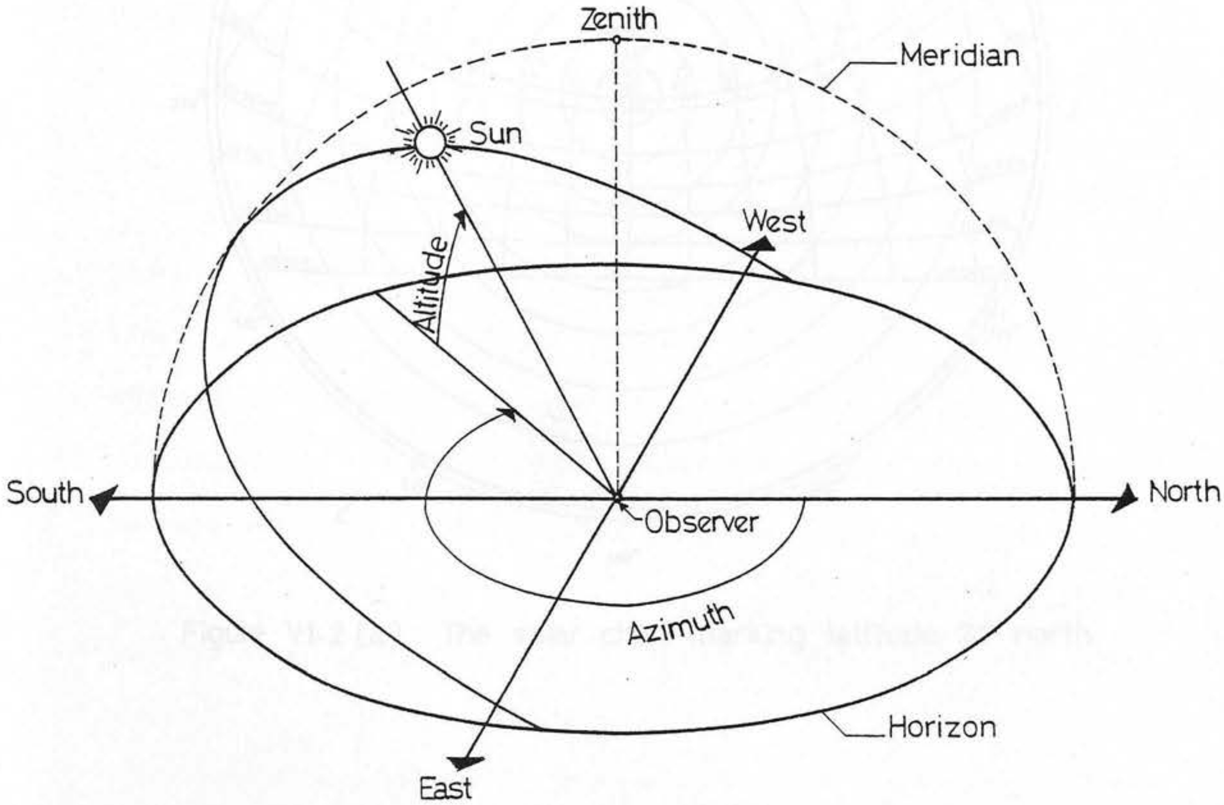


Figure VI.1 Isometric view of the solar azimuth and the solar altitude defining the sun's position

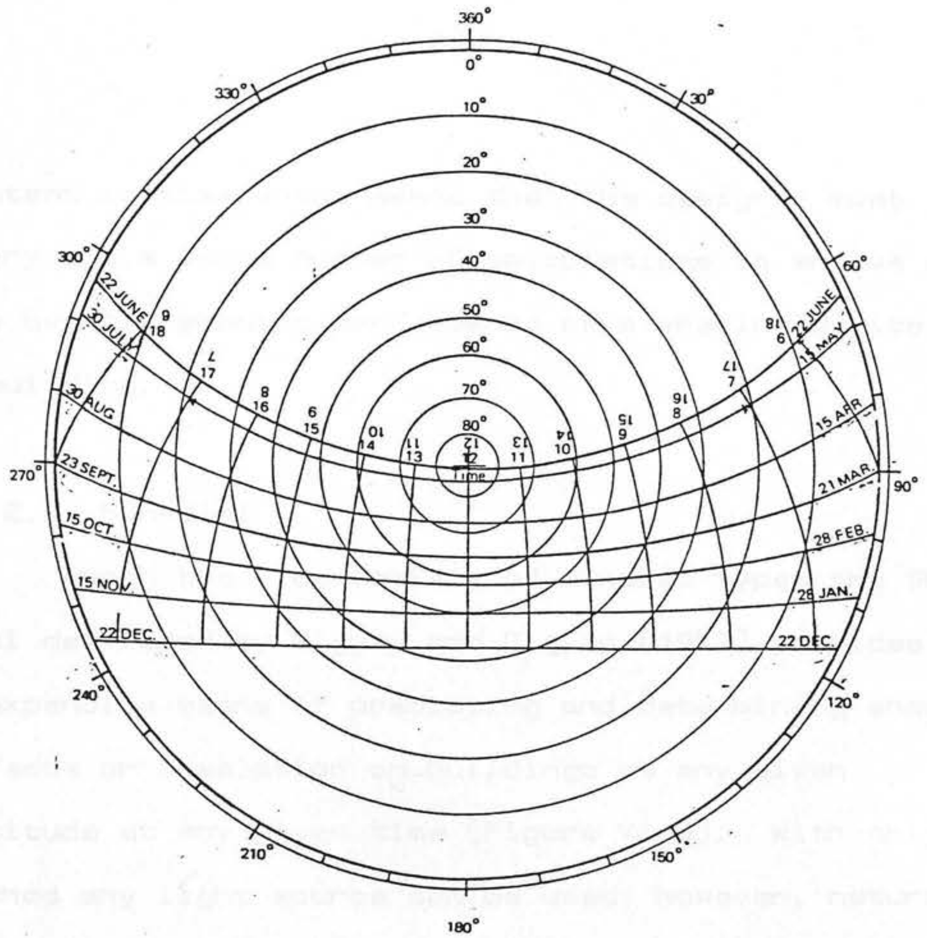


Figure VI.2 (a) The solar chart marking latitude 24° north

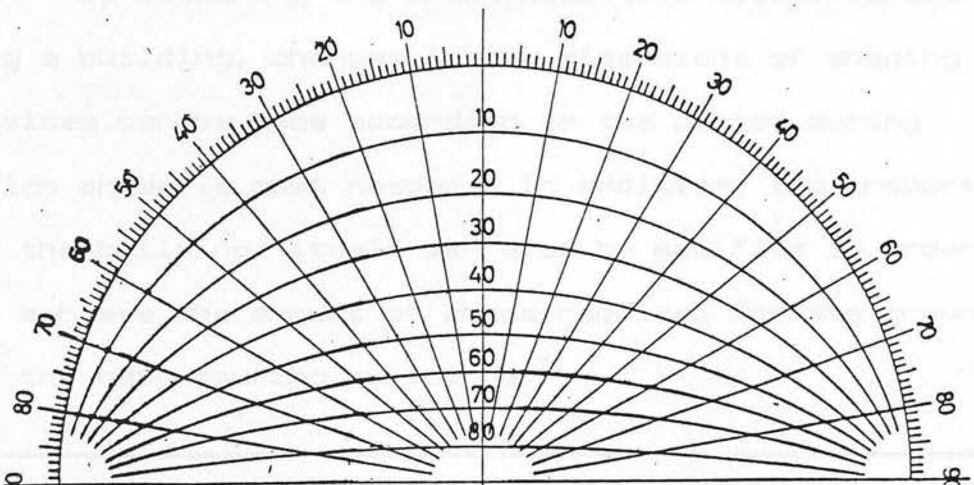


Figure VI.2 (b) The shadow angle protractor

Figure VI.2 The solar chart (sun-path) for the city of Abu Dhabi and the associated shadow angle protractor instant in time which means that the designer must carry out a large number of calculations to arrive at the overall shading performance of a shading device or a building.

VI.2.2 Sun-dial

Among the wide variety of sundial types the Shade dial developed by Olgyay and Olgyay [1957] provides an inexpensive means of predicting and determining shading effects or insolation on buildings at any given latitude at any given time [Figure VI.3]. With this method any light source can be used; however, natural sunlight is recommended so as to avoid distortion due to the small distance of an artificial light from the model.

By attaching the Shade-dial to a model representing a building, changes in the dimensions of shading devices can be made according to the period during which shade is most needed. In addition, the proportions of the building itself can also be modified in order to achieve the amount of shade required for the ground or the neighbouring buildings.[1]

---

[1] For more information on the use of the Shade-dial in practical applications, see Olgyay and Olgyay [1957].

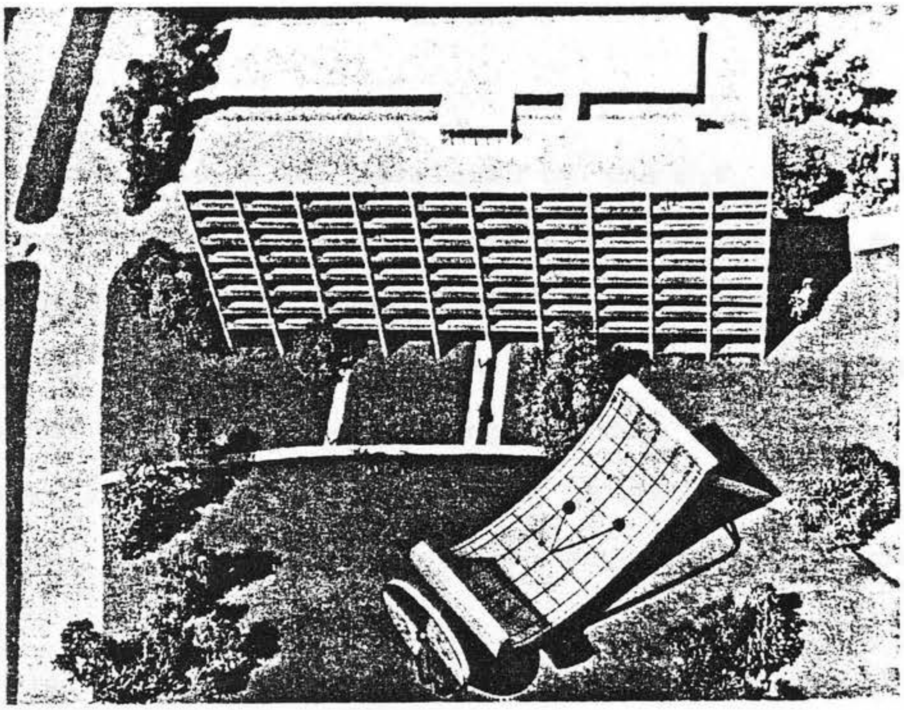


Figure VI.3 The Shade-Dial
(after Olgyay and Olgyay., 1957)

Just as with the previous method the Shade-dial can also be criticised for allowing a building to be tested only for instants of time which makes the assessment of average shade over long periods cumbersome.

VI.2.3 The Heliodon

This device was developed by the U.K. Building Research Station. It consists of two parts: [i] a movable table tilting about a horizontal axis for latitude adjustments and revolving around a vertical axis for hourly changes during the day, and [ii] a movable light source that slides up and down along a vertical axis representing month adjustments[1] [Figure VI.4].

Although the heliodon provides a simple and inexpensive technique of predicting shade patterns by using a scale model of the building[s], it has in fact two principal disadvantages: [i] the movable model table is relatively small which makes it difficult for a large number of buildings to be investigated, and [ii] due to the tilting mechanism of the table the model has to be fixed which limits the flexibility

---

1 The vertical axis is at a fixed distance from the centre of the table.

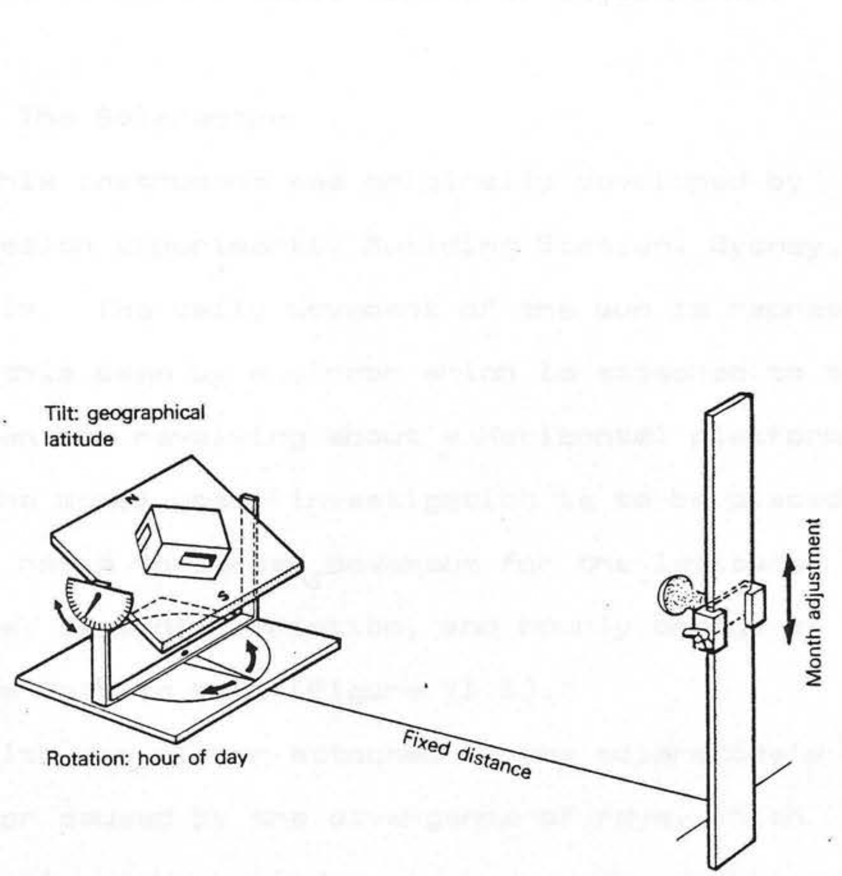


Figure VI.4 The Heliodon
(after Koenigsberger et al., 1974)

needed to conduct a whole series of adjustments.[1]

VI.2.4 The Solarscope

This instrument was originally developed by Commonwealth Experimental Building Station, Sydney, Australia. The daily movement of the sun is represented in this case by a mirror which is attached to the end of an arm revolving about a horizontal platform on which the model under investigation is to be placed. The arm has a three-way movement for the latitude variable, seasonal variation, and hourly change of the sun from East to West [Figure VI.5].

With the mirror attached to the solarscope's arm, the error caused by the divergence of rays, which characterizes the heliodon, is reduced by doubling the apparent distance of the light source from the model. Another advantage is the solarscope's horizontal platform on which larger models can be accommodated and on which buildings can be moved more easily.

In addition to the limitation of latitude adjustment, this particular instrument also shares with the previous ones the disadvantage of producing instantaneous shade patterns.

---

[1] This difficulty can be got round by using a steel table on which the model can be fixed with magnetics.

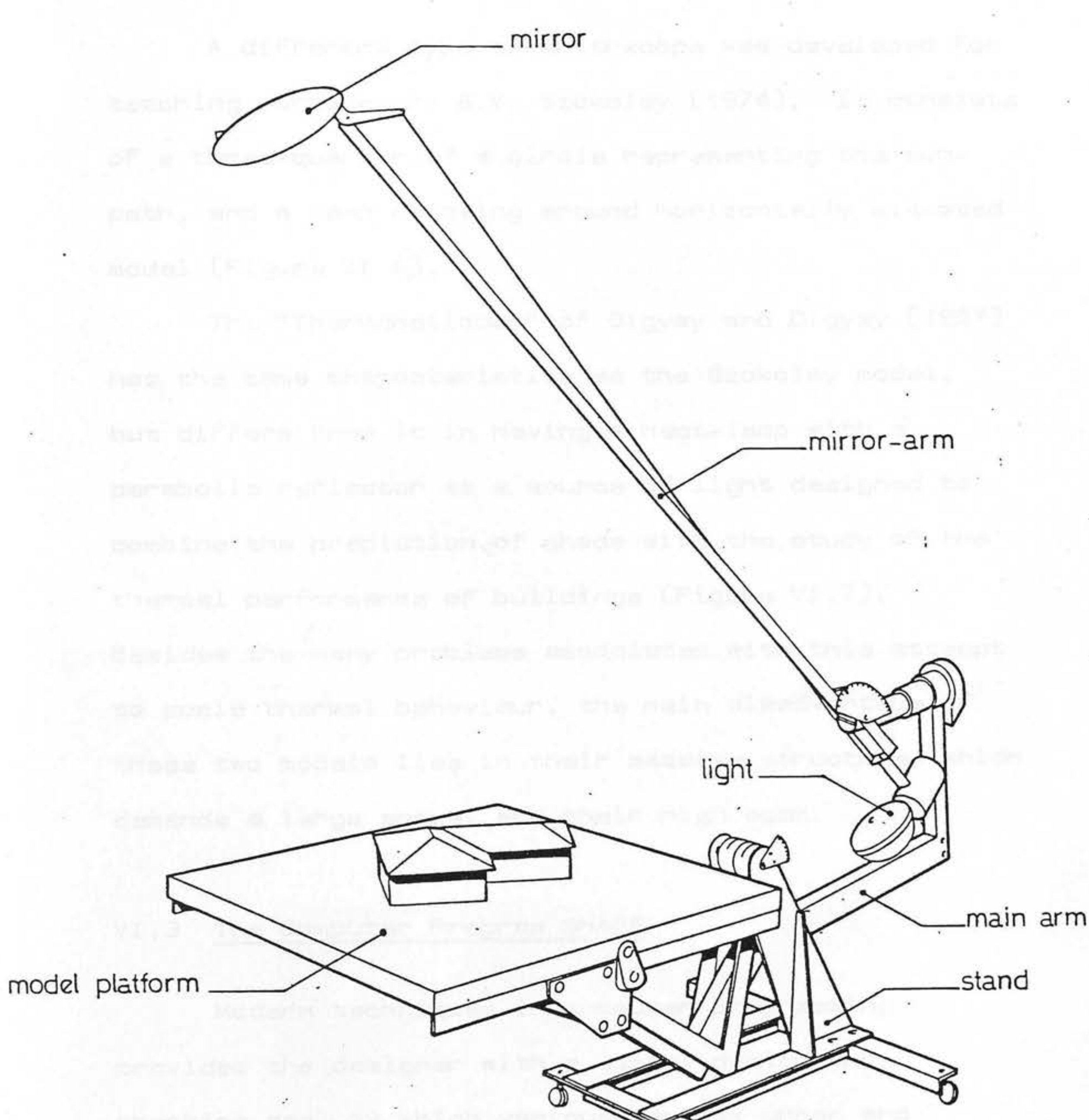


Figure VI.5 The Solarscope
(after Koenigsberger et al., 1974)

A different type of solarscope was developed for teaching purposes by S.V. Szokolay [1974]. It consists of a three-quarter of a circle representing the sun-path, and a lamp rotating around horizontally situated model [Figure VI.6].

The "Thermoheliodon" of Olgyay and Olgyay [1957] has the same characteristics as the Szokolay model, but differs from it in having a heat-lamp with a parabolic reflector as a source of light designed to combine the prediction of shade with the study of the thermal performance of buildings [Figure VI.7]. Besides the many problems associated with this attempt to scale thermal behaviour, the main disadvantage of these two models lies in their massive structure, which demands a large space, and their high cost.

VI.3 The Computer Program SHADE

Modern techniques in computer programming provides the designer with a useful design and checking tool by which various complex urban and architectural problems can effectively be investigated and solved.

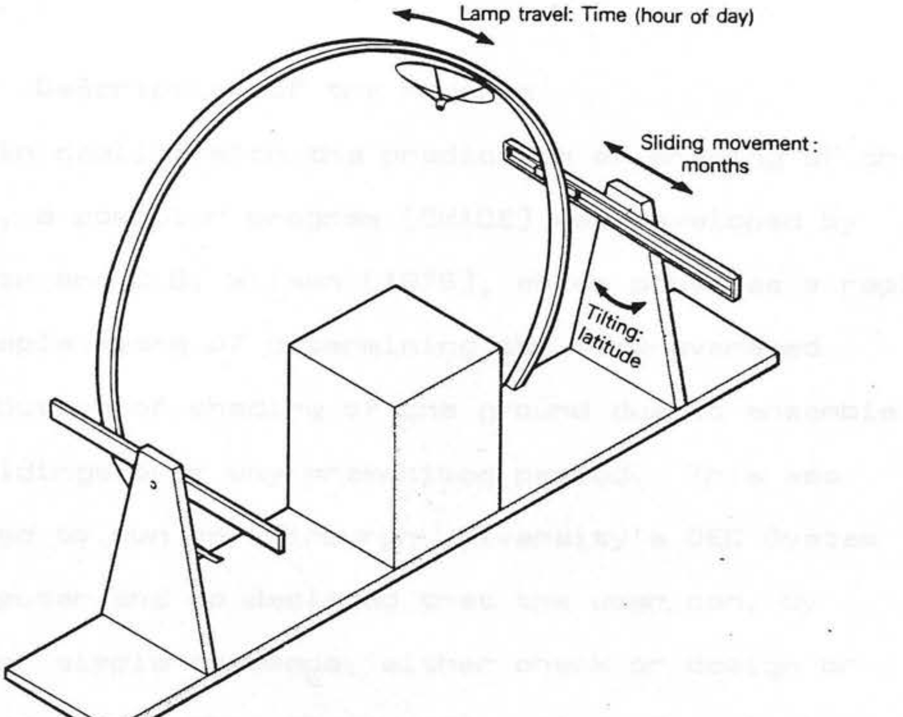


Figure VI.6 The Solarscope developed by S. V. Szokolay at the Polytechnic of Central London (after Koenigsberger et al., 1974)

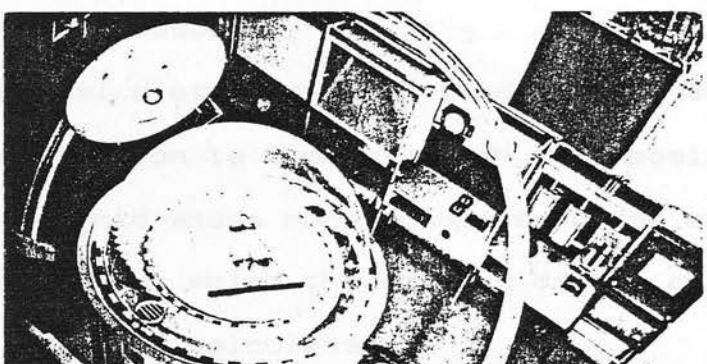


Figure VI.7 The Thermoheliodon developed by A. Olgyay and V. Olgyay at Princeton University (after Olgyay and Olgyay., 1957)

VI.3.1 Description of the Program

In dealing with the prediction of shading of the ground, a computer program [SHADE] was developed by F. Smith and C.B. Wilson [1976], which provides a rapid and simple means of determining the time-averaged distribution of shading of the ground due to ensemble of buildings over any prescribed period. This was prepared to run on Edinburgh University's DEC System 10 computer and so designed that the user can, by means of simple commands, either check or design or modify a layout through several cycles of evaluation and adjustment at low cost.

The program generates maps of the distribution of shading on the ground by arbitrary groups of buildings over a designer-prescribed span of hours and days. This is done by conducting a statistical survey using the following procedure:

[i] The spatial distribution of shading over the area under investigation is accounted for by imposing upon it a regular grid whose nodes comprise a set of sampling points at which the shading of the ground by buildings is to be calculated.[1]

[ii] The temporal variation of shading is accounted for in terms of samples. From designer specified data

---

[1] These samples are selected in terms of a parameter known as the declination.

on the maximum span of days over which shading information is required and the number of samples to be used, the program selects a set of samples on certain representative days.[1] Once the specification of these parameters has been completed, the program then scans every grid node on each of the sample days and compiles a detailed data base describing the shading effects of all buildings defined by the designer. When a shading map is requested, the program searches through the data base and extracts and consolidates all the relevant information in order to produce the average shading subtended at each of the grid nodes, expressed as a percentage of the possible hours of sunlight.

With SHADE the designer is therefore able to overcome many difficulties inherent in the sophisticated calculations needed for averages or aggregates in shade prediction. The effectiveness of this program and the potential benefit to the present study lies in its versatility and speed. Without it, it would have been impracticable to carry out so many investigations

---

1 The designer is given control over the method's temporal resolution by being allowed to select the number of samples which are to be used.

[requiring quantities of information, data and calculations] using manual or conventional techniques. The program is characterized by the following features: [i] flexibility of input, i.e., buildings may be changed, generated or even moved giving the possibility of developing several layouts simultaneously, [ii] a synopsis of the contents of the system can be provided on request, so that the designer is free to correct errors and secure results at any stage, and [iii] the output is provided in mathematical and graphical forms so shade patterns generated in different situations can easily be compared.

VI.3.2 The designer's interaction with the program

The designer may run SHADE either interactively or in batch mode.

When the designer begins working with a new site,[1] he is required to supply the following data: [i] the site's latitude and longitude, [ii] the site's maximum dimensions in both the East/West and North/South

---

[1] The program also provides the designer with the possibility of developing a layout over a series of runs. This is done by entering the word OLD whereupon the program returns to its state immediately before the previous run is terminated.

directions, and [iii] the resolution of calculation in both the East/West and North/South directions. He is also asked to provide: [i] the span of hours and days over which the shading is to be predicted, and [ii] particular times within the previous maximum period for which shading data is required.

Once this preparatory input is complete, the program is ready for the main body of calculation, and the designer is then free to test and develop his layout by means of any combination of the following commands:

[i] The DEFINE command - introduces buildings to the program. Buildings are then specified in terms of their geometry [building types such as a house, a block, a courtyard, etc., to which the appropriate dimensions are to be added] and their position [determined for each building by its distance from the bottom, left hand corner of the rectangular box which encloses the site and its orientation with respect to the compass].

[ii] The DISPLAY command - produces a contour map which shows the average distribution of shading between the prescribed hours and days.

[iii] The BACKGROUND command - manipulates the shading effects of existing buildings within and around the site. The designer can employ this facility to amalgamate these effects which may have a significant

influence on the arrangement of buildings and thus on the choice of layout.

[iv] The DELETE command - is used to discard obsolete buildings and to cancel their description and shading data from the computer's memory so as to clear space in the program for new building to be defined.

[v] The RELOCATE command - is used to move or re-orientate previously defined buildings about the site.

[vi] The COPY command - simplifies input by placing an identical copy of previously defined building at another location.

[vii] The RESCALE command - provides the designer with a focusing device by which certain areas can be examined at different scales within the site.

[viii] The END command - ensures that the data base describing a layout is preserved between runs.

[ix] The LIST command - gives the designer a list of the contents of the system.

VI.3.3 Remarks on the implementation of the program

The city of Abu Dhabi [Latitude 24° 25' 55" N, Longitude 54° 27' 37" E] was chosen as a typical place for the prevailing tropical climatic conditions in the Gulf region. The program was then applied to assess the distribution of shading of the ground by a cluster of courtyard forms assumed to be situated in this particular place and arranged in grid-iron grouping. The shading was averaged over three selected periods [8th December to 5th January, 7th March to 4th April and 8th June to 6th July] covering the seasonal variation of its distribution between the hours of 0700 and 1700.

The phases of change of the geometrical configuration of the courtyard form and surroundings described in Chapter VII were specified. Changes in proportion were considered by changing each set of the following ratios: [i] the ratio R_1 which relates courtyard area to built-up area [A_c/A_b], [ii] the ratio R_2 which relates built-up area to site area [A_b/A_s], [iii] the ratio R_3 which relates height of the courtyard form to its perimeter [H_c/P_c], and [iv] the ratio R_4 which relates height of the courtyard form to height of its surroundings [H_c/H_s]. It was also assumed that these courtyard forms have a constant value of orientation of zero degrees.

For each phase of change, the seasonal averages of the daily distribution of shading of the ground were calculated. Three sets of values were produced for the ground surface of both the courtyard's inner space and the urban space surrounding it: [i] for summer, [ii] for spring and autumn, and [iii] for winter.

CHAPTER VII

THE STRUCTURE OF A MODEL REPRESENTING THE INTERACTION BETWEEN THE COURTYARD FORM AND SOLAR SHADING

CHAPTER VII

THE STRUCTURE OF A MODEL REPRESENTING THE INTERACTION BETWEEN THE COURTYARD FORM AND SOLAR SHADING

VII.1 Introduction

This chapter is concerned with the structure of a mathematical model for assessing the shading behaviour of the courtyard form. Section VII.2 establishes the underlying principle governing the interaction between buildings and solar shading, and emphasizes the importance of treating the courtyard form and its surroundings as one built form.

Section VII.3 gives the geometrical description of both solar shading and the geometry of the courtyard form and surroundings. A representation of the model is given in section VII.4 where two sets of descriptors are related together to determine the shading of the ground from the sun.

VII.2 The Underlying Principle

The evaluation of the time-averaged distribution of shading of the ground by the courtyard form [the qualitatively chosen form in the present study] may be carried out by testing a model representing the interaction between this particular form and the sun's geometry.

The complexity of such an interaction can be seen in real urban situations where built forms may shade one another or cast separate patches or amalgamated patterns of shade on the ground.

In establishing the general principles which underly the interaction between buildings and their environments, Lord and Wilson [1980] argue that 'there is a complex interaction between the forms of individual buildings, the layout of the group and the wind, and the form which has to be studied is the whole group treated as one built form, i.e., models of the flow in it cannot be constructed by adding together models of the flows about individual buildings'. They concluded that 'if operational models are to be made of processes as complex as these, there must be some simplification; but reducing the performance of buildings to a sum of the performances of their parts is not the only way of proceeding and in many cases it is misleading' [1980, p. 152].

Since a group of buildings placed in an air stream would act in a quite non-linear way, this underlying principle was considered, in this particular argument, to be a matter of 'necessity' for the wind. However, the thing that concerns us here is the idea of treating a group of buildings as if they were one built form. Although this particular argument is much stronger for the wind than it is for solar shading, we shall, for the purposes of the present study, consider this underlying principle as a matter of 'convenience' for the SHADE investigations.

However, with all the varieties of possible built form arrangements, we encounter the problem of choosing the pattern in which this group of courtyard forms might be laid out. In this work the emphasis is placed only upon one specific arrangement in which courtyards are uniformly patterned in grid-iron formation.[1] There

---

[1] Urban structures comprise a complex set of mass/void relationships interwoven with a complex set of people/activity. However, in order to simplify the procedure by which a systematic quantitative investigation of shade can be carried out, masses and voids are assumed to occur in all directions with equal pattern, and evenly distributed on the ground. The basic assumption about the ground that it is flat and homogeneous, i.e., an isotropic plain with equal physical properties in all directions; this of course may take the form of either a grid-iron or checkerboard grouping [Figure VII.1].

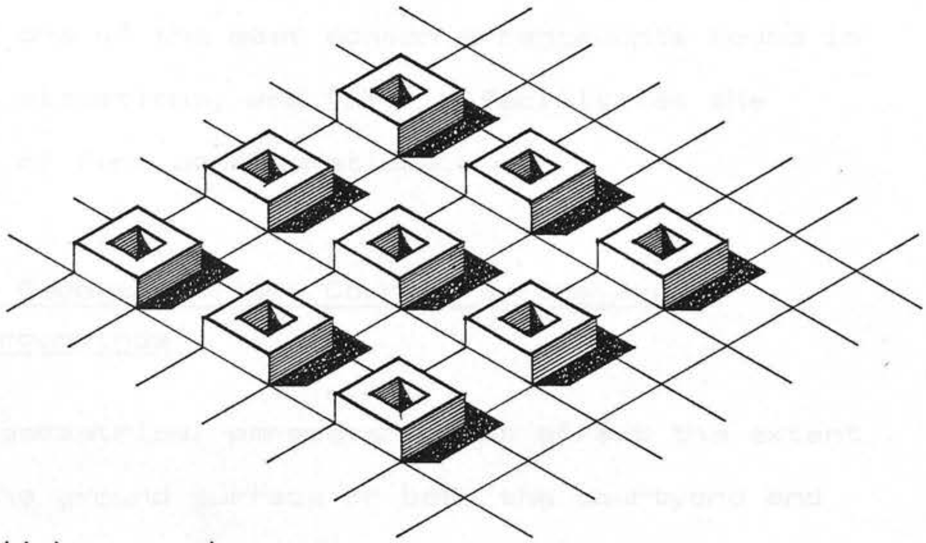


Figure VII.1(a) Grid-iron grouping

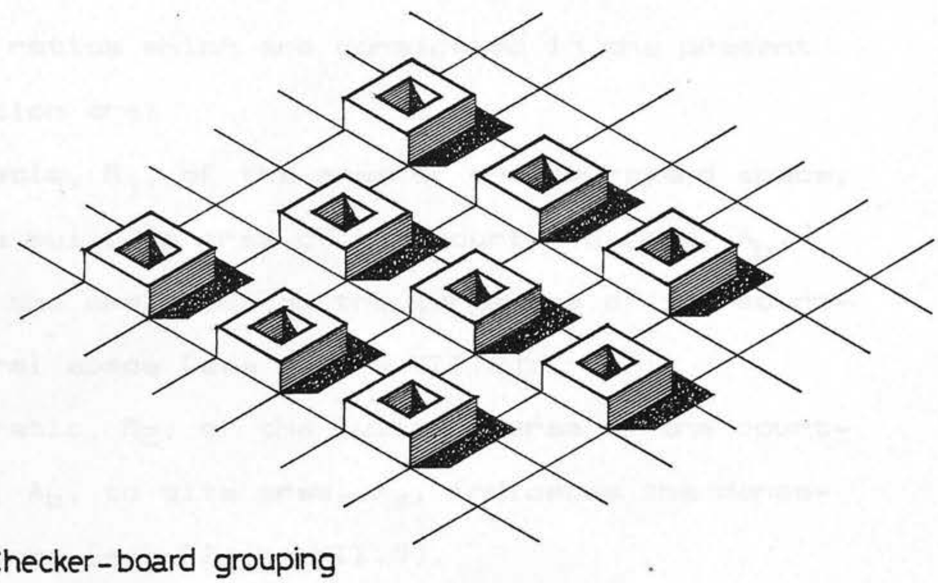


Figure VII.1(b) Checker-board grouping

Figure VII.1 The two arrangements of the geometrical configuration of the courtyard form and surroundings are two reasons for this particular choice: [i] it represents one of the most common arrangements found in real urban situations, and [ii] it facilitates the generation of form configurations.

VII.3 The Geometry of the Courtyard Form and Surroundings

The geometrical parameters that affect the extent to which the ground surface of both the courtyard and urban space are shaded from the sun are the proportions and orientation of the courtyard form and surroundings.

VII.3.1 Proportions of the Courtyard Form

The ratios which are considered in the present investigation are:

[i] The ratio, R_1, of the area of the courtyard space, A_c, to the built-up area of the courtyard form, A_b, indicates the smallness or the largeness of the courtyard central space [see Figure VII.2].

[ii] The ratio, R_2, of the built-up area of the courtyard form, A_b, to site area, A_s, indicates the denseness of forms [see Figure VII.3].

[iii] The ratio, R_3, of the height of the courtyard form, H_c, to its perimeter, P_c, indicates the shallowness or the deepness of forms [see Figure VII.4].

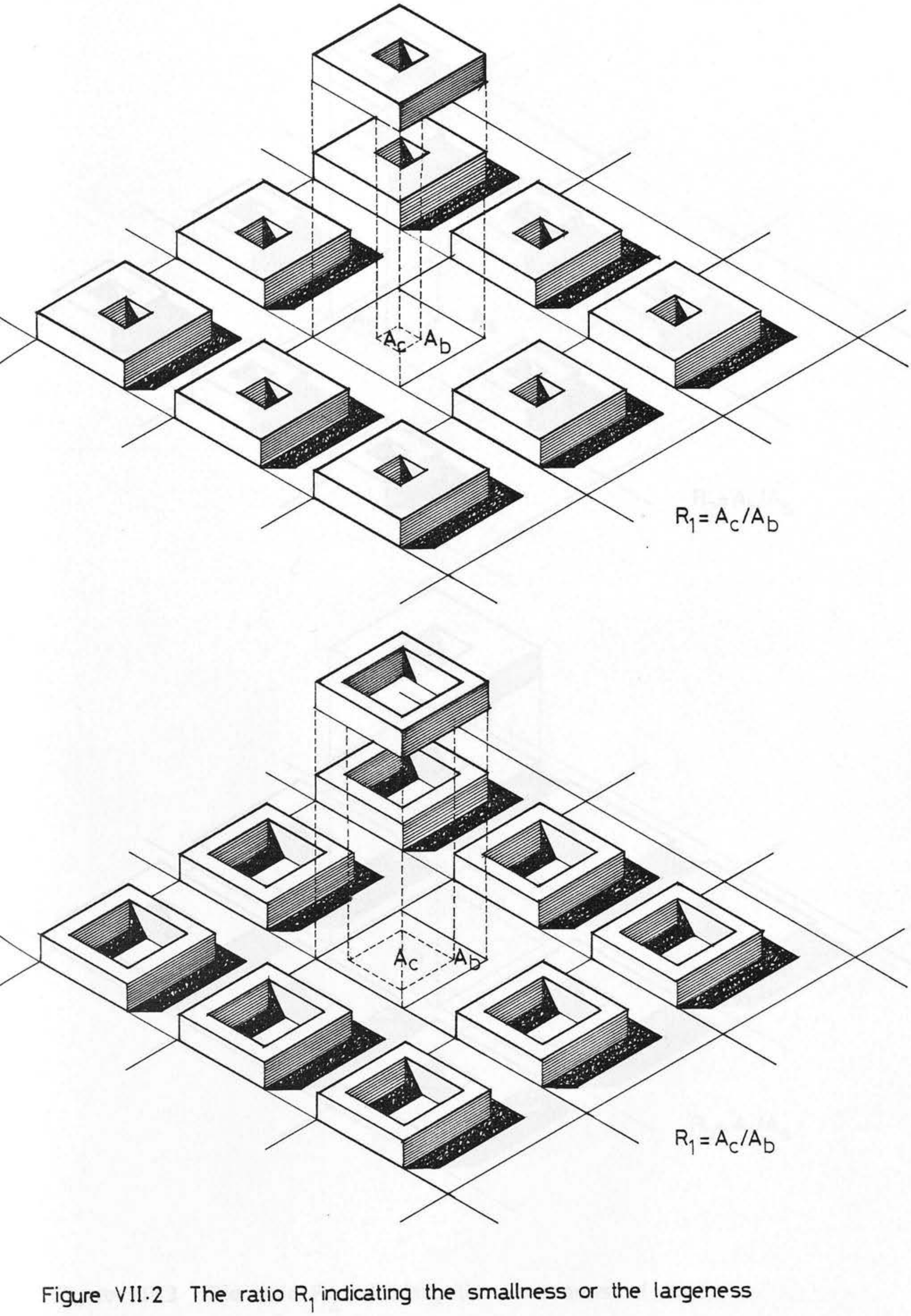


Figure VII.2 The ratio R_1 indicating the smallness or the largeness of the courtyard space

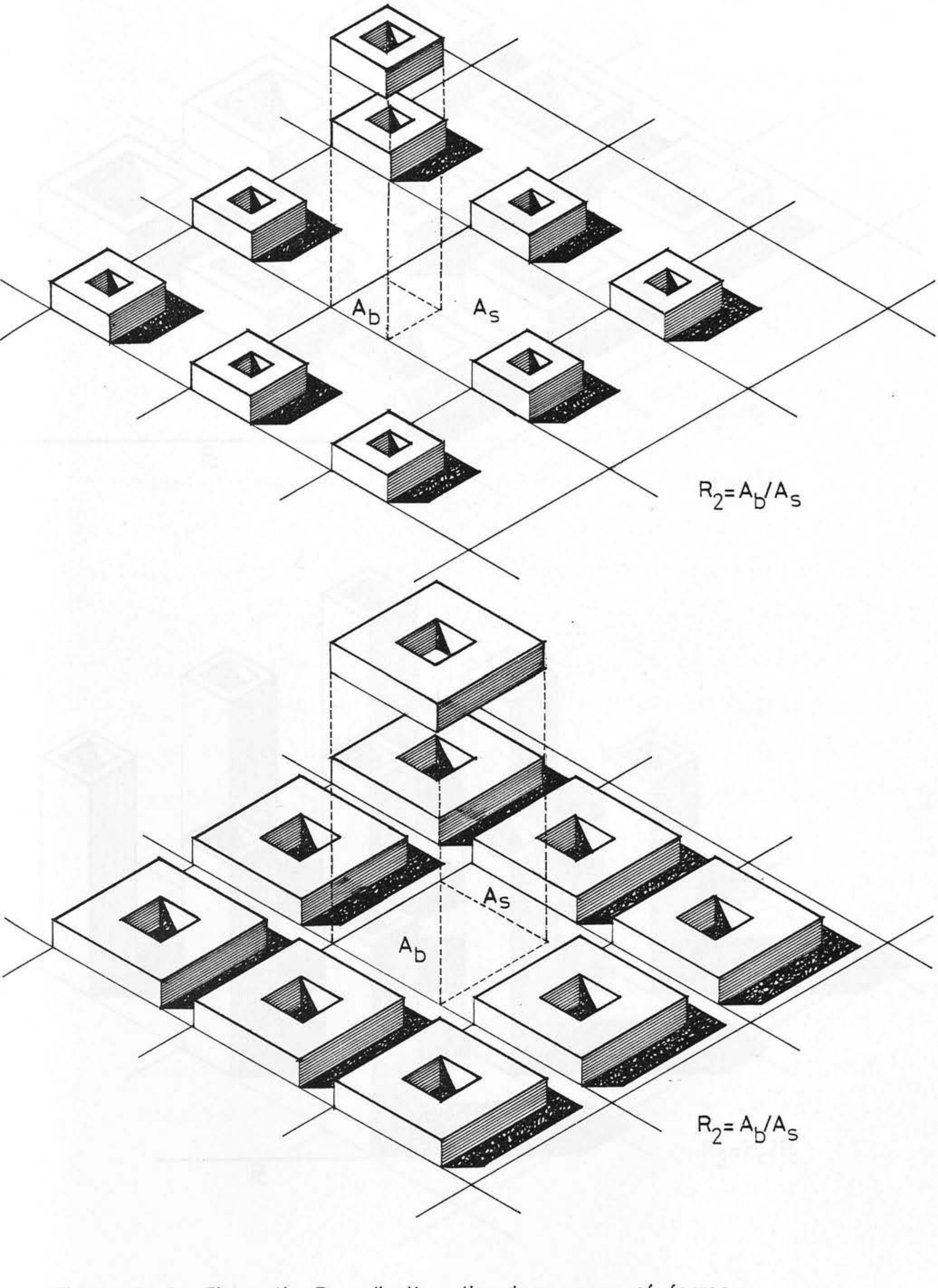


Figure VII.3 The ratio R_2 indicating the denseness of forms

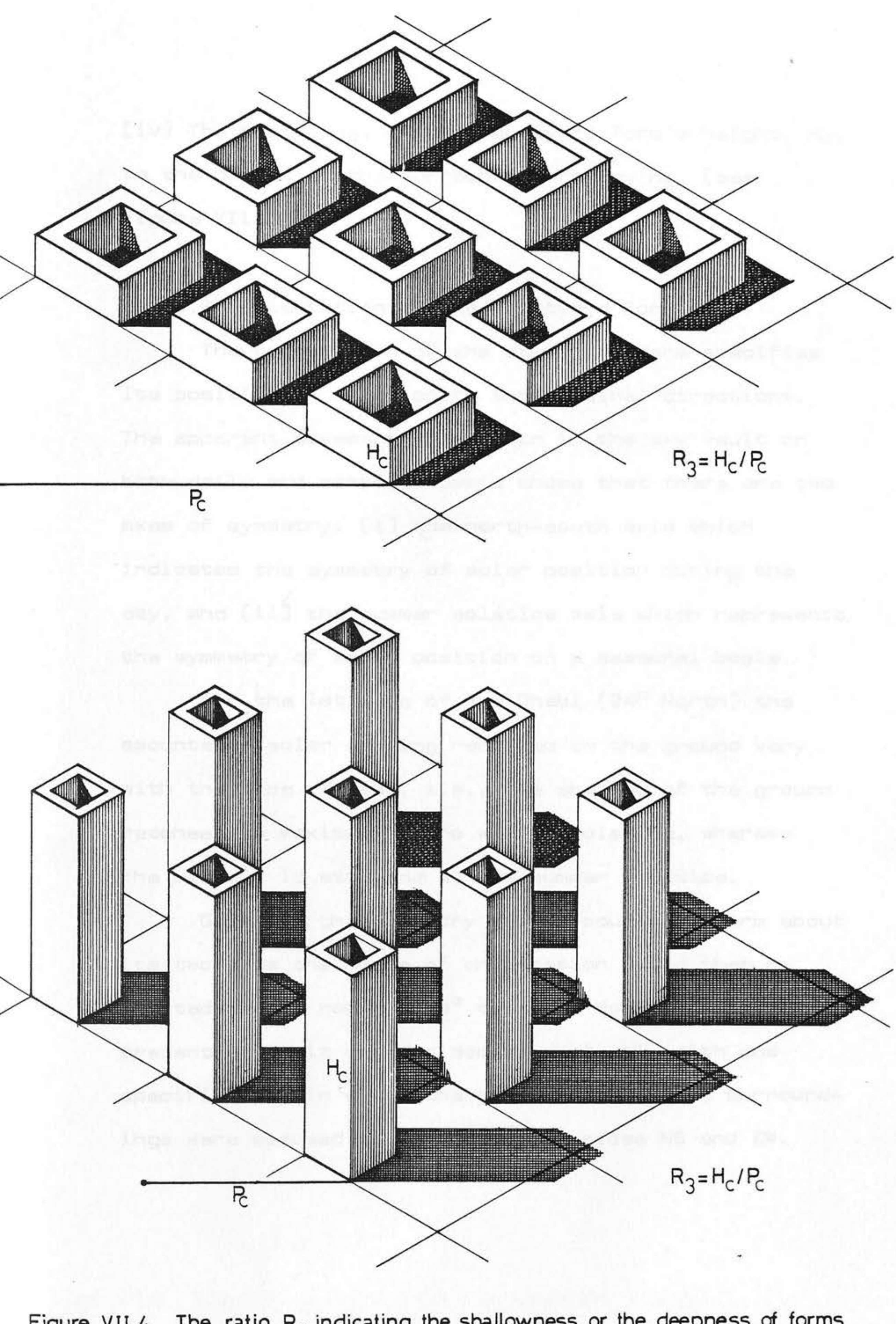


Figure VII.4 The ratio R_3 indicating the shallowness or the deepness of forms

[iv] The ratio, R_4, of the courtyard form's height, H_c, to the height of the surrounding forms, H_s, [see Figure VII.5].

VII.3.2 Orientation of the Courtyard Form

The orientation of the courtyard form specifies its position in relation to the cardinal directions. The apparent movement of the sun in the sky vault on both daily and seasonal basis shows that there are two axes of symmetry: [i] the north-south axis which indicates the symmetry of solar position during the day, and [ii] the summer solstice axis which represents the symmetry of solar position on a seasonal basis.

For the latitude of Abu Dhabi [24^o North] the amounts of solar shading received on the ground vary with the time of year, i.e., the shading of the ground reaches its maximum at the winter solstice, whereas the minimum is attained at the summer solstice.

Owing to the symmetry of the courtyard form about its two axes the range of orientation would then be limited to the range of 0^o to 90^o. However, in the present study it was decided to deal only with one specific case in which the courtyard form and surroundings were assumed to be with their sides NS and EW.

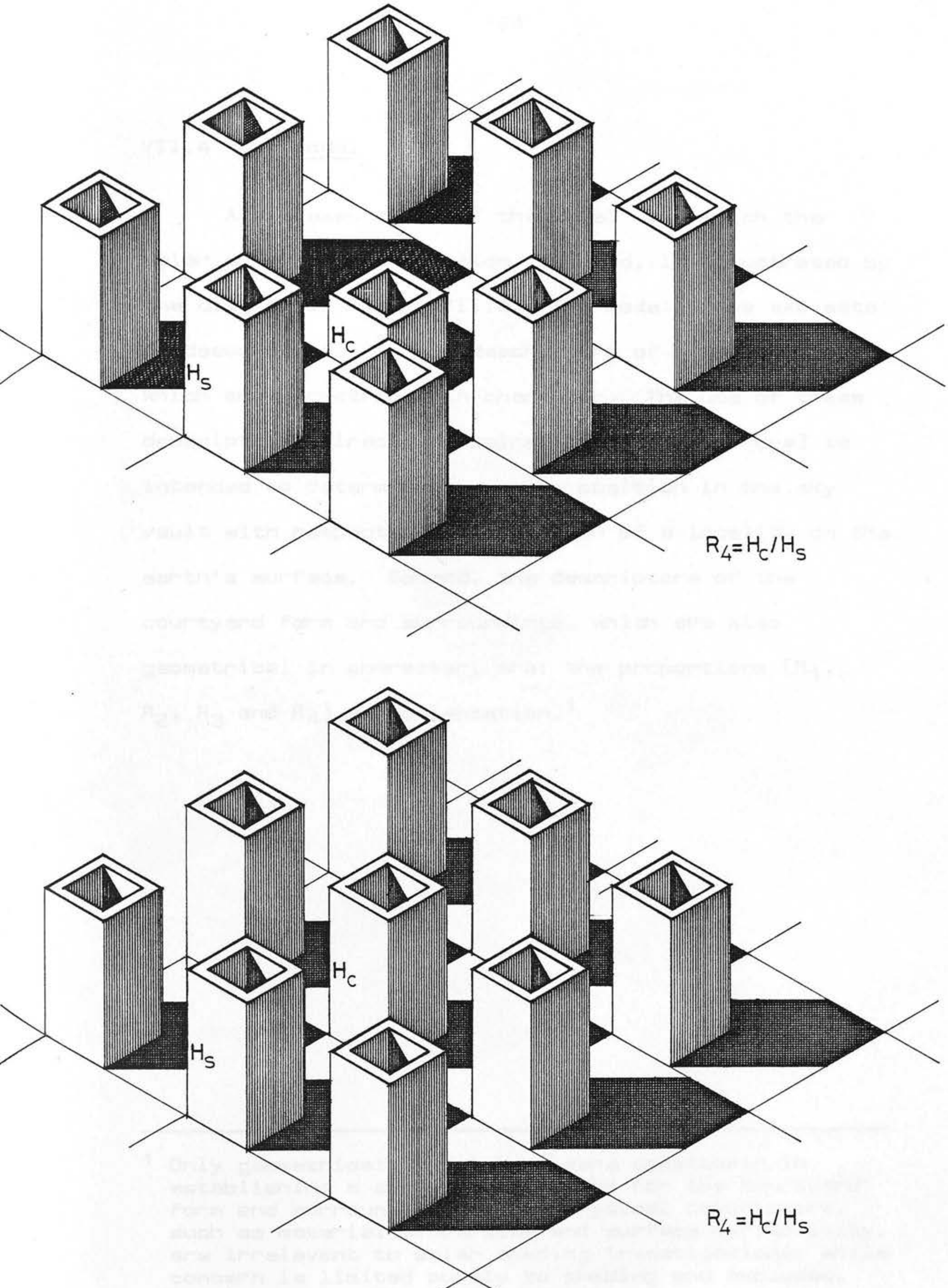


Figure VII.5 The ratio R_4 relating the courtyard form's height to the height of the surrounding forms

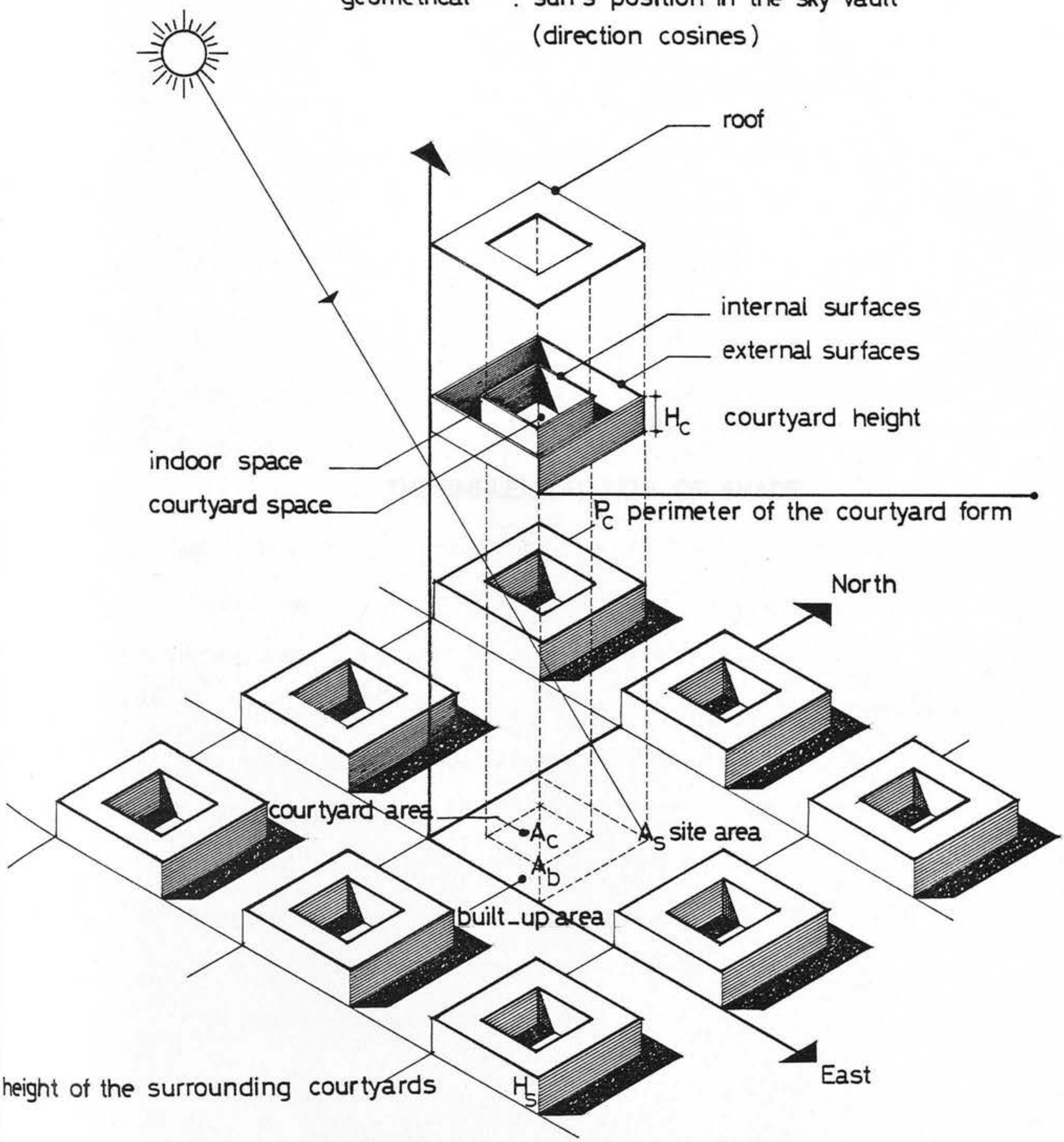
VII.4 The Model

A representation of the model upon which the solar shading investigation is based, is illustrated by the diagram of Figure VII.6. The model shows two sets of descriptors. First, descriptors of solar shading which are geometrical in character. The use of these descriptors [direction cosines of the sun's rays] is intended to determine the solar position in the sky vault with respect to the position of a locality on the earth's surface. Second, the descriptors of the courtyard form and surroundings, which are also geometrical in character, are: the proportions [R_1, R_2, R_3 and R_4] and orientation.[1]

---

1 Only geometrical descriptors were considered in establishing a set of descriptors for the courtyard form and surroundings, since physical descriptors, such as material properties and surface reflectivity, are irrelevant to solar shading investigations; while concern is limited purely to shading and excludes, for example, reflected radiation.

Descriptors of solar shading :
geometrical : sun's position in the sky vault
(direction cosines)



Descriptors of the courtyard form and surroundings :
geometrical : a) proportions : courtyard area ratio,
built_up area ratio,
and height ratio
b) orientation

Figure VII.6 The model

CHAPTER VIII

THE IMPLEMENTATION OF SHADE

CHAPTER VIII

THE IMPLEMENTATION OF SHADE

VIII.1 Introduction

This chapter describes the kind of results that the designer would get from SHADE, and provides a complete description of how the program is run.

Section VIII.2 is concerned with the assessment of the different categories of input that the program requires to perform an analysis. Section VIII.3 provides examples of the program's output.

The site selected for the present investigation was assumed to be located in the city of Abu Dhabi [latitude 24^{o}]. The ground surface of the site was assumed to be level as required by the program in its present state. The site comprises 9 courtyard forms in a grid-iron arrangement with their axes lying in the North-South direction.

VIII.2 Input to the Program

In preparation for an analysis, the program has to be presented with two categories of input: The first, which defines the general characteristics of the site and the scope and resolution of the analysis, is used by the program to prepare itself to start the main calculation. The second consists of a selection of commands [see Chapter VI], and their associated data, which the designer may specify in any order and which allow him to set up and analyze any layout.

VIII.2.1 Preparation for analysis

Before defining and analyzing a layout the following data must be specified in order to perform an analysis:

[1] Running mode. The program may be run either interactively from a teletype or visual display unit or in batch mode. When the designer enters the word INTERACTIVE the program issues a prompt when input is required and draws his attention if erroneous input is made. In BATCH mode the prompts are restrained and calculation gets terminated once the first error has been detected.

[2] Initialization mode. The program provides the facility of developing a layout over a series of runs. This is done by entering the word OLD whereupon the program will return itself to its state immediately before the previous run is terminated. If the designer wishes to start analyzing a new site he must enter the word NEW. As soon as NEW is entered the data describing the previous layout is deleted.

[3] Site definition. In the case of analyzing a new layout the designer should specify the following data:

[i] The longitude of the site

[ii] The latitude of the site

[iii] The maximum dimension of the site in the East/West direction XMAX

[iv] The maximum dimension of the site in the North/South direction YMAX

[v] The resolution of calculation in the East/West direction NXMAX*

[vi] The resolution of calculation in the North/South direction NYMAX*

In the present study the latitude 24° N was chosen to define a site assumed to be located within Abu Dhabi area [see Figure VIII.1]. The longitude and latitude of the site are specified in degrees.

In order to define the locations of buildings, a co-ordinate system must be imposed upon the site. The rows and columns of grid nodes must be aligned with the cardinal directions, i.e., the X and Y axes should point towards East and North respectively. The point where the X and Y axes intersect is taken as a datum to which the locations of the buildings are referred,

---

* NXMAX and NYMAX are input of two digit numbers lying within the range 2 to 20.

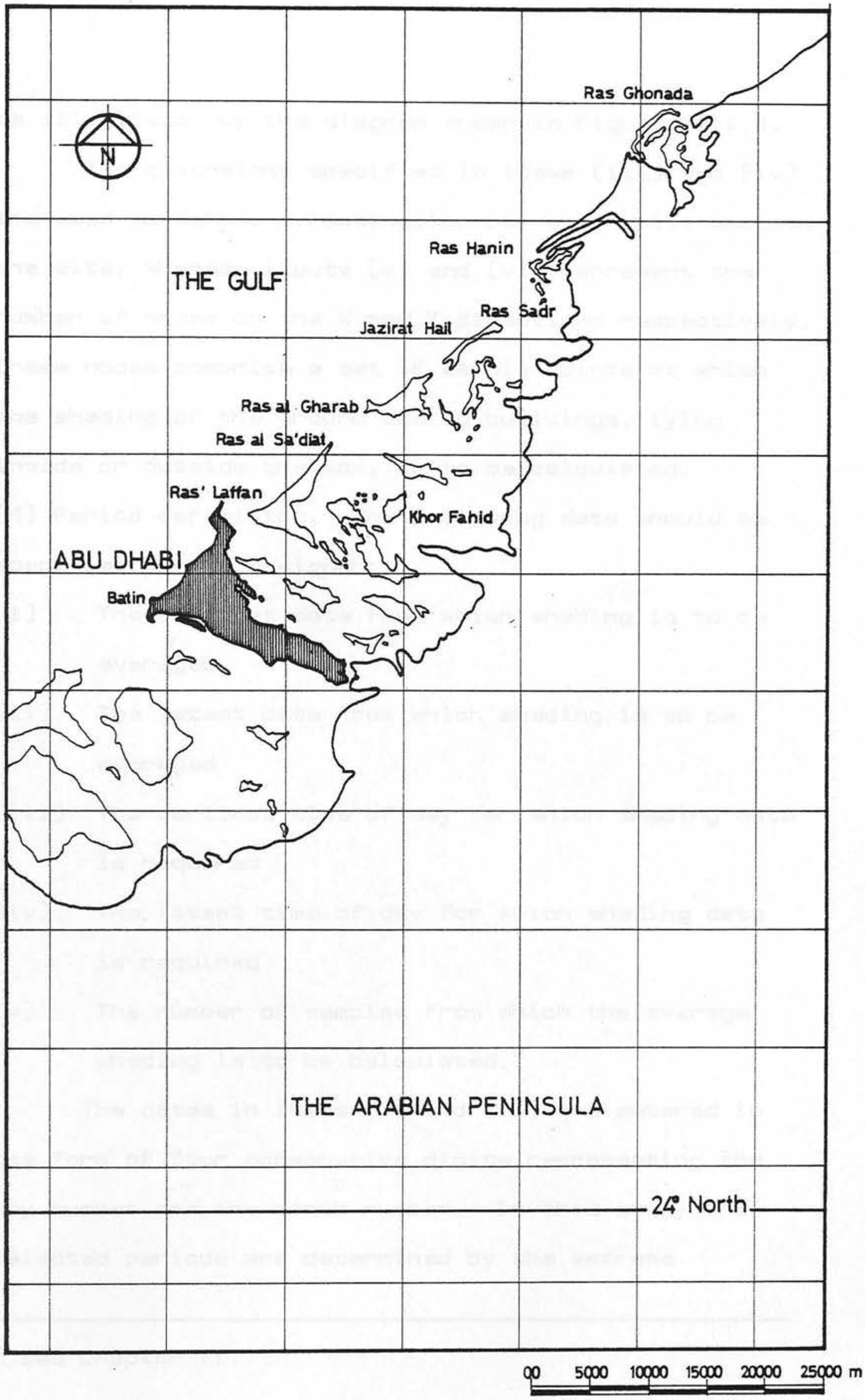


Figure VIII.1 Map of Abu Dhabi area

as illustrated by the diagram shown in Figure VIII.2.

The dimensions specified in items [iii] and [iv] are used to define a rectangular box which will enclose the site, whereas inputs [v] and [vi] represent the number of nodes in the X and Y directions respectively. These nodes comprise a set of sample points at which the shading of the ground due to buildings, lying inside or outside the box, is to be calculated.

[4] Period definition. The following data should be specified by the designer:

[i] The earliest date from which shading is to be averaged

[ii] The latest date from which shading is to be averaged

[iii] The earliest time of day for which shading data is required

[iv] The latest time of day for which shading data is required

[v] The number of samples from which the average shading is to be calculated.*

The dates in items [i] and [ii] are entered in the form of four consecutive digits representing the day number and the month number. In this study the selected periods are determined by the extreme

---

* See Chapter VI.

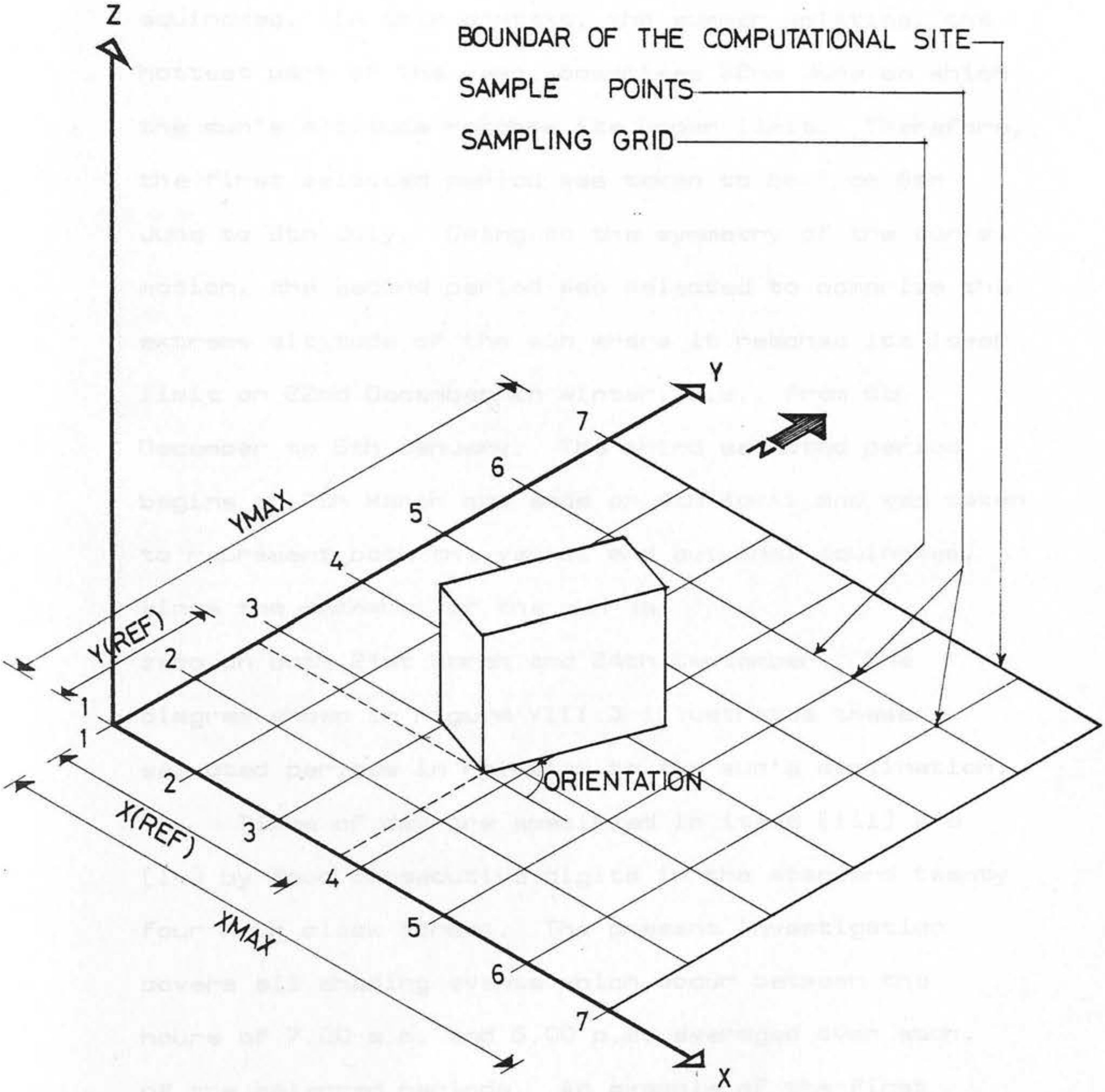


Figure VIII·2 Computational site definition and label convention position of the sun and the equinoxes, i.e., the summer and winter solstices as well as the vernal and autumnal equinoxes. In this context, the summer solstice, the hottest part of the year, comprises 22nd June on which the sun's altitude reaches its upper limit. Therefore, the first selected period was taken to be from 8th June to 6th July. Owing to the symmetry of the sun's motion, the second period was selected to comprise the extreme altitude of the sun where it reaches its lower limit on 22nd December in winter, i.e., from 8th December to 5th January. The third selected period begins on 7th March and ends on 4th April and was taken to represent both the vernal and autumnal equinoxes, since the declination of the sun is zero on both 21st March and 24th September. The diagram shown in Figure VIII.3 illustrates these selected periods in relation to the sun's declination.

Times of day are specified in items [iii] and [iv] by four consecutive digits in the standard twenty four hour clock format. The present investigation covers all shading events which occur between the hours of 7.00 a.m. and 5.00 p.m. averaged over each of the selected periods. An example of the first category of inputs is given in Figure VIII.4.

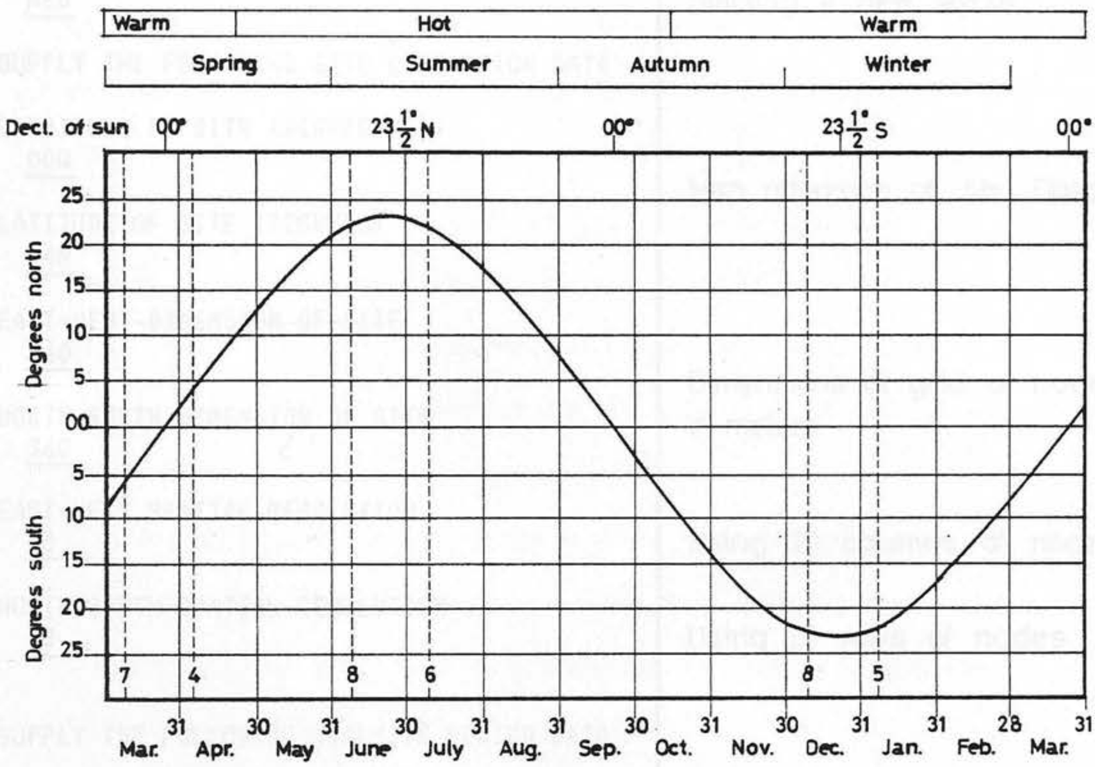


Figure VIII·3 The three selected periods in reference to the declination of the sun

*** SHADE SYSTEM *** VERSION 4.0 PRODUCED FROM VERSION 3.0 BY T HANSON AT 1 JUNE 1982	
*** BEGINNING START-UP PROCEDURE ***	Explanatory remarks
PROGRAM TO BE RUN INTERACTIVELY OR IN BATCH INT	Program to be run under direct user control
PLEASE SUPPLY ALL FOLLOWING INPUTS, ONE ITEM PER LINE	
NEW OR OLD SITE NEW	Starting a new layout
SUPPLY THE FOLLOWING SITE DEFINITION DATA	
LONGITUDE OF SITE (DEGREES) 00W LATITUDE OF SITE (DEGREES) 24N	Map reference of Abu Dhabi
~~EAST-WEST-DIMENSION-OF-SITE~~ 360 NORTH-SOUTH DIMENSION OF SITE 360	Dimensions of grid of nodes in meters
EAST-WEST SPATIAL RESOLUTION 20	Using 20 columns of nodes
NORTH-SOUTH SPATIAL RESOLUTION 20	Using 20 rows of nodes
SUPPLY THE FOLLOWING ANALYSIS PERIOD DATA	
START DATE 0812 END DATE 0607	Data base to contain sufficient information so that results can be averaged over period 8 Dec. to 6 July
START HOUR 0700 END HOUR 1700	Data base to contain sufficient information so that results can be provided over the hours of 7.00 am to 5.00 pm
ENTER NUMBER OF SAMPLES TO BE USED 5	5 sample days to be used
*** START-UP PROCEDURE COMPLETE ***	
READY	

Note: Only underlined items are typed by user.

Figure VIII.4 An example of the start-up procedure

VIII.2.2 Definition and analysis of layout

Once the start-up procedure has been completed, the second category of inputs, which consist of a set of commands, can be entered by the designer. The use of these commands allows layouts to be constructed and modified by providing a means of introducing and positioning new buildings or of manipulating existing ones. The two main commands are: [i] DEFINE, by which a new building can be introduced to the program, and [ii] DISPLAY, by which output can be obtained.

The DEFINE command is qualified by three kinds of information:

[i] A reference number by which the program can distinguish the given building and its associated information, and hence prevents multiple usages.

[2] A description of the geometry of the building. The program simplifies this geometrical description by the provision of a library of generalized form descriptions to which dimensional information is added by the designer.[1] Since the present study includes

---

1 Although the program's library did not include the geometry of the courtyard form, it was nonetheless possible to introduce this particular form to the program by defining four identical blocks intersecting at 90° as illustrated by the diagram shown in Figure VIII.5.

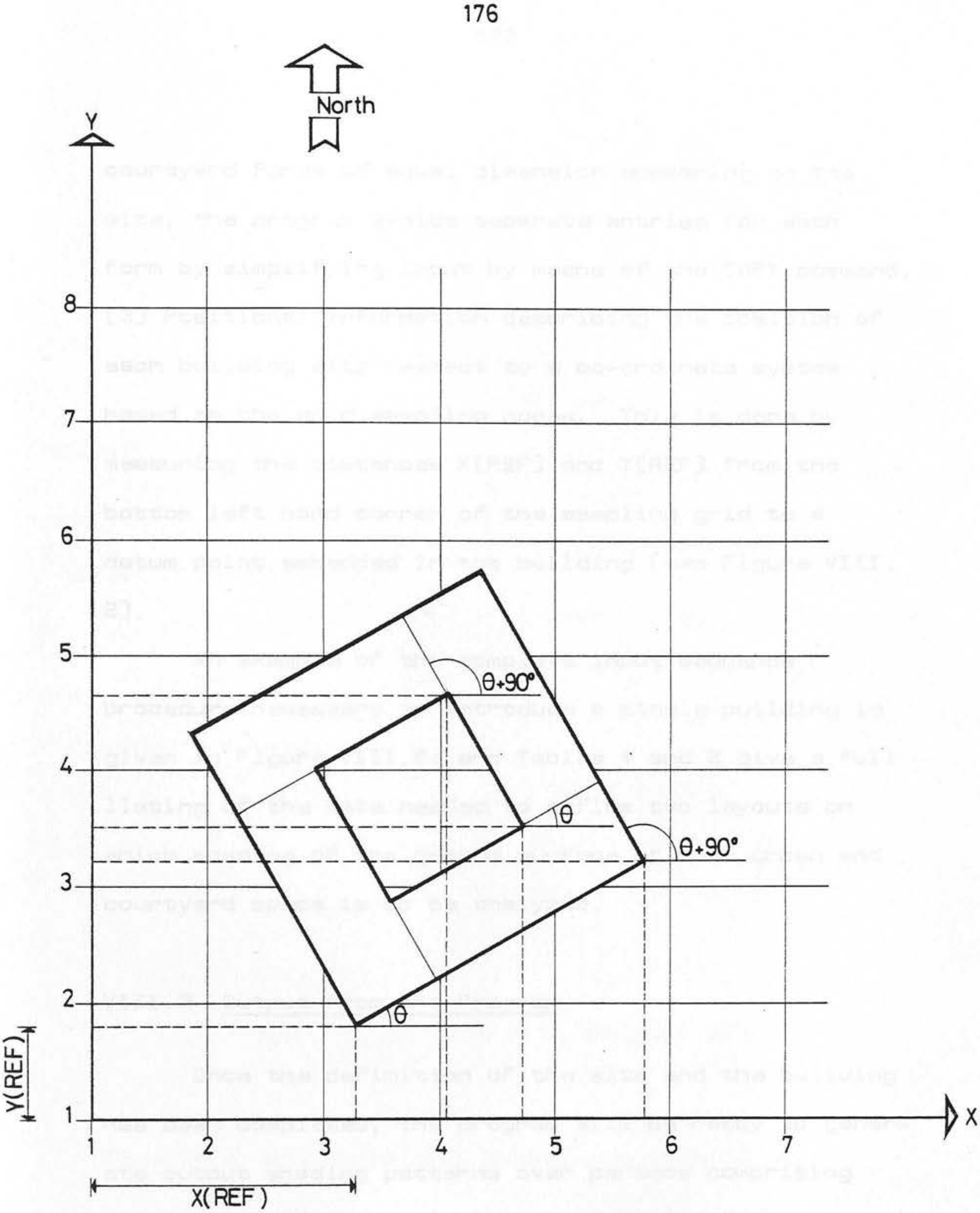


Figure VIII·5 Definition of courtyard by means of four blocks courtyard forms of equal dimension appearing on the site, the program avoids separate entries for each form by simplifying input by means of the COPY command. [3] Positional information describing the position of each building with respect to a co-ordinate system based on the grid sampling nodes. This is done by measuring the distances X[REF] and Y[REF] from the bottom left hand corner of the sampling grid to a datum point embedded in the building [see Figure VIII. 2].

An example of the complete input sequence procedure necessary to introduce a single building is given in Figure VIII.6; and Tables 1 and 2 give a full listing of the data needed to define two layouts on which shading of the ground surface of both urban and courtyard space is to be analyzed.

VIII.3 Output from the Program

Once the definition of the site and the building has been completed, the program will be ready to generate output shading patterns over periods comprising all or part of the maximum span of days and hours specified during the start up procedure. This is done by using the DISPLAY command. An example of the procedure needed to produce output is given in

	Explanatory remarks
READY	
DEF	New building to be introduced to program
REFERENCE NUMBER	
02	Will henceforth be referred to as building no. 2
COMPONENT TYPE	
BLOCK	Building is a rectangular block
ENTER REFERENCE POINT INFORMATION	
X(REF)	
18	It is 18.00m to East of grid datum
Y(REF)	
1	It is 1.00m to North of grid datum
ORIENTATION (DEGREES)	
00	It runs 00 degrees to North of East_West axis
ENTER DIMENSIONS AS PER MANUAL	
WHEN AT END OF LIST TYPE EOL	
18	Length of building
38	Width of building
39.4360	Height of building
EOL	Terminator used to signal the end of input of each building
WAIT	
READY	

Note: Only underlined items are typed by user.

Figure VIII.6 An example of a building specification

```
         REF. NO.  2  TYPE BLOCK
 X(REF) =    0.00  Y(REF) =    0.00  ORIENTATION =    0.00
   L =   9.49  W =   9.49  H =   9.49

         REF. NO.  3  TYPE BLOCK
 X(REF) =   30.00  Y(REF) =    0.00  ORIENTATION =    0.00
   L =   9.49  W =   9.49  H =  18.97

         REF. NO.  4  TYPE BLOCK
 X(REF) =   30.00  Y(REF) =  -30.00  ORIENTATION =    0.00
   L =   9.49  W =   9.49  H =  18.97

         REF. NO.  5  TYPE BLOCK
 X(REF) =    0.00  Y(REF) =  -30.00  ORIENTATION =    0.00
   L =   9.49  W =   9.49  H =  18.97

         REF. NO.  6  TYPE BLOCK
 X(REF) =  -30.00  Y(REF) =  -30.00  ORIENTATION =    0.00
   L =   9.49  W =   9.49  H =  18.97

         REF. NO.  7  TYPE BLOCK
 X(REF) =  -30.00  Y(REF) =    0.00  ORIENTATION =    0.00
   L =   9.49  W =   9.49  H =  18.97
```

Table VIII.1 Data describing a layout for the analysis of shading events occurring in the urban space

```
        REF. NO.  3  TYPE BLOCK
X(REF) =  107.02  Y(REF) =  -12.97  ORIENTATION =    0.00
  L =  37.95  W =  37.95  H =  75.89

        REF. NO.  4  TYPE BLOCK
X(REF) =  107.02  Y(REF) = -132.97  ORIENTATION =    0.00
  L =  37.95  W =  37.95  H =  75.89

        REF. NO.  5  TYPE BLOCK
X(REF) =  -12.97  Y(REF) = -132.97  ORIENTATION =    0.00
  L =  37.95  W =  37.95  H =  75.89

        REF. NO.  6  TYPE BLOCK
X(REF) = -132.97  Y(REF) = -132.97  ORIENTATION =    0.00
  L =  37.95  W =  37.95  H =  75.89

        REF. NO.  7  TYPE BLOCK
X(REF) = -132.97  Y(REF) =  -12.97  ORIENTATION =    0.00
  L =  37.95  W =  37.95  H =  75.89

        REF. NO.  8  TYPE BLOCK
X(REF) =   -6.00  Y(REF) =   -1.00  ORIENTATION =    0.00
  L =   6.00  W =  14.00  H =  45.54

        REF. NO.  9  TYPE BLOCK
X(REF) =   12.00  Y(REF) =   -1.00  ORIENTATION =    0.00
  L =   6.00  W =  14.00  H =  45.54

        REF. NO. 10  TYPE BLOCK
X(REF) =   13.00  Y(REF) =   -6.00  ORIENTATION =   90.00
  L =   6.00  W =  14.00  H =  45.54
```

Table VIII·2 Data describing a layout for the analysis of shading events occurring within the courtyard space

Figure VIII.7 which represents shading distribution in urban space generated by the courtyard form and its surroundings identified by reference numbers 2, 3, 4, 5, 6 and 7 between the hours of 0700 and 1700 averaged over the period of 8th December to 5th January which represents shading events during winter.

The program's output is presented in two forms: [i] numerically, in the form of a synopsis comprising a table of the percentage of shading at each of the grid nodes [see Figure VIII.8], and [ii] graphically, in the form of an annotated map on which the distribution of shading is presented as a range of ten tones used to differentiate variations between total and zero shading [see Figure VIII.9].

	Explanatory remarks
READY DIS	User requests a printout
ENTER PERIOD OVER WHICH RESULTS REQUIRED	
START DATE 0812 END DATE 0501	Results to be averaged over the period from 8 Dec. to 5 Jan.
START HOUR 0700 END HOUR 1700	User requires shading distribution between the hours of 7.00 am and 5.00 pm
ENTER REFERENCE NUMBERS OF FORMS TO BE DISPLAYED WHEN AT END OF LIST TYPE EOL	
2 3 4 5 6 7	Shading effects will be due to buildings with reference numbers 2,3,4,5,6 and 7
EOL WAIT	Terminator

Note: Only underlined items are typed by user.

Figure VIII.7 An example of a printout request

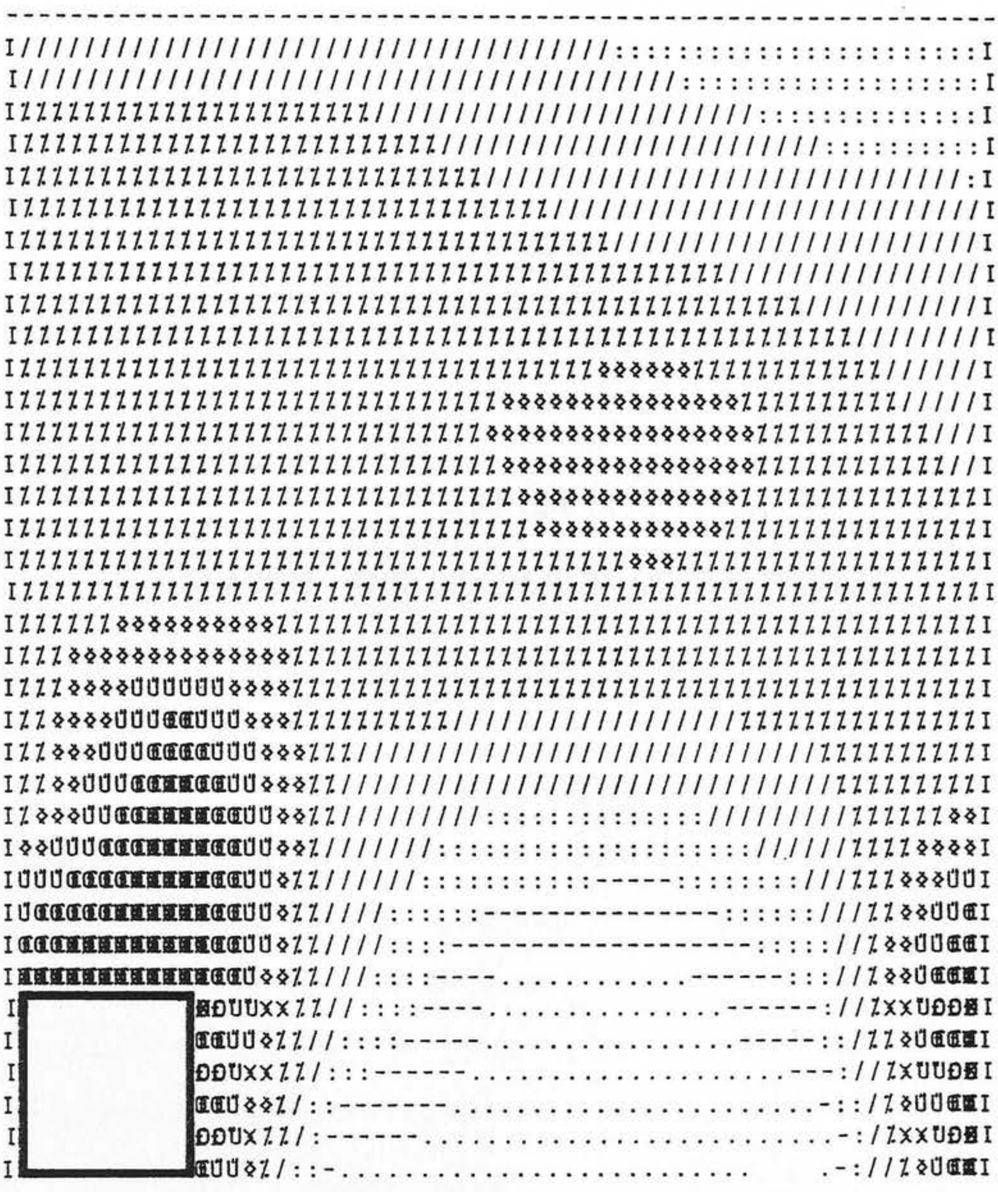
Explanatory remarks

```
*** SYNOPTIC OUTPUT ***

SHADING AS A PERCENTAGE OF THE POSSIBLE HOURS BETWEEN
0700 AND 1700 AVERAGED OVER THE PERIOD  8-12 TO  5- 1
THE VALUES HAVE BEEN ROUNDED TO THE NEAREST PERCENTAGE
BUT ARE OTHERWISE EXACT

THE SHADING IS GIVEN AT EACH OF THE GRID NODES AND
** MEANS TOTAL SHADING AT THAT POINT

SHADING DUE TO FORMS WITH FOLLOWING REFERENCE NOS.
  2   3   4   5   6   7

THE NODES ARE SEPARATED BY  5.00 AND  5.00 UNITS IN
THE X AND Y DIRECTIONS RESPECTIVELY

                        N
                       NNN
                      NNNNN
                        N
                        N NORTH
                        N
                        N
   I  48 48 47 43 39 36 34
 5 I  58 59 58 53 48 45 43
   I  55 56 56 62 67 58 47
   I  58 61 60 60 59 60 58
   I  50 ** 49 43 41 48 62
   I  ** ** 47 19 15 34 **
 0 I  ** ** 18 16 12  8 **
   I
   -----------------------
      0                 5

THE OPEN SPACES OF THE SITE ARE SHADED  50.00 PERCENT OF THE POSSIBLE HOURS

WOULD YOU LIKE A MAP OF THE ABOVE TO BE PRINTED
PLEASE ANSWER YES OR NO
 YES

READY
```

User requests average shading distribution map

Figure VIII·8 An example of the program's numerical output

A map of the average shading beteen the hours of 700 and 1700 over the period 8_December to 5_January inclusive



This is a map of the shading due to the forms with the following reference numbers 2, 3, 4, 5, 6 and 7

```
         KEY TO SYMBOLS                                    KEY TO LENGTH SCALES
         --------------                                    --------------------
                                                      I
  REPRESENTS  0 TO  10 PERCENT SHADING   N            I
. REPRESENTS 11 TO  20 PERCENT SHADING  NNN           I
- REPRESENTS 21 TO  30 PERCENT SHADING NNNNN          I <- LINE IS     5.00 UNITS HIGHT
: REPRESENTS 31 TO  40 PERCENT SHADING   N            I
/ REPRESENTS 41 TO  50 PERCENT SHADING   N            I
% REPRESENTS 51 TO  60 PERCENT SHADING   N             ----------
X REPRESENTS 61 TO  70 PERCENT SHADING
Ü REPRESENTS 71 TO  80 PERCENT SHADING       LINE ABOVE IS     5.00 UNITS LONG
Œ REPRESENTS 81 TO  90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING
```

Figure VIII·9 An example of the program's graphical output

CHAPTER IX

ANALYSIS AND DISCUSSION OF THE RESULTS

CHAPTER IX

ANALYSIS AND DISCUSSION OF THE RESULTS

IX.1 Introduction

The main purpose of the model is to carry out a systematic quantitative investigation into the shading performance of the groups of courtyard forms. Although the study is illustrative, the information generated by it may also have practical implications for the designer.

The phenomenological analysis presented in Chapters II, III, IV and V brought into view the courtyard form as a design hypothesis for the present investigation into solar shading. This made it possible to define the inner areas, proportions, built-up areas and orientations of groups of courtyard forms in terms of the time-averaged distribution of shading of the ground surface of spaces in and around these forms.

Having generated the output data it is important to clarify the following points: [i] For the Gulf region, where skies are generally clear throughout the year, the shading events occurring between the hours of 7.00 a.m. and 5.00 p.m. during each of the three selected periods representing summer, spring and autumn, and winter, were considered as a useful measure for evaluating the shading performance of the courtyard form, [ii] although the distribution of shade varies with the orientation it was decided to deal only with one specific case in which the courtyard forms were assumed to be with their sides NS and EW, and [iii] during the course of the present study it was considered practical to concentrate attention on a limited number of cases common to real urban situations; the courtyard forms of identical square plan were therefore laid out in grid-iron grouping, giving the possibility of studying an urban pattern currently applied in the planning of the city of Abu Dhabi [see Chapter V].

However limited this objective may be, it is nonetheless significant, since the qualitative choice of the courtyard would then secure any further investigation from the endless analysis of meaningless forms, and hence confines it to the assessment of different arrangements and orientations which can be carried out along similar lines.

The shading data was generated for a range of form parameters. This was carried out for two different kinds of space: [i] the enclosed space of the courtyard, and [ii] the urban space surrounding it.

IX.2 The Effect of Changing R_2 and R_3 on SH_{tad} of the Urban Space Ground Surface

Concerning the height ratio R_3, it was decided to consider the range from 0.1 to 0.8 at 0.1 intervals; this means that the courtyard form and surroundings range uniformly from those having shallow courtyards to those having deeper ones. The averages were calculated for their individual values for summer (from 8th June to 6th July), spring and autumn (from 7th March to 4th April), and winter (from 8th December to 5th January) between the hours of 7.00 a.m. to 5.00 p.m. The time-averaged distribution of shading as a percentage, SH_{tad}, was then plotted against R_3 with the ratio R_2 ranging from 0.1 to 0.7 at 0.2 intervals.

Figure IX.1 illustrates the effect of changing the ratios R_2 and R_3 on SH_{tad} of the ground surface of the urban space in summer. The graphs show that the increase in the values of R_2 and R_3 results in a corresponding increase in the percentage of SH_{tad}. The increase however is less significant with R_3 approaching 0.8 for all values of R_2.

In summer, where shade is most needed, the contribution of R_2 to the percentage of SH_{tad} is best when it is given the value of 0.7 (built-up area is greater than that of the open space) with R_3 ranging from 0.1 to 0.4.

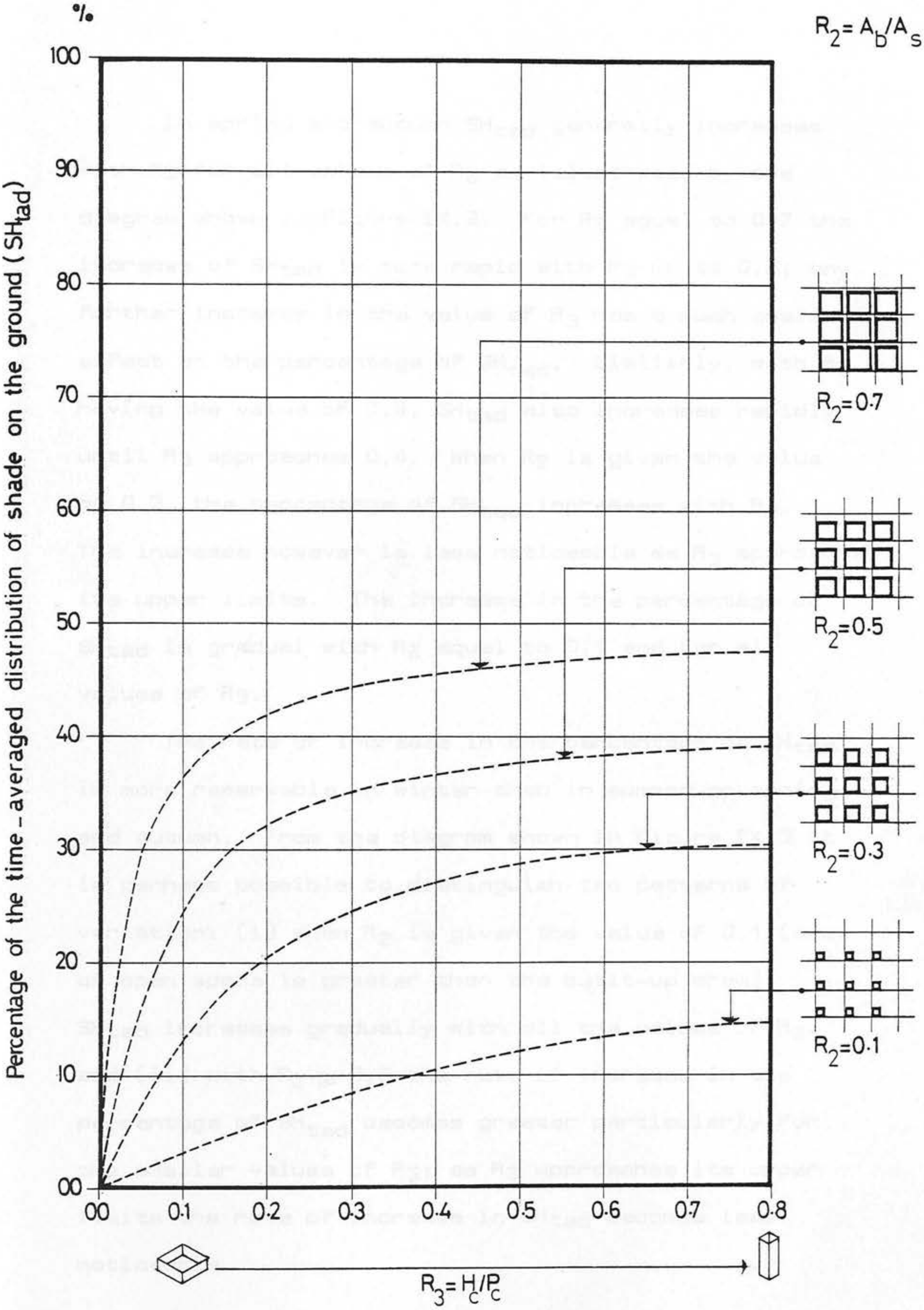


Figure IX.1 The effect of changing the ratios R_2 and R_3 on the time - averaged distribution of shading of the ground surface of the urban space in summer

In spring and autumn SH_{tad} generally increases with R_3 for all values of R_2 as illustrated by the diagram shown in Figure IX.2. For R_2 equal to 0.7 the increase of SH_{tad} is more rapid with R_3 up to 0.2; any further increase in the value of R_3 has a much smaller effect on the percentage of SH_{tad}. Similarly, with R_2 having the value of 0.5, SH_{tad} also increases rapidly until R_3 approaches 0.4. When R_2 is given the value of 0.3, the percentage of SH_{tad} increases with R_3. The increase however is less noticeable as R_3 approaches its upper limits. The increase in the percentage of SH_{tad} is gradual with R_2 equal to 0.1 and for all values of R_3.

The rate of increase in the percentage of SH_{tad} is more remarkable in winter than in summer or spring and autumn. From the diagram shown in Figure IX.3 it is perhaps possible to distinguish two patterns of variation: (i) when R_2 is given the value of 0.1 (area of open space is greater than the built-up area), SH_{tad} increases gradually with all the values of R_3, and (ii) with $R_2 \geqslant 0.3$ the rate of increase in the percentage of SH_{tad} becomes greater particularly for the smaller values of R_3; as R_3 approaches its upper limits the rate of increase in SH_{tad} becomes less noticeable.

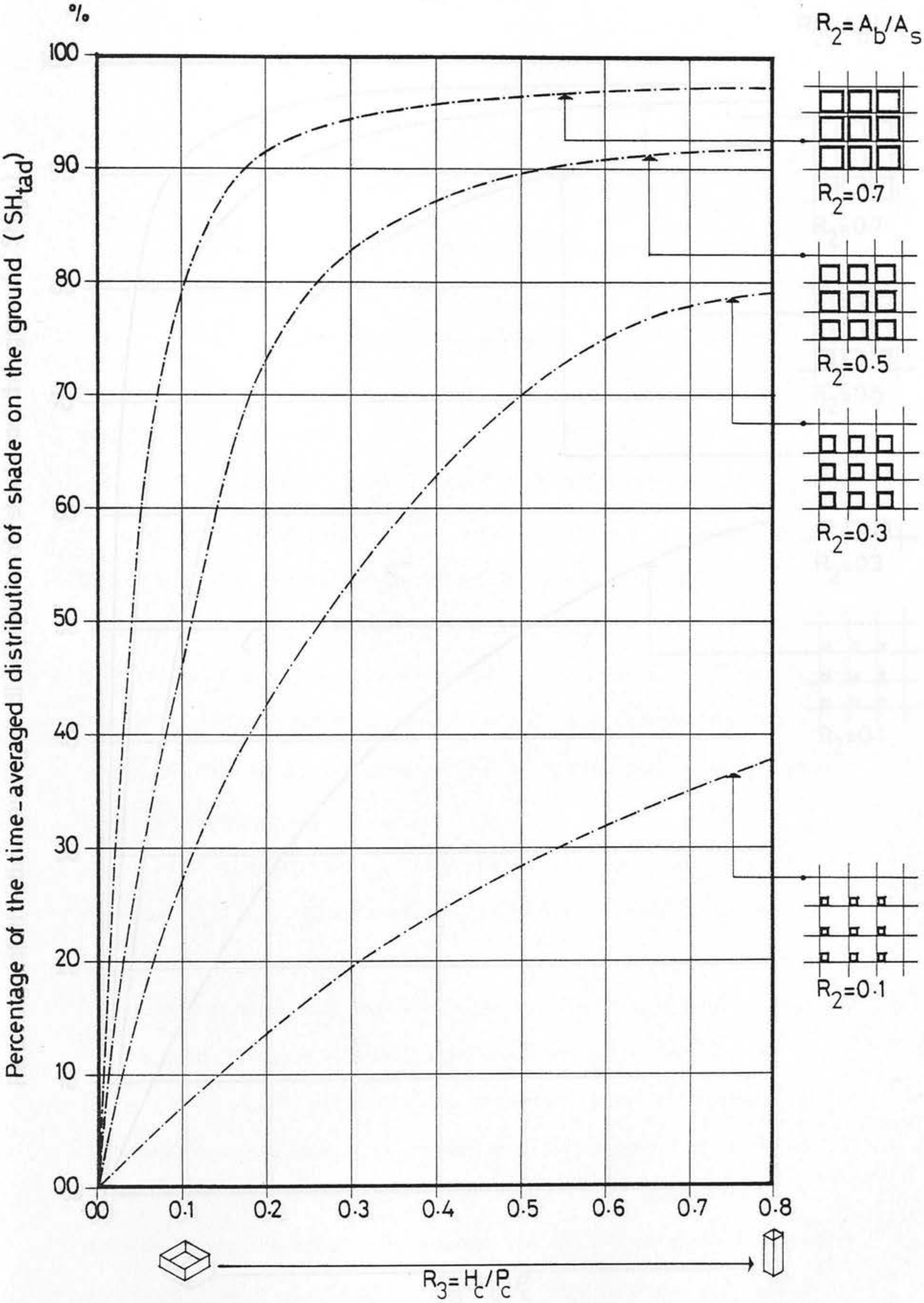


Figure IX.2 The effect of changing the ratios R_2 and R_3 on the time_averaged distribution of shading of the ground surface of the urban space in spring and autumn

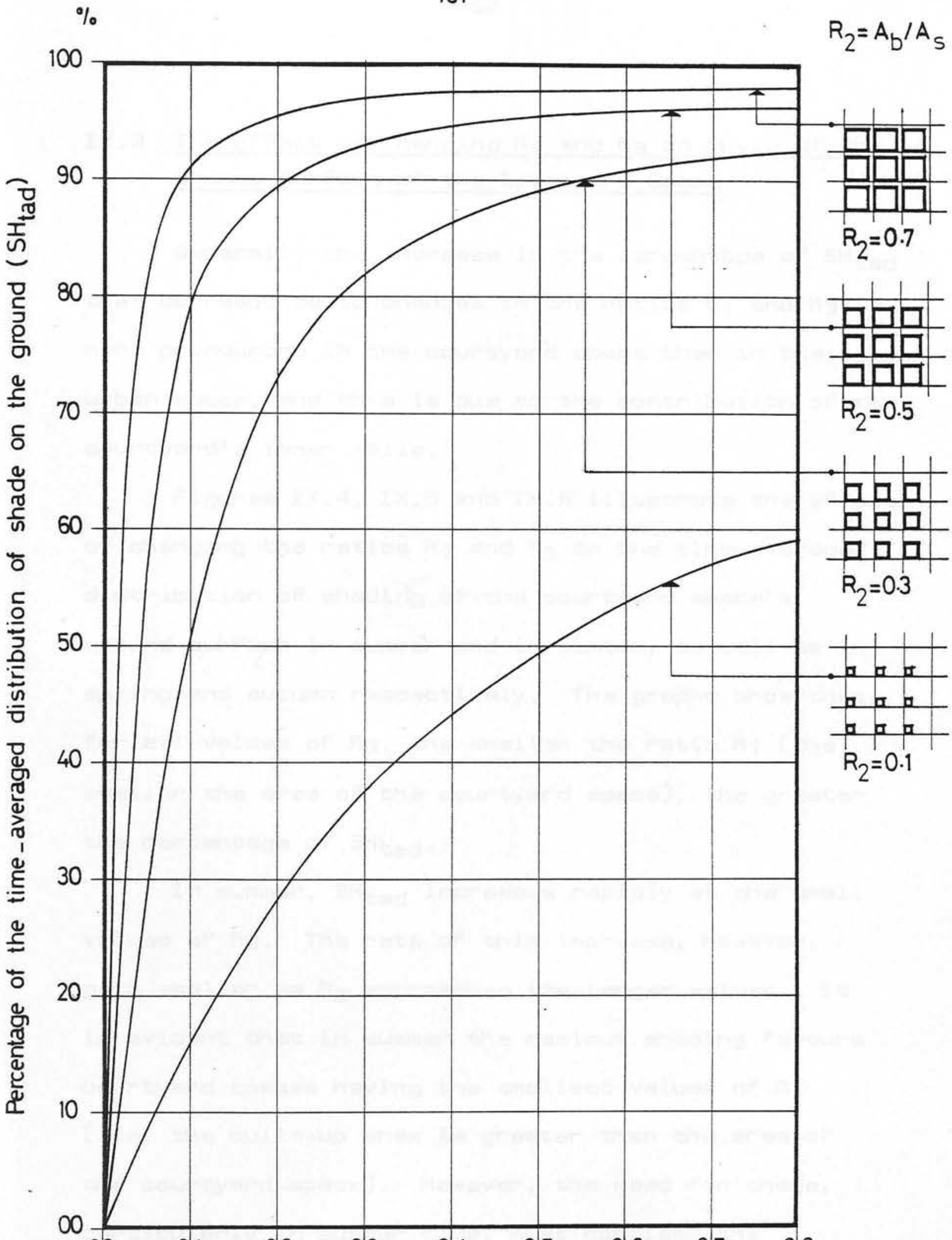


Figure IX·3 The effect of changing the ratios R_2 and R_3 on the time-averaged distribution of shading of the ground surface of the urban space in winter

IX.3 The Effect of Changing R_1 and R_3 on SH_{tad} of the Ground Surface of the Courtyard Space

Generally the increase in the percentage of SH_{tad} that corresponds to changes in the ratios R_1 and R_3 is more pronounced in the courtyard space than in the urban space, and this is due to the contribution of the courtyard's inner walls.

Figures IX.4, IX.5 and IX.6 illustrate the effect of changing the ratios R_1 and R_3 on the time-averaged distribution of shading of the courtyard space's ground surface in summer and in winter, as well as in spring and autumn respectively. The graphs show that, for all values of R_3, the smaller the ratio R_1 (the smaller the area of the courtyard space), the greater the percentage of SH_{tad}.

In summer, SH_{tad} increases rapidly at the small values of R_3. The rate of this increase, however, gets smaller as R_3 approaches its larger values. It is evident that in summer the maximum shading favours courtyard spaces having the smallest values of R_1 (i.e. the built-up area is greater than the area of the courtyard space). However, the need for shade, particularly in summer time, must not lead the designer to reducing the area of the courtyard space without limits, since in real urban situations this area is not only determined by the amount of shade

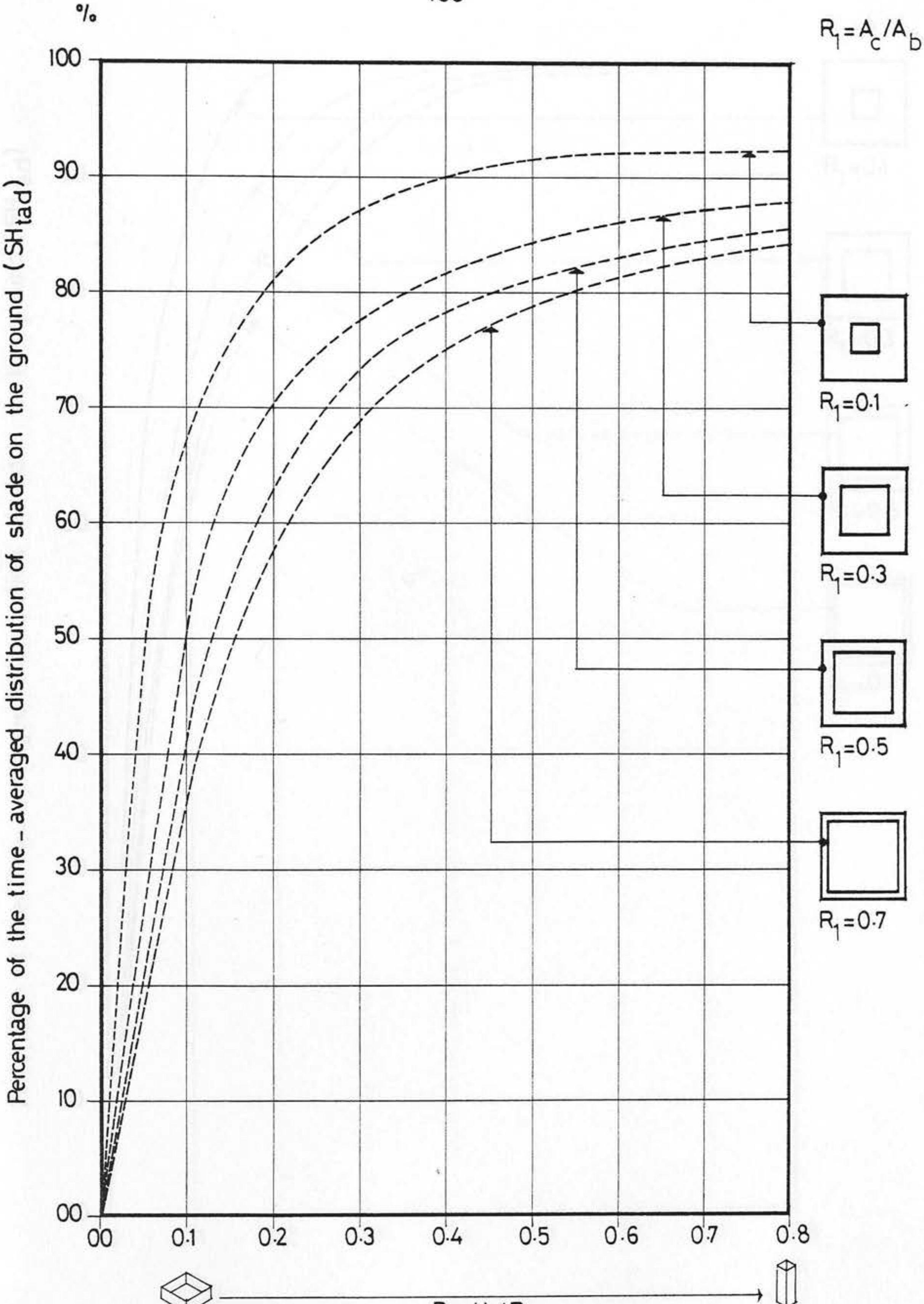


Figure IX.4 The effect of changing the ratios R_1 and R_3 on the time-averaged distribution of shading of the ground surface of the courtyard space in summer

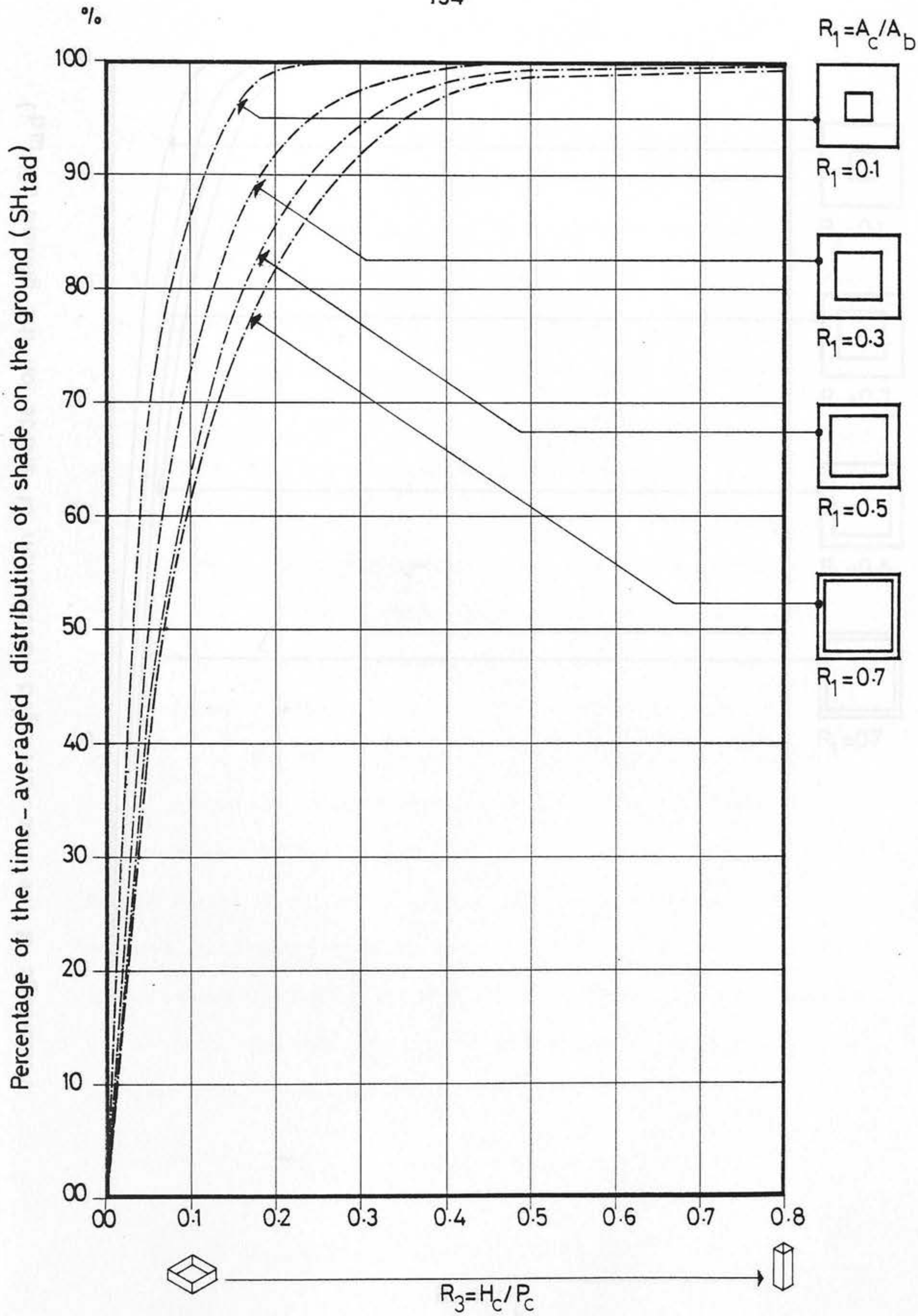


Figure IX·5 The effect of changing the ratios R_1 and R_3 on the time-averaged distribution of shading of the ground surface of the courtyard space in spring and autumn

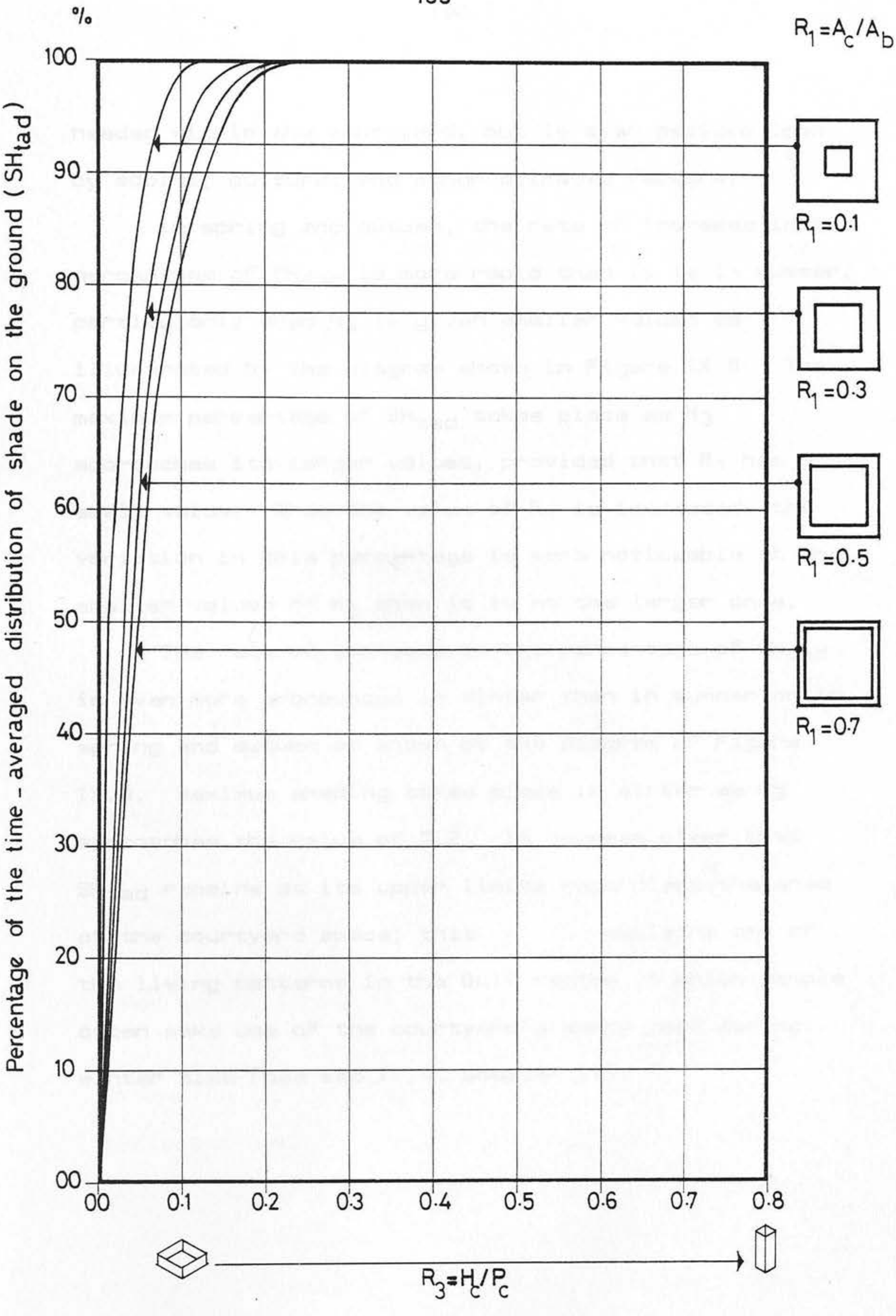


Figure IX·6 The effect of changing the ratios R_1 and R_3 on the time - averaged distribution of shading of the ground surface of the courtyard space in winter needed within the courtyard, but is also decided upon by social, cultural and other climatic factors.

In spring and autumn, the rate of increase in the percentage of SH_{tad} is more rapid than it is in summer, particularly when R_3 is given smaller values as illustrated by the diagram shown in Figure IX.5. The maximum percentage of SH_{tad} takes place as R_3 approaches its larger values, provided that R_1 has a small value. When the value of R_1 is increased, the variation in this percentage is more noticeable at the smaller values of R_3 than it is at the larger ones.

The rate of increase in the percentage of SH_{tad} is even more pronounced in winter than in summer or in spring and autumn as shown by the diagram of Figure IX.6. Maximum shading takes place in winter as R_3 approaches the value of 0.2. It becomes clear that SH_{tad} remains at its upper limits regardless of the area of the courtyard space; this explains one of the living patterns in the Gulf region in which people often make use of the courtyard's sunny roof during winter time [see sec.IV.4, Chapter IV].

IX.4 The Effect of Changing R_2 and R_4 on SH_{tad} of the Urban Space Ground Surface

Regarding the ratio of the height of the courtyard form to the height of the surrounding forms R_4, it was decided to consider the range from 0.1 to 0.6 at 0.1 intervals, i.e., the surrounding courtyard forms were considered to be of equal height, and was kept constant, whereas the height of the courtyard form was varied.

The averages of the distribution of shading cast on the ground surface of the urban space by a grid-iron grouping of the courtyard forms and surroundings were computed over the three selected periods. The percentage of SH_{tad} was plotted against R_4 with R_2 ranging from 0.1 to 0.7 at 0.2 intervals.

In summer, SH_{tad} increases gradually with R_4 for all the values of R_2 as illustrated by the diagram shown in Figure IX.7. However, this increase becomes less noticeable as R_4 approaches its larger values.

The percentage of the time-averaged distribution of shading of the ground is more significant in spring and autumn than in summer, particularly when R_2 is given values > 0.1 as shown in the diagram of Figure IX.8. The increase in the percentage of SH_{tad} is gradual at the small values of R_4. However, this

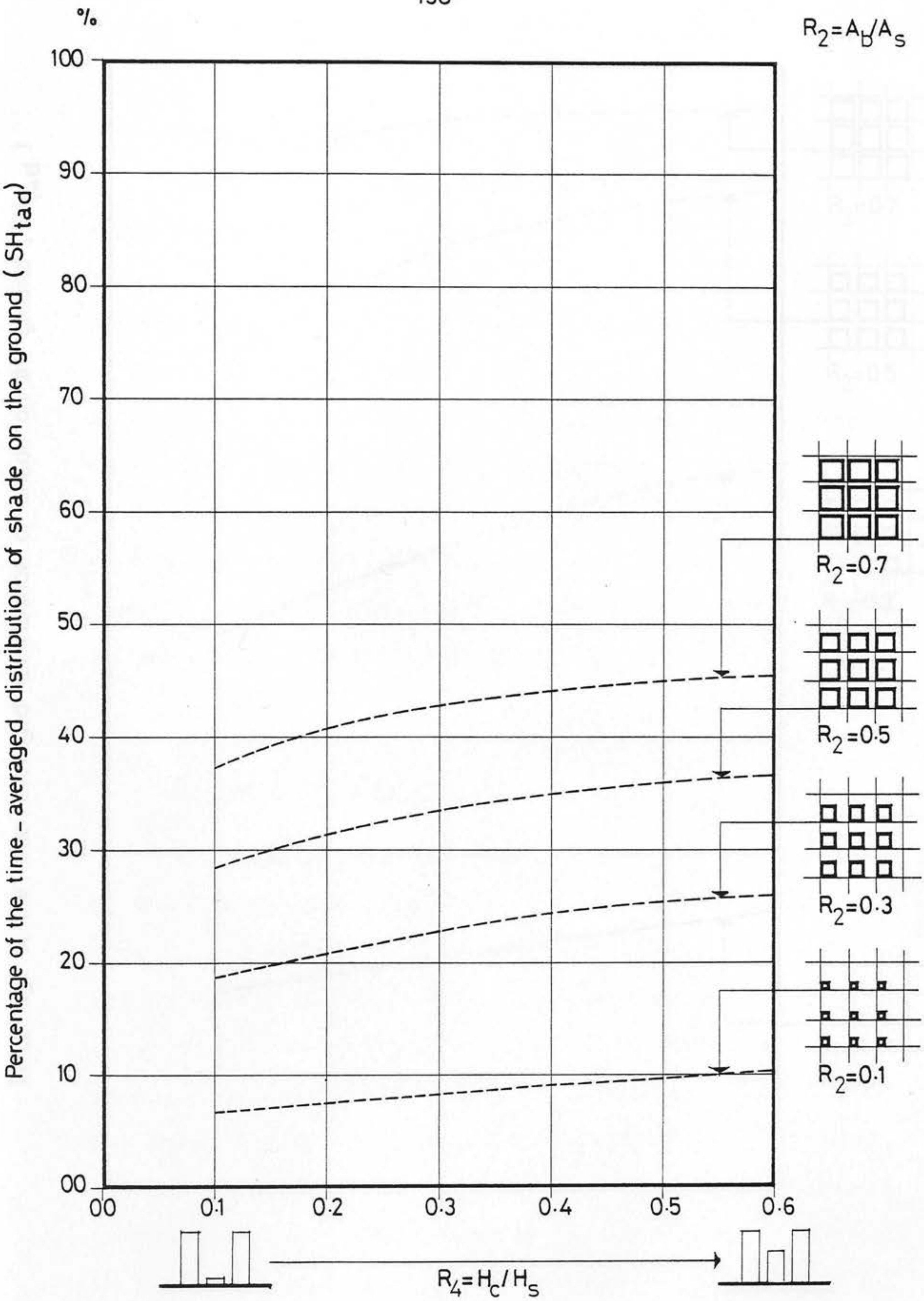


Figure IX·7 The effect of changing the ratios R_2 and R_4 on the time - averaged distribution of shading of the ground surface of the urban space in summer

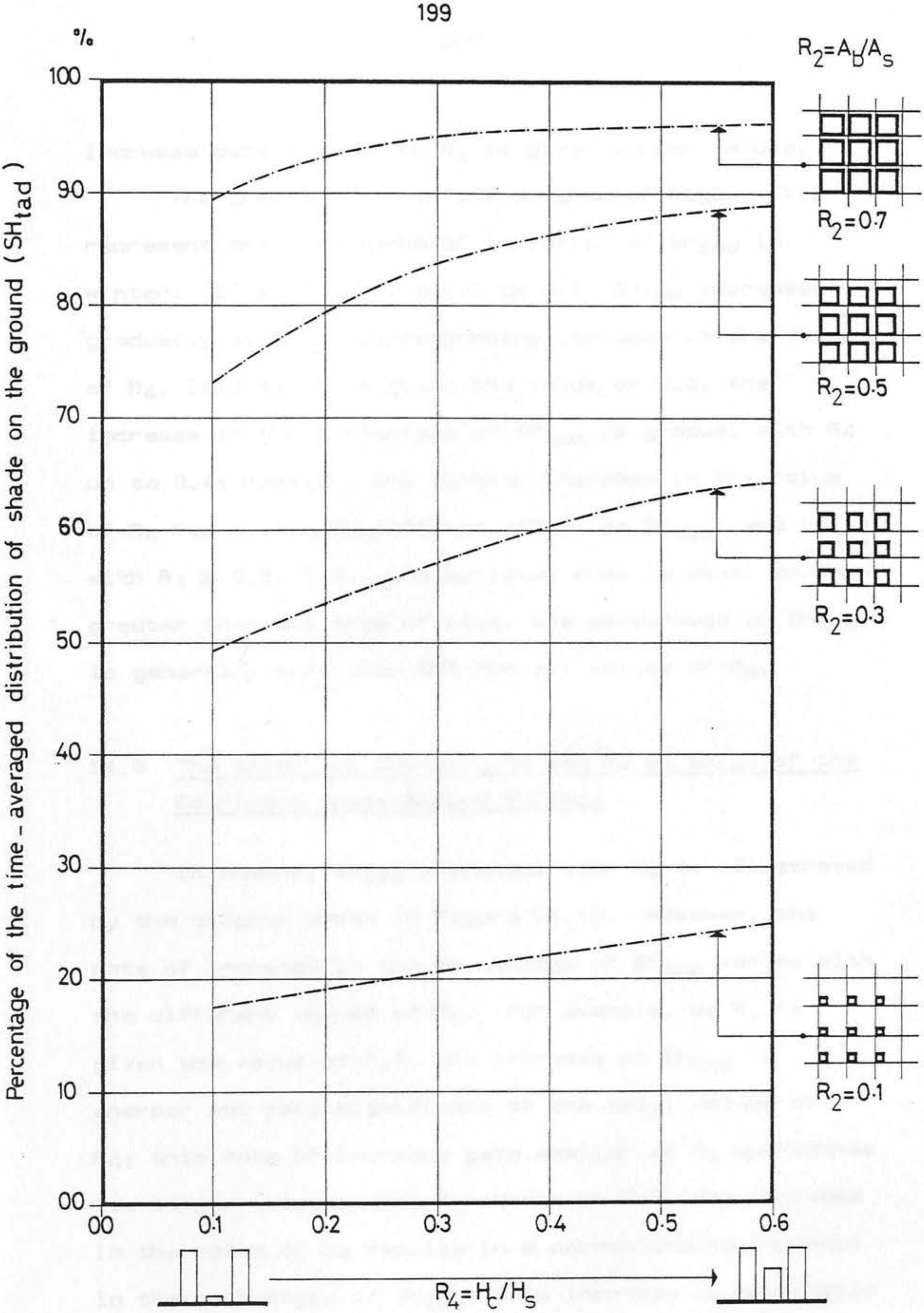


Figure IX.8 The effect of changing the ratios R_2 and R_4 on the time-averaged distribution of shading of the ground surface of the urban space in spring and autumn increase gets smaller as R_4 is given larger values.

The graphs shown in the diagram of Figure IX.9 represent three patterns of variation of SH_{tad} in winter: [i] when R_2 is equal to 0.1, SH_{tad} increases gradually with the corresponding increase in the value of R_4, [ii] as R_2 is given the value of 0.3, the increase in the percentage of SH_{tad} is gradual with R_4 up to 0.4; however, any further increase in the value of R_4 has a less significant effect on SH_{tad}, and [iii] with $R_1 \geqslant 0.5$, i.e., the built-up area is equal to or greater than the area of site, the percentage of SH_{tad} is generally more than 95% for all values of R_4.

IX.5 The Effect of Changing R_1 and R_4 on SH_{tad} of the Courtyard Space Ground Surface

In summer, SH_{tad} increases with R_4 as illustrated by the diagram shown in Figure IX.10. However, the rate of increase in the percentage of SH_{tad} varies with the different values of R_1. For example, as R_1 is given the value of 0.1, the increase of SH_{tad} is sharper and more significant at the small values of R_4; this rate of increase gets smaller as R_4 approaches its larger values. For R_1 equals to 0.3, any increase in the value of R_4 results in a corresponding increase in the percentage of SH_{tad}; this increase is noticeable throughout the range of R_4. With R_1 equal to or

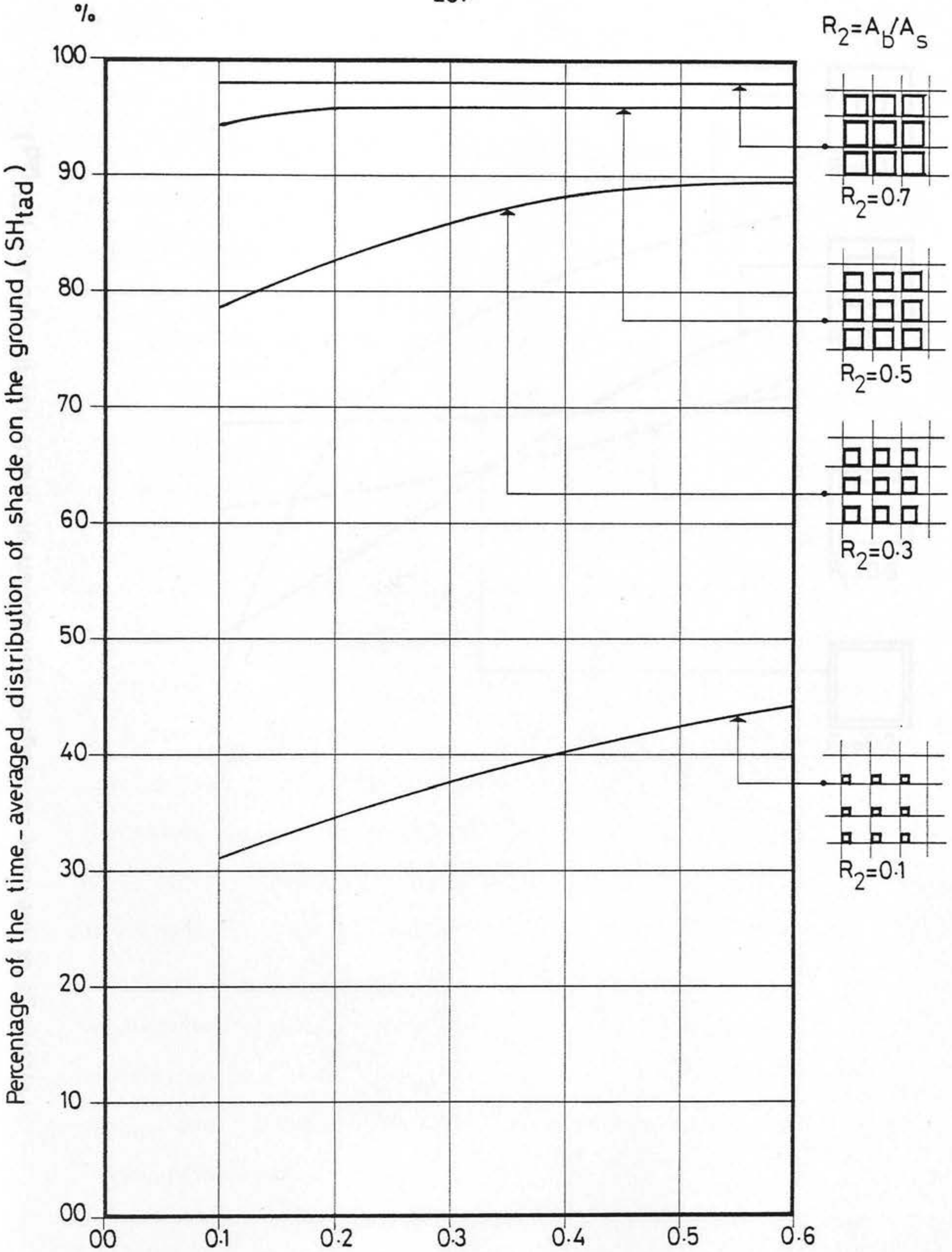


Figure IX·9 The effect of changing the ratios R_2 and R_4 on the time-averaged distribution of shading of the ground surface of the urban space in winter

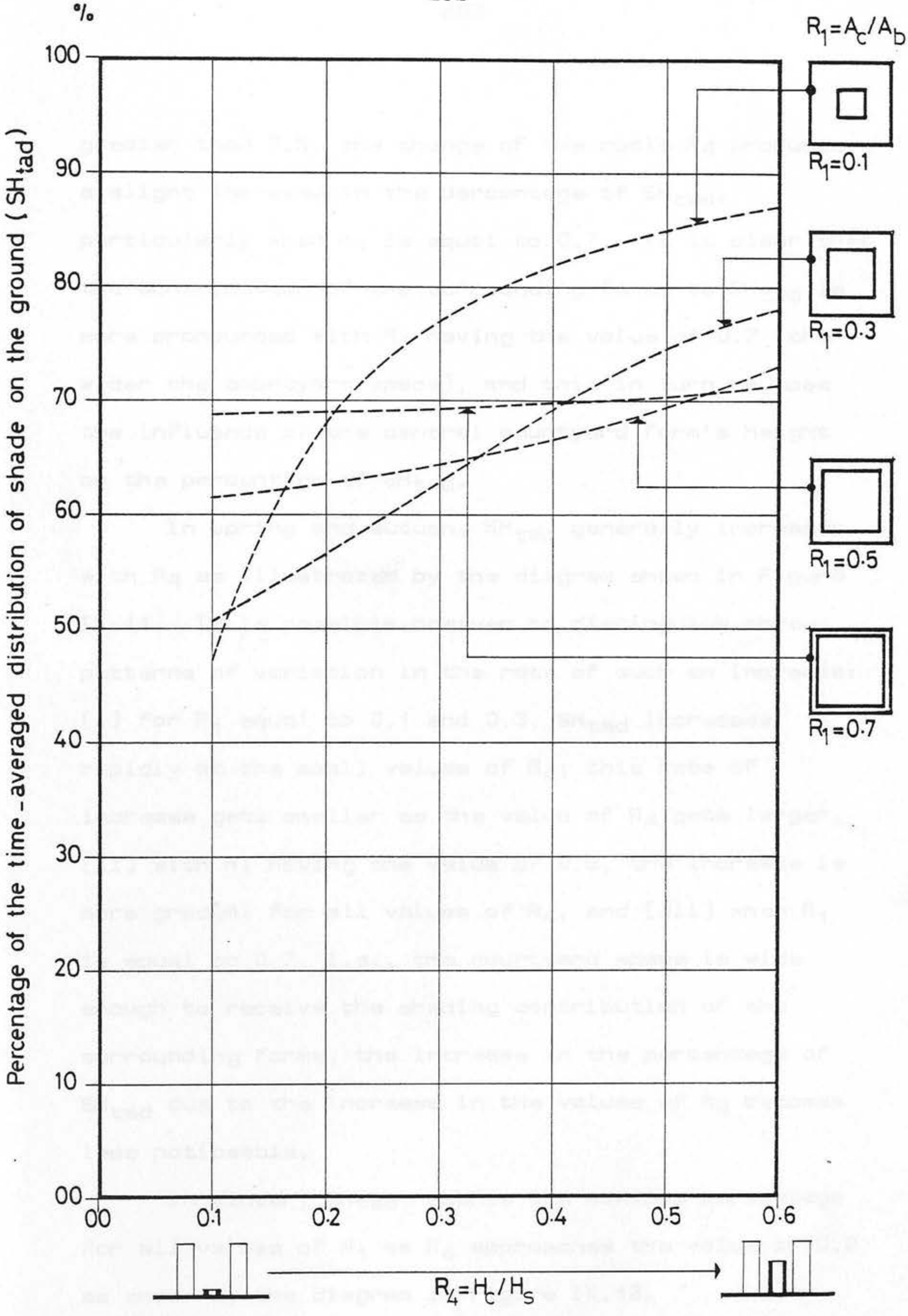


Figure IX·10 The effect of changing the ratios R_1 and R_4 on the time_averaged distribution of shading of the ground surface of the courtyard space in summer greater than 0.5, the change of the ratio R_4 produces a slight increase in the percentage of SH_{tad}, particularly when R_1 is equal to 0.7. It is clear that the contribution of the surrounding forms to SH_{tad} is more pronounced with R_1 having the value of 0.7 [the wider the courtyard space], and this in turn reduces the influence of the central courtyard form's height on the percentage of SH_{tad}.

In spring and autumn, SH_{tad} generally increases with R_4 as illustrated by the diagram shown in Figure IX.11. It is possible however to distinguish three patterns of variation in the rate of such an increase: [i] for R_1 equal to 0.1 and 0.3, SH_{tad} increases rapidly at the small values of R_4; this rate of increase gets smaller as the value of R_4 gets larger, [ii] with R_1 having the value of 0.5, the increase is more gradual for all values of R_4, and [iii] when R_1 is equal to 0.7, i.e., the courtyard space is wide enough to receive the shading contribution of the surrounding forms, the increase in the percentage of SH_{tad} due to the increase in the values of R_4 becomes less noticeable.

In winter, SH_{tad} reaches its maximum percentage for all values of R_1 as R_4 approaches the value of 0.2 as shown by the diagram in Figure IX.12.

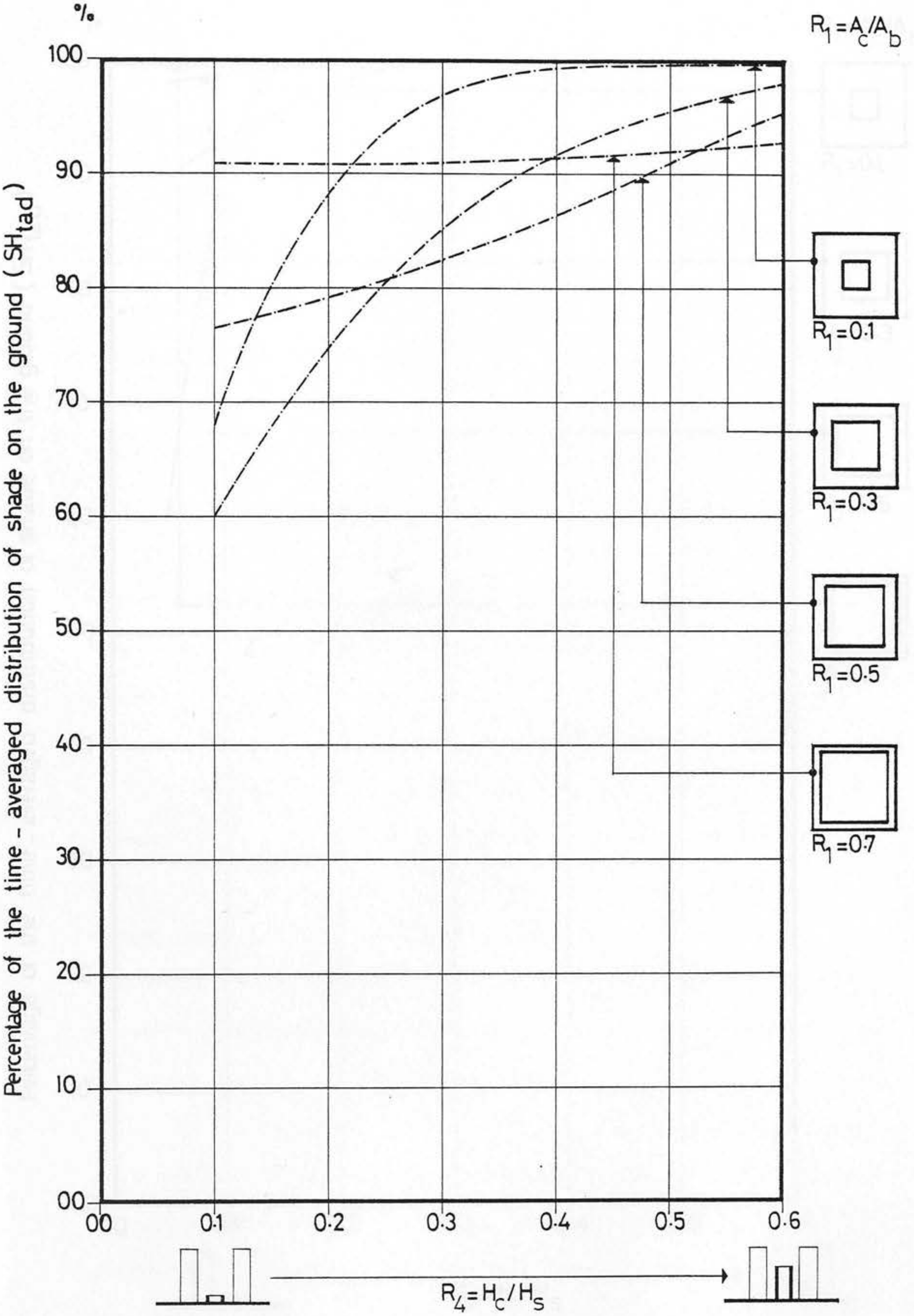


Figure IX·11 The effect of changing the ratios R_1 and R_4 on the time - averaged distribution of shading of the ground surface of the courtyard space in spring and autumn

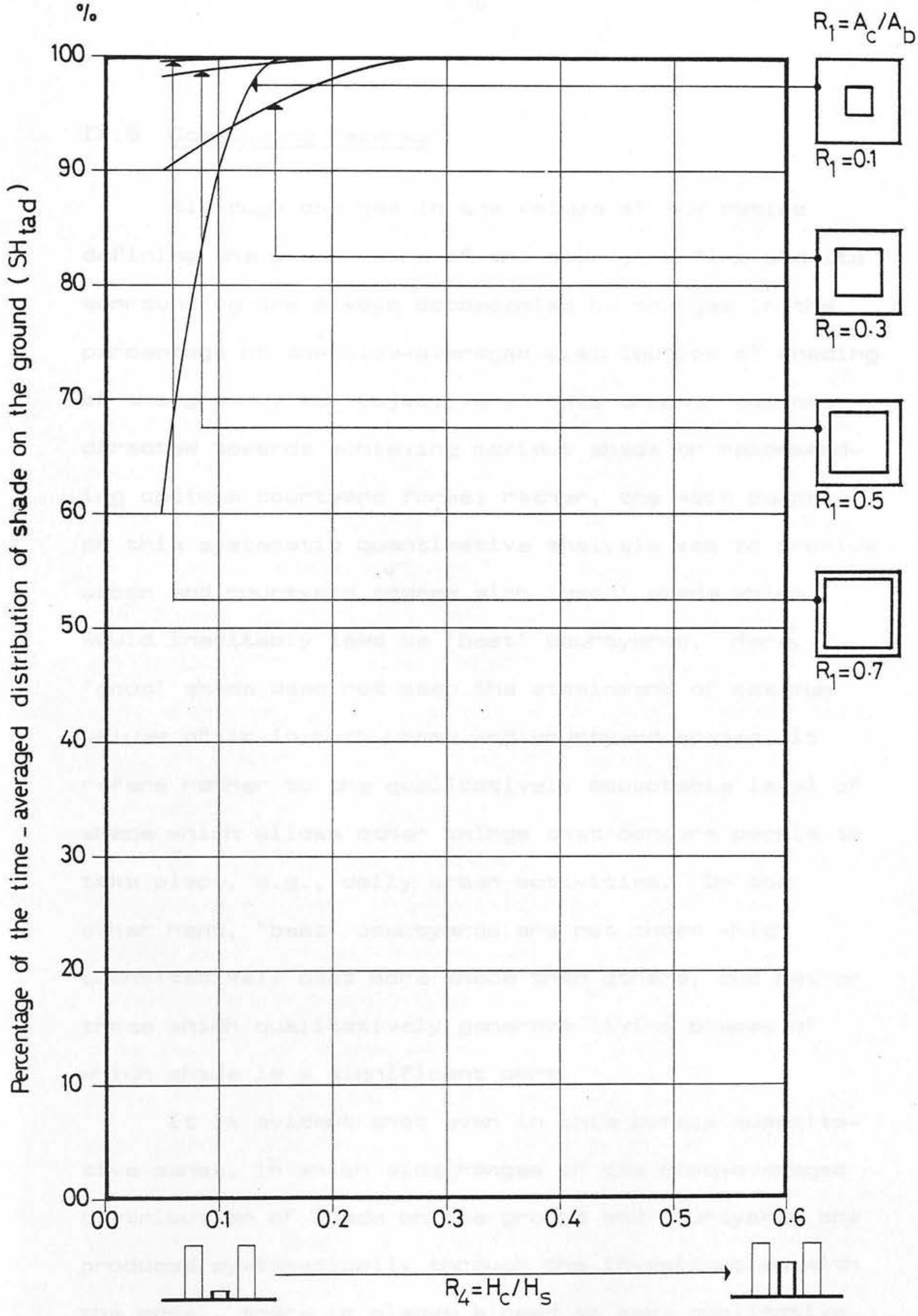


Figure IX·12 The effect of changing the ratios R_1 and R_4 on the time - averaged distribution of shading of the ground surface of the courtyard space in winter

IX.6 Concluding Remarks

Although changes in the values of the ratios defining the proportions of the courtyard form and its surrounding are always accompanied by changes in the percentage of the time-averaged distribution of shading of the ground, our objective in this chapter was not directed towards achieving maximum shade or recommending optimum courtyard forms; rather, the main purpose of this systematic quantitative analysis was to provide urban and courtyard spaces with 'good' shade which would inevitably lead to 'best' courtyards. Here, 'good' shade does not mean the attainment of maximum values of it in both urban and courtyard spaces, it refers rather to the qualitatively acceptable level of shade which allows other things that concern people to take place, e.g., daily urban activities. On the other hand, 'best' courtyards are not those which quantitatively cast more shade than others, but rather those which qualitatively generate living places of which shade is a significant part.

It is evident that even in this purely quantitative sense, in which wide ranges of the time-averaged distribution of shade on the ground and courtyards are produced systematically through the investigation with the model, there is always a need to make qualitative choices which grant 'good' shade and 'best' courtyards a place in the living reality. This of course involves many considerations beyond the mere provision of maximum shade and optimum forms [storey height, use of enclosure etc.].

From this standpoint, the effect of the geometrical parameters of the courtyard form and surroundings on the time-averaged distribution of shading of the ground of the courtyard and urban space was analyzed.

It was shown through the output of the model that the contribution of the courtyard forms' internal surfaces to the shading distribution within the courtyard space was much greater than the contribution made by their external surfaces to the urban spaces separating them.

On the basis of the analysis of the variation of SH_{tad} with the variation of the courtyard forms' geometrical parameters a number of remarks can be made:

1. Different proportions affecting the time-averaged distribution of shade on the ground are generated by means of four ratios: [i] R_1 relating the area of the courtyard space to the built-up area of the form, and indicating the smallness or the largeness of the courtyard central space, [ii] R_2 relating the built-up area to the area of site, and indicating denseness of forms, [iii] R_3 relating the form's height to its perimeter,

and indicating the shallowness or the deepness of forms, and [iv] R_4 relating the height of the courtyard form to the height of the surrounding forms, and indicating the variation of form's height.

2. In the case of groups of courtyard forms of equal height the changes in the values of R_2 significantly affect the shading of the ground surface of the urban space. Changing the value of R_2 from 0.1 to 0.7 is naturally accompanied by an increase in the percentage of SH_{tad} for all values of R_3. The following table shows the values of R_3 at which good average shade is attained for different values of R_2 during the three selected periods. Figures IX.13, IX.14, IX.15 and

R_2	0.1	0.3	0.5	0.7
R_3	0.5	0.4	0.3	0.3
Summer	11.85%	26.69%	35.16%	44.69%
Spring and Autumn	28.03%	62.61%	83.31%	94.63%
Winter	49.12%	86.62%	92.99%	97.24%

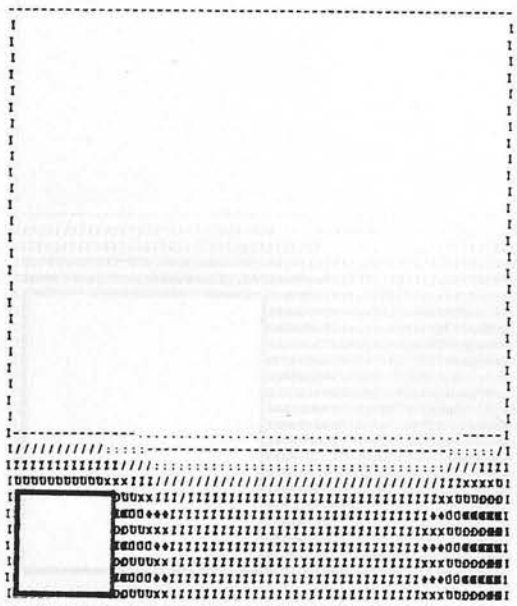
IX.16 illustrate the three-dimensional interpretations of these values and their average shading distribution maps for summer, spring and autumn, and winter.

As for the courtyard space, the effect of R_1 on

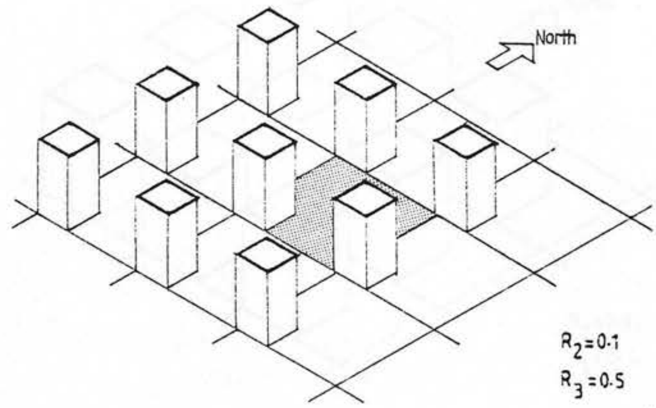
KEY TO SYMBOLS

```
  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING
- REPRESENTS 21 TO  30 PERCENT SHADING
: REPRESENTS 31 TO  40 PERCENT SHADING
/ REPRESENTS 41 TO  50 PERCENT SHADING
I REPRESENTS 51 TO  60 PERCENT SHADING
+ REPRESENTS 61 TO  70 PERCENT SHADING
0 REPRESENTS 71 TO  80 PERCENT SHADING
€ REPRESENTS 81 TO  90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING
```

```
  N
 NNN
NNNNN
  N
  N    NORTH
  N
  N
```



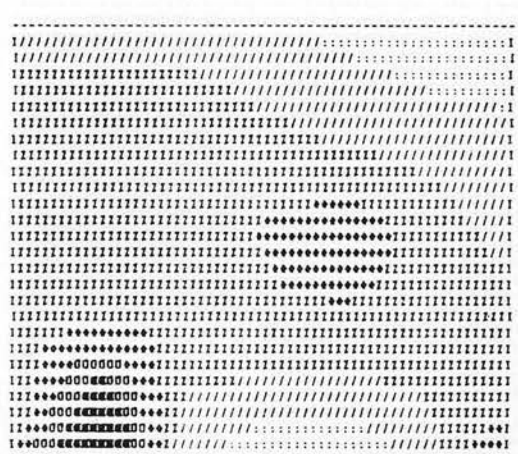
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive



KEY TO LENGTH SCALES

```
I
I
I <- LINE IS    5.00 UNITS HIGH
I
I
 ---------
LINE ABOVE IS    5.00 UNITS LONG
```

A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



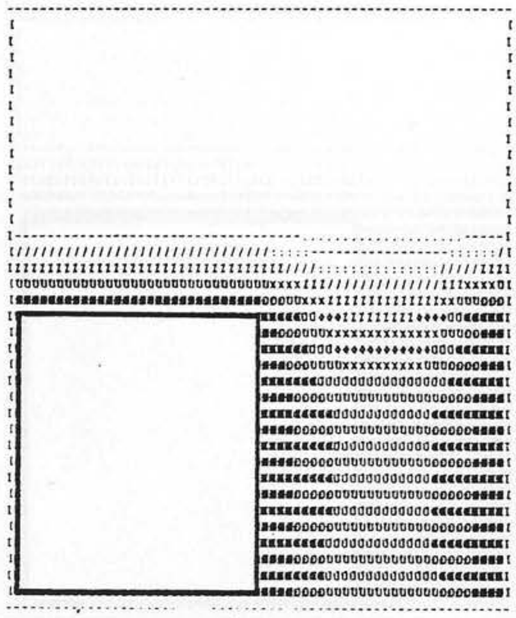
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.13 The proportions of a group of courtyards of equal height expressed by the ratios R_2 and R_3 and their average shading distribution in urban space in summer, spring and autumn, and winter

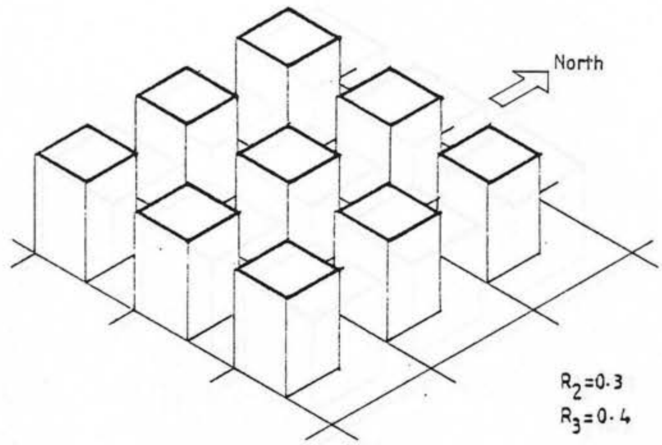
KEY TO SYMBOLS

  REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
I REPRESENTS 51 TO 60 PERCENT SHADING
+ REPRESENTS 61 TO 70 PERCENT SHADING
0 REPRESENTS 71 TO 80 PERCENT SHADING
X REPRESENTS 81 TO 90 PERCENT SHADING
M REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



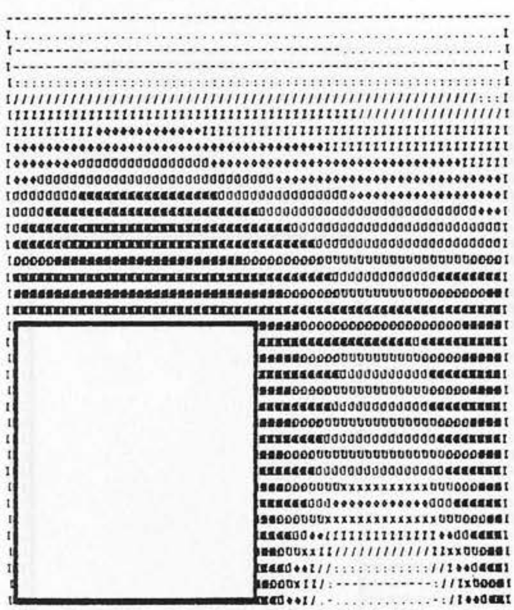
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive



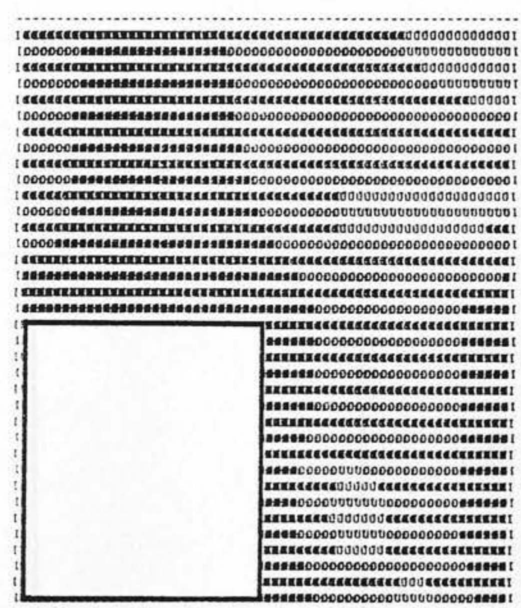
KEY TO LENGTH SCALES

I <- LINE IS 5.00 UNITS HIGH

LINE ABOVE IS 5.00 UNITS LONG



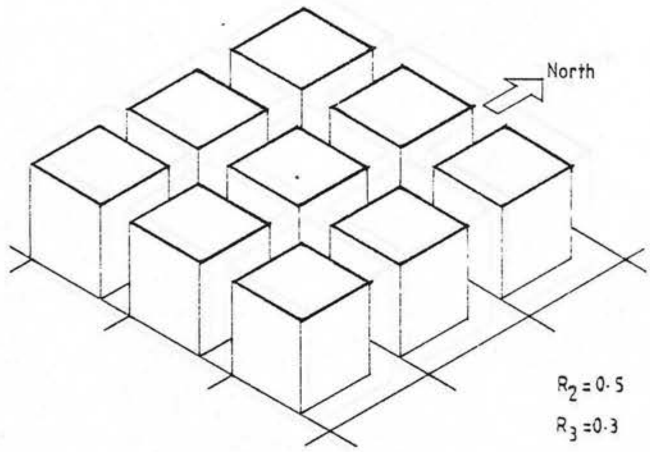
A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive

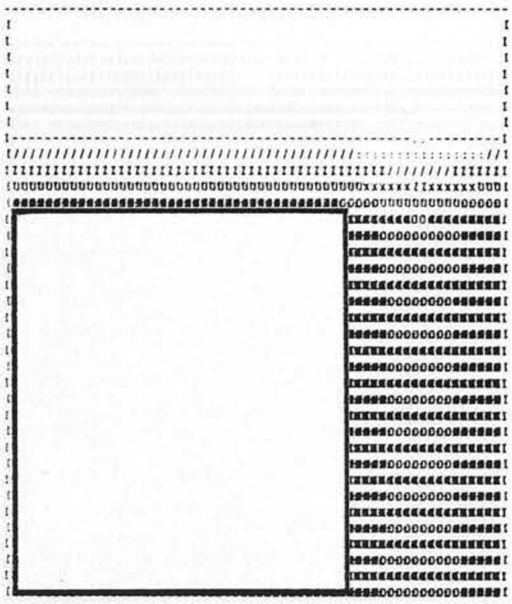


A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.14 The proportions of a group of courtyards of equal height expressed by the ratios R_2 and R_3 and their average shading distribution in urban space in summer, spring and autumn, and winter

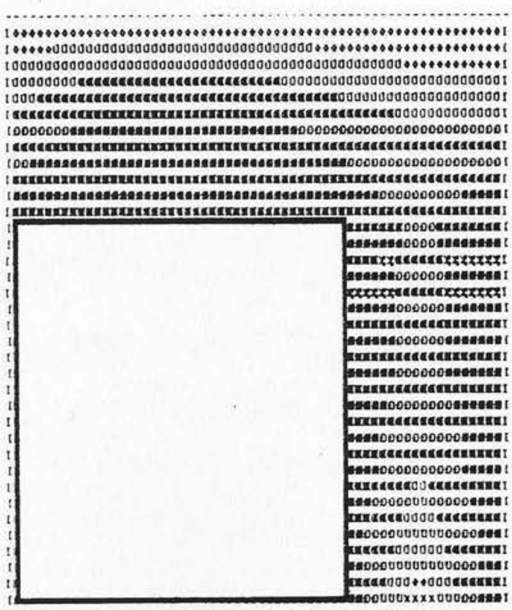
```
            KEY TO SYMBOLS
            --------------

   REPRESENTS  0 TO  10 PERCENT SHADING
 . REPRESENTS 11 TO  20 PERCENT SHADING          N
 - REPRESENTS 21 TO  30 PERCENT SHADING         NNN
 : REPRESENTS 31 TO  40 PERCENT SHADING        NNNNN
 / REPRESENTS 41 TO  50 PERCENT SHADING          N
 I REPRESENTS 51 TO  60 PERCENT SHADING          N     NORTH
 + REPRESENTS 61 TO  70 PERCENT SHADING          N
 0 REPRESENTS 71 TO  80 PERCENT SHADING          N
 X REPRESENTS 81 TO  90 PERCENT SHADING
 # REPRESENTS 91 TO 100 PERCENT SHADING
```



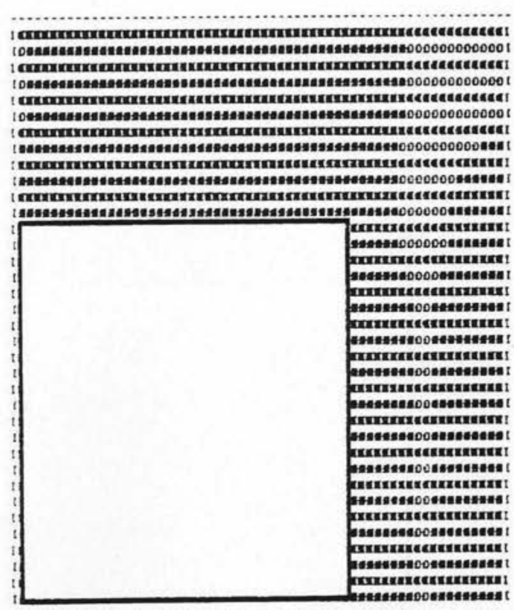


A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

```
           KEY TO LENGTH SCALES
           --------------------
 I
 I
 I
 I <- LINE IS     5.00 UNITS HIGH
 I
 I
 ----------

LINE ABOVE IS    5.00 UNITS LONG
```



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



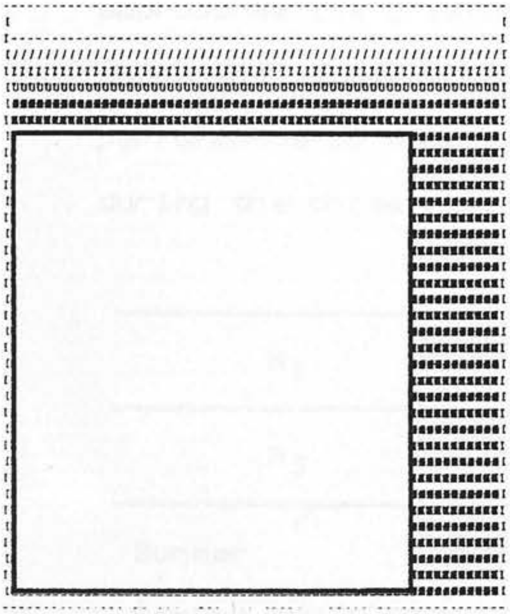
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.15 The proportions of a group of courtyards of equal height expressed by the ratios R_2 and R_3 and their average shading distribution in urban space in summer, spring and autumn, and winter

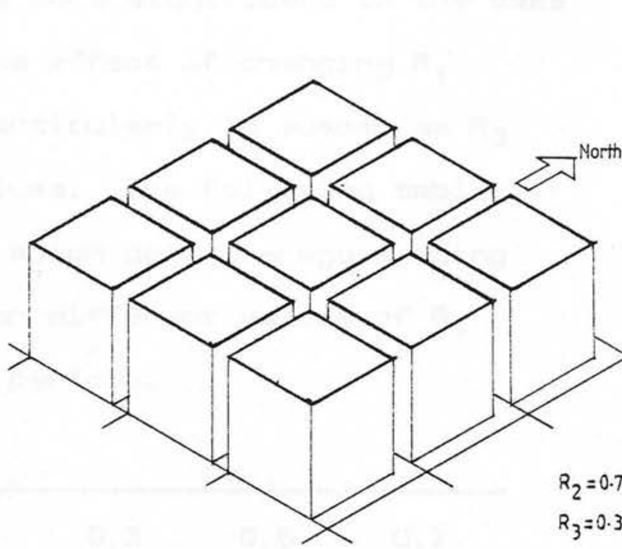
KEY TO SYMBOLS

  REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
I REPRESENTS 51 TO 60 PERCENT SHADING
0 REPRESENTS 61 TO 70 PERCENT SHADING
0 REPRESENTS 71 TO 80 PERCENT SHADING
REPRESENTS 81 TO 90 PERCENT SHADING
REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



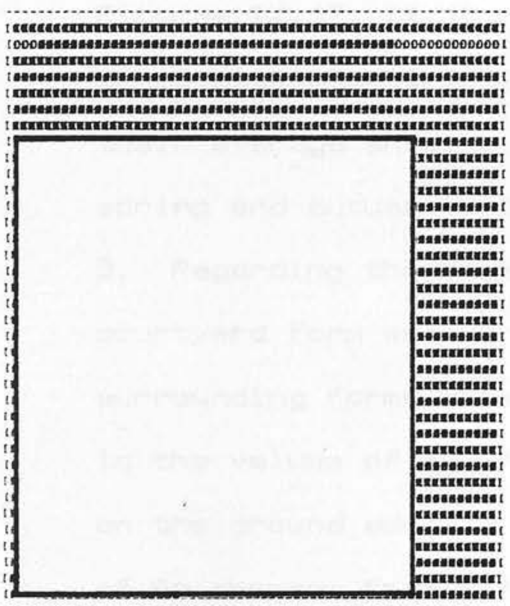
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive



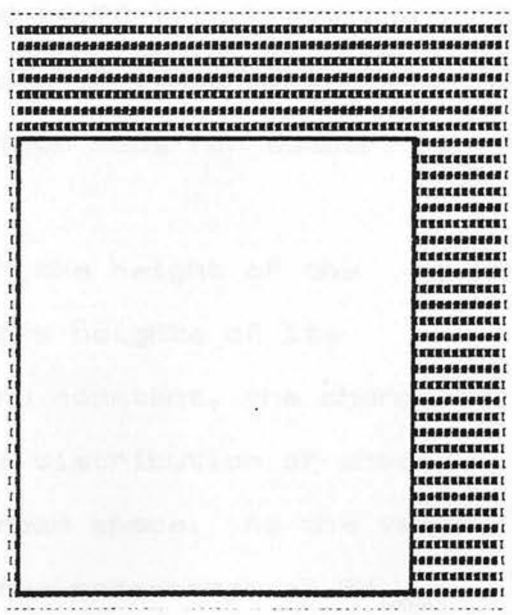
KEY TO LENGTH SCALES

<- LINE IS 5.00 UNITS HIGH

LINE ABOVE IS 5.00 UNITS LONG



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.16 The proportions of a group of courtyards of equal height expressed by the ratios R_2 and R_3 and their average shading distribution in urban space in summer, spring and autumn, and winter

the percentage of SH_{tad} is more significant in the case of small values of R_3. The effect of changing R_1 becomes less pronounced particularly in summer as R_3 approaches its greater values. The following table shows the values of R_3 at which good average shading performance is achieved for different values of R_1 during the three selected periods.

R_1	0.1	0.3	0.5	0.7
R_3	0.3	0.4	0.4	0.5
Summer	87.43%	81.63%	78.43%	78.96%
Spring and Autumn	99.79%	98.17%	99.09%	98.73%
Winter	100%	100%	100%	100%

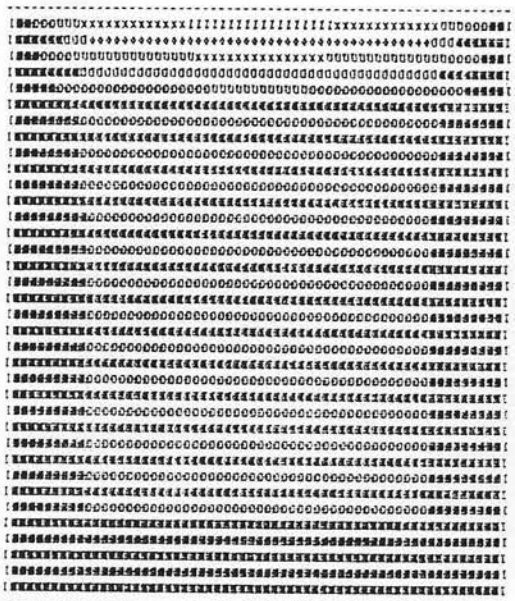
Figures IX.17, IX.18, IX.19 and IX.20 illustrate the three dimensional interpretations of these values and their average shading distribution maps for summer, spring and autumn, and winter.

3. Regarding the case in which the height of the courtyard form was varied and the heights of its surrounding forms were equal and constant, the change in the values of R_2 effects the distribution of shade on the ground surface of the urban space. As the value of R_2 changes from 0.1 to 0.7 the percentage of SH_{tad}

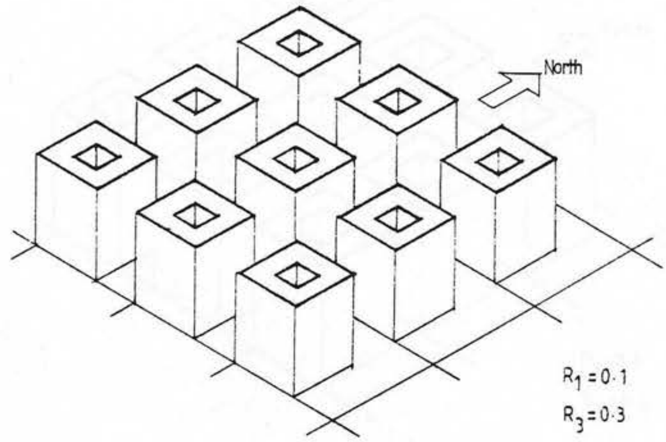
KEY TO SYMBOLS

  REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
I REPRESENTS 51 TO 60 PERCENT SHADING
+ REPRESENTS 61 TO 70 PERCENT SHADING
0 REPRESENTS 71 TO 80 PERCENT SHADING
REPRESENTS 81 TO 90 PERCENT SHADING
X REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



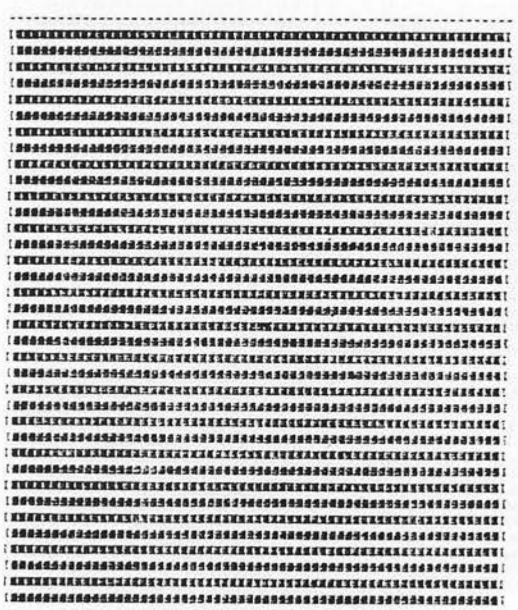
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive



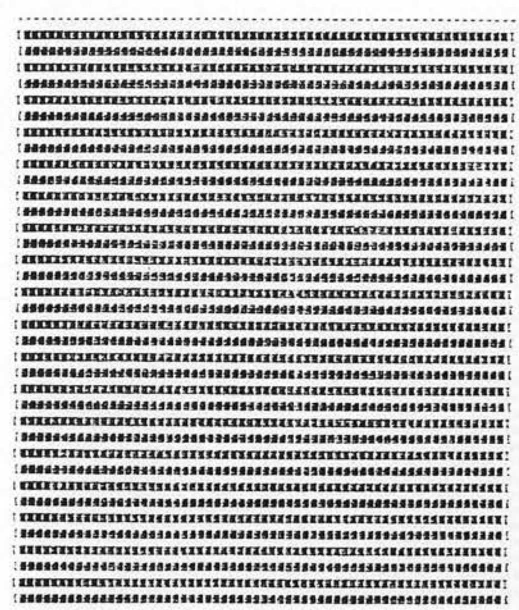
KEY TO LENGTH SCALES

I <- LINE IS 2.00 UNITS HIGH

LINE ABOVE IS 2.00 UNITS LONG



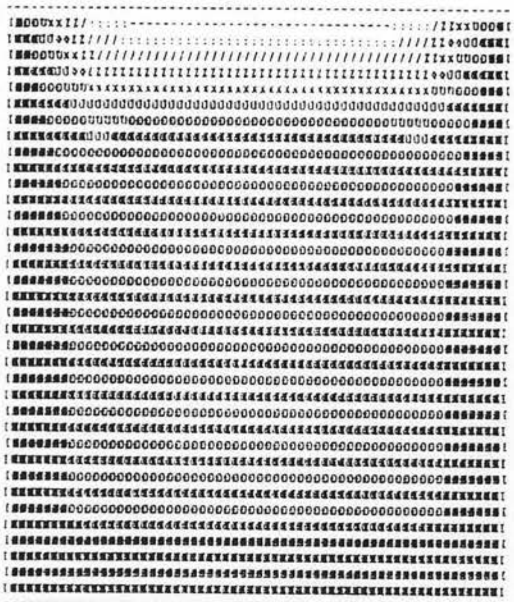
A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



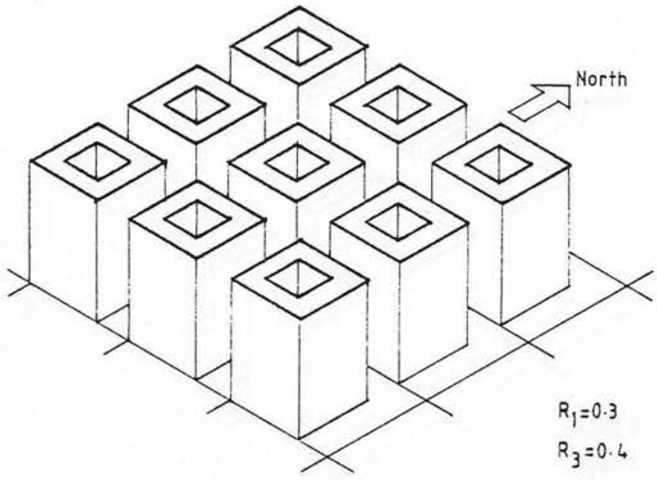
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.17 The proportions of a group of courtyards of equal height expressed by the ratios R_1 and R_3 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

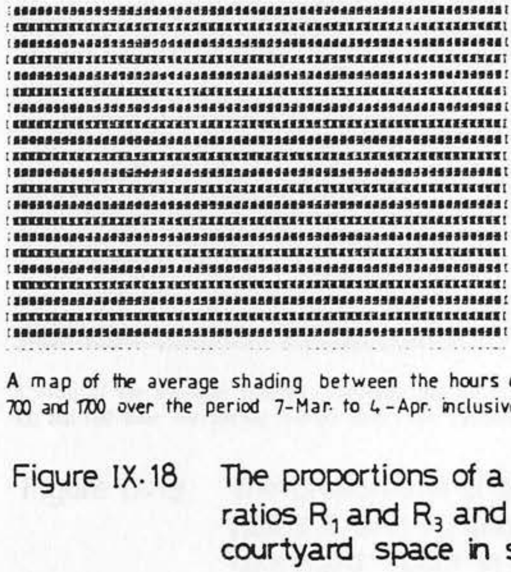
```
          KEY TO SYMBOLS
          --------------

  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING            N
- REPRESENTS 21 TO  30 PERCENT SHADING           NNN
: REPRESENTS 31 TO  40 PERCENT SHADING          NNNNN
/ REPRESENTS 41 TO  50 PERCENT SHADING            N
I REPRESENTS 51 TO  60 PERCENT SHADING            N     NORTH
+ REPRESENTS 61 TO  70 PERCENT SHADING            N
0 REPRESENTS 71 TO  80 PERCENT SHADING            N
# REPRESENTS 81 TO  90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING
```



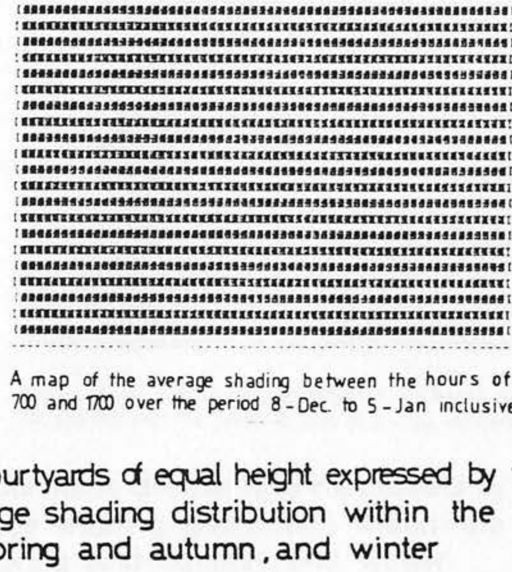
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive




```
KEY TO LENGTH SCALES
--------------------
I
I
I
I <- LINE IS    6.00 UNITS HIGH
I
I
 ---------

LINE ABOVE IS    6.00 UNITS LONG
```



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive

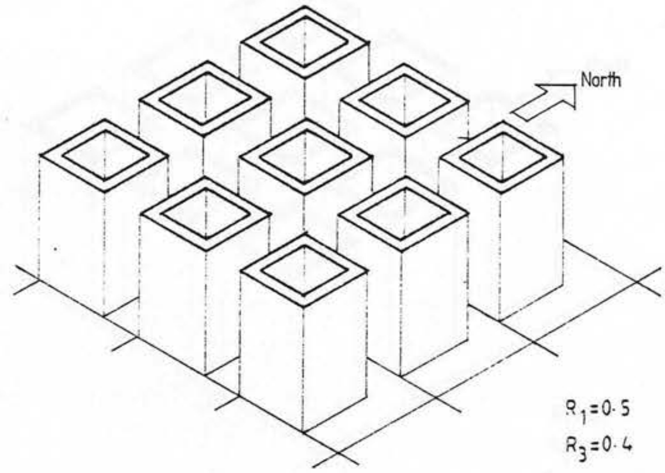


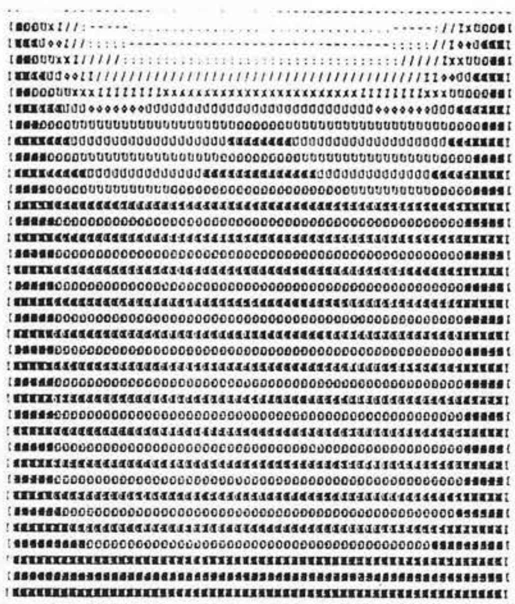
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.18 The proportions of a group of courtyards of equal height expressed by the ratios R_1 and R_3 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

KEY TO SYMBOLS

```
  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING          N
- REPRESENTS 21 TO  30 PERCENT SHADING         NNN
: REPRESENTS 31 TO  40 PERCENT SHADING        NNNNN
/ REPRESENTS 41 TO  50 PERCENT SHADING          N
I REPRESENTS 51 TO  60 PERCENT SHADING          N    NORTH
+ REPRESENTS 61 TO  70 PERCENT SHADING          N
0 REPRESENTS 71 TO  80 PERCENT SHADING          N
# REPRESENTS 81 TO  90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING
```

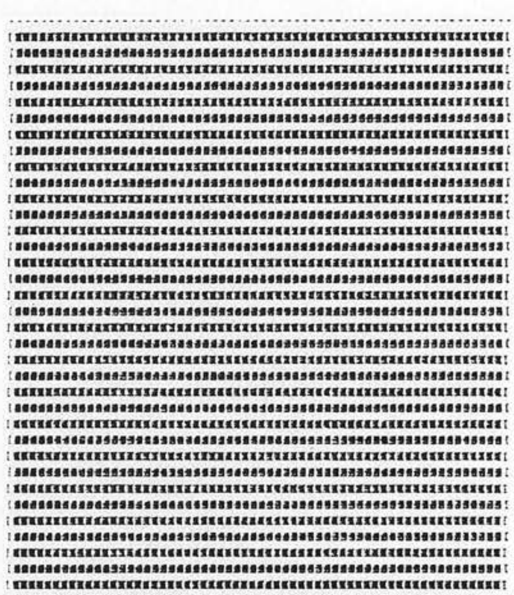




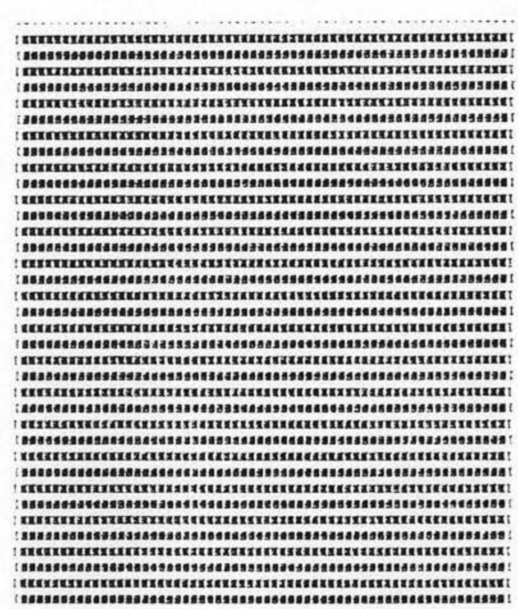
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

KEY TO LENGTH SCALES

```
I
I
I
I <- LINE IS   10.00 UNITS HIGH
I
I
 ----------
LINE ABOVE IS   10.00 UNITS LONG
```



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



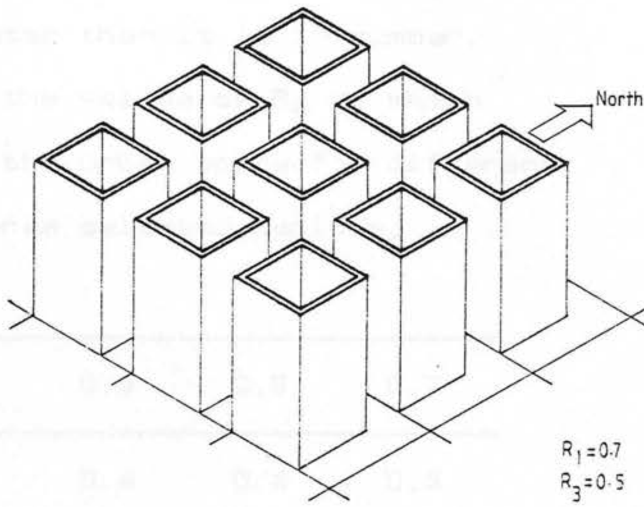
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

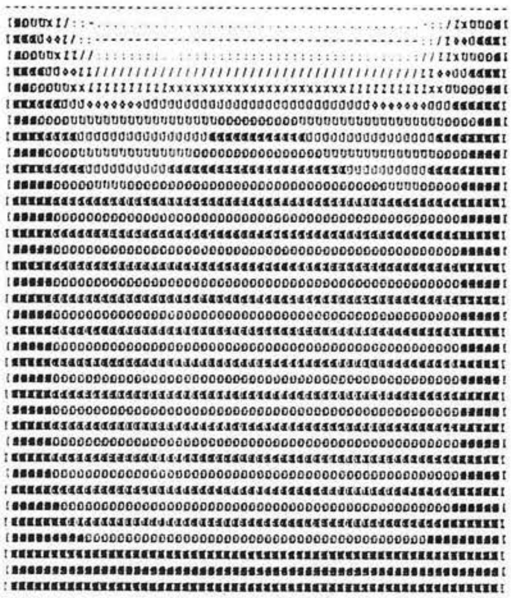
Figure IX.19 The proportions of a group of courtyards of equal height expressed by the ratios R_1 and R_3 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

KEY TO SYMBOLS

  REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
I REPRESENTS 51 TO 60 PERCENT SHADING
+ REPRESENTS 61 TO 70 PERCENT SHADING
0 REPRESENTS 71 TO 80 PERCENT SHADING
€ REPRESENTS 81 TO 90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



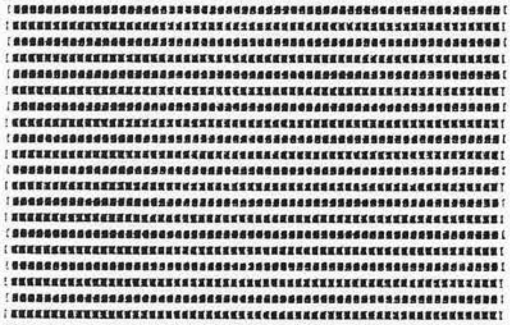


A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

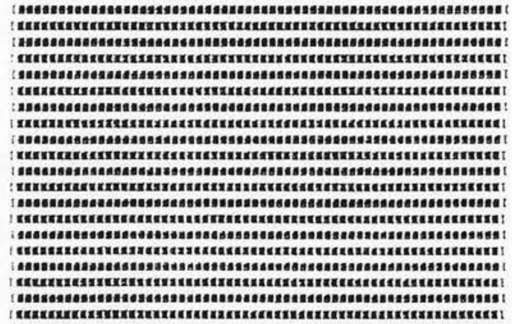
KEY TO LENGTH SCALES

<- LINE IS 14.00 UNITS HIGH

LINE ABOVE IS 14.00 UNITS LONG



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.20 The proportions of a group of courtyards of equal height expressed by the ratios R_1 and R_3 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

also increases. This increase is more significant in spring and autumn, and winter than it is in summer. The following table shows the values of R_4 at which good shade is obtained in the urban space for different values of R_2 during the three selected periods.

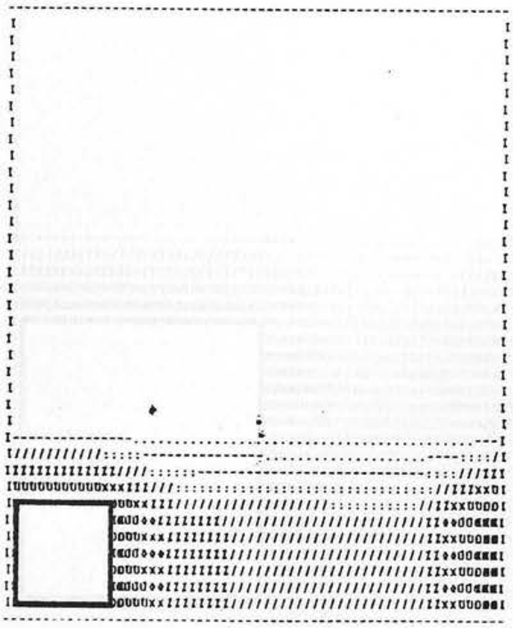
R_2	0.1	0.3	0.5	0.7
R_4	0.5	0.4	0.4	0.3
Summer	9.63%	24.43%	35.03%	42.37%
Spring and Autumn	23.07%	60.45%	86.25%	95.08%
Winter	42.22%	88.42%	95.86%	97.92%

Figures IX.21, IX.22, IX.23 and IX.24 illustrate the three-dimensional interpretations of these values and their average shading distribution maps for summer, spring and autumn, and winter.

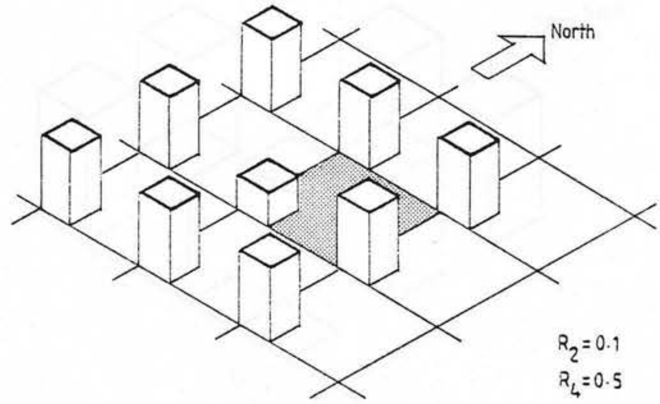
Concerning the ground surface of the courtyard space, the contribution of R_4 to the percentage of SH_{tad} is more pronounced with R_1 having values smaller than 0.3. However, when R_1 is given values greater than 0.3 the courtyard begins to receive the shading contribution of its surrounding forms which in turn diminishes the effect of changing the values of R_4. The following table shows a number of values for R_4

```
KEY TO SYMBOLS
--------------

  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING
- REPRESENTS 21 TO  30 PERCENT SHADING
: REPRESENTS 31 TO  40 PERCENT SHADING
/ REPRESENTS 41 TO  50 PERCENT SHADING
I REPRESENTS 51 TO  60 PERCENT SHADING
+ REPRESENTS 61 TO  70 PERCENT SHADING
0 REPRESENTS 71 TO  80 PERCENT SHADING
X REPRESENTS 81 TO  90 PERCENT SHADING
# REPRESENTS 91 TO 100 PERCENT SHADING
```

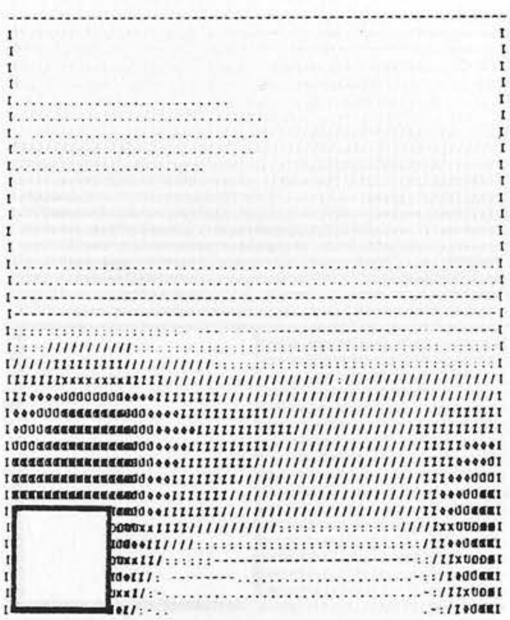
```
  N
 NNN
NNNNN
  N
  N     NORTH
  N
  N
```



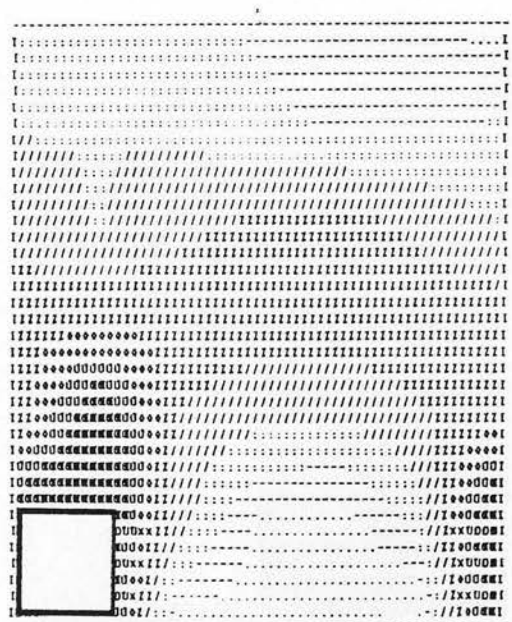
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive




```
KEY TO LENGTH SCALES
--------------------

I
I
I
I <- LINE IS    5.00 UNITS HIGH
I
I
 ---------

LINE ABOVE IS    5.00 UNITS LONG
```



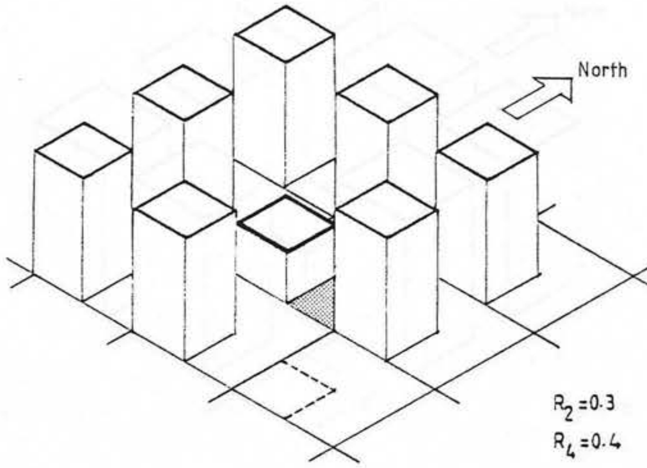
A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive

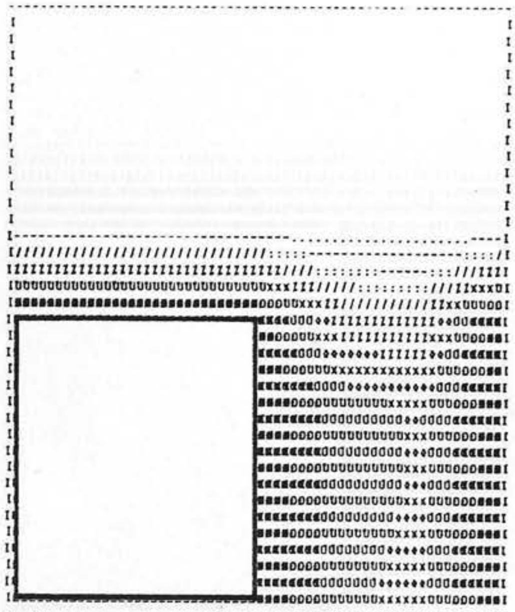


A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX·21 The proportions of a group of courtyards of varied heights expressed by the ratios R_2 and R_4 and their average shading distribution in urban space in summer, spring and autumn, and winter

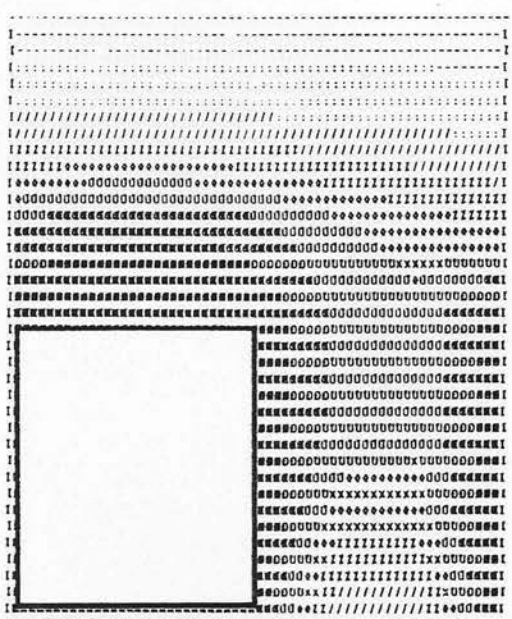
```
          KEY TO SYMBOLS
          --------------

  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING                    N
- REPRESENTS 21 TO  30 PERCENT SHADING                   NNN
: REPRESENTS 31 TO  40 PERCENT SHADING                  NNNNN
/ REPRESENTS 41 TO  50 PERCENT SHADING                    N
I REPRESENTS 51 TO  60 PERCENT SHADING                    N     NORTH
+ REPRESENTS 61 TO  70 PERCENT SHADING                    N
O REPRESENTS 71 TO  80 PERCENT SHADING                    N
X REPRESENTS 81 TO  90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING
```



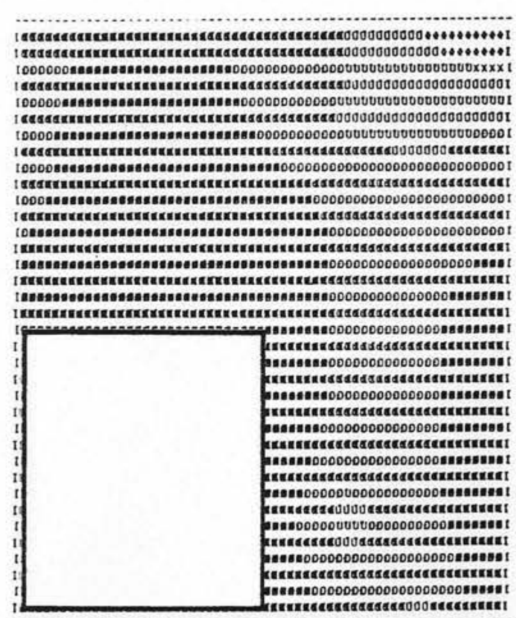


A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

```
     KEY TO LENGTH SCALES
     -------------- ----
I
I
I
I <- LINE IS    5.00 UNITS HIGH
I
I
---------

LINE ABOVE IS    5.00 UNITS LONG
```



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



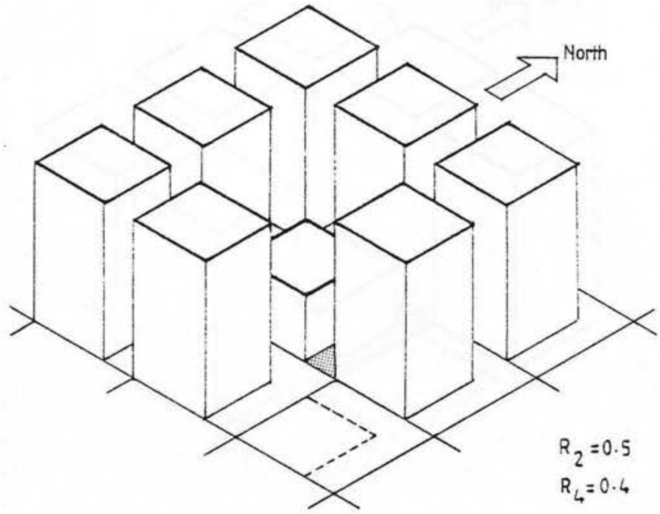
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.22 The proportions of a group of courtyards of varied heights expressed by the ratios R_2 and R_4 and their average shading distribution in urban space in summer, spring and autumn, and winter

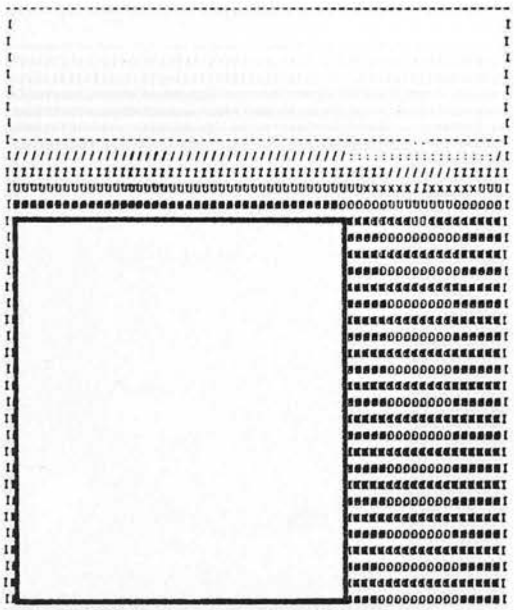
KEY TO SYMBOLS

REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
I REPRESENTS 51 TO 60 PERCENT SHADING
x REPRESENTS 61 TO 70 PERCENT SHADING
O REPRESENTS 71 TO 80 PERCENT SHADING
REPRESENTS 81 TO 90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



$R_2 = 0.5$
$R_4 = 0.4$

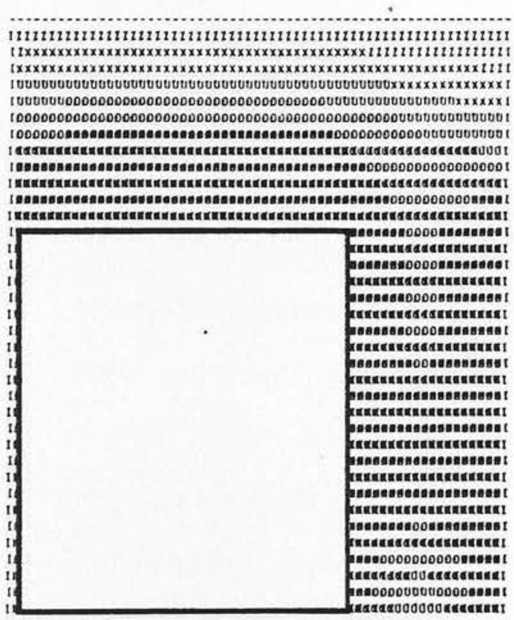


A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

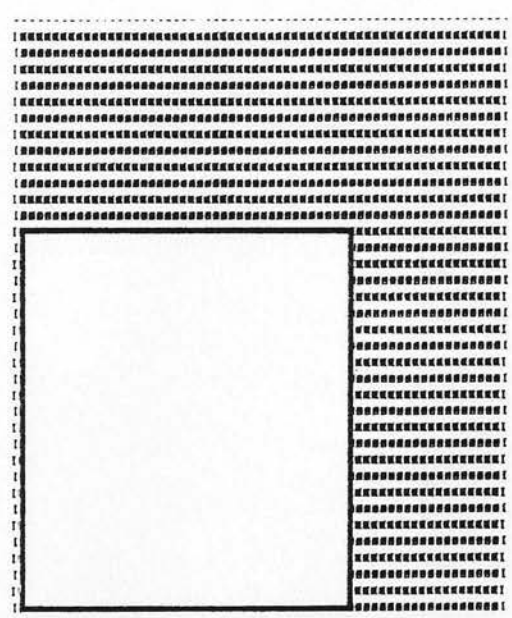
KEY TO LENGTH SCALES

<- LINE IS 5.00 UNITS HIGH

LINE ABOVE IS 5.00 UNITS LONG

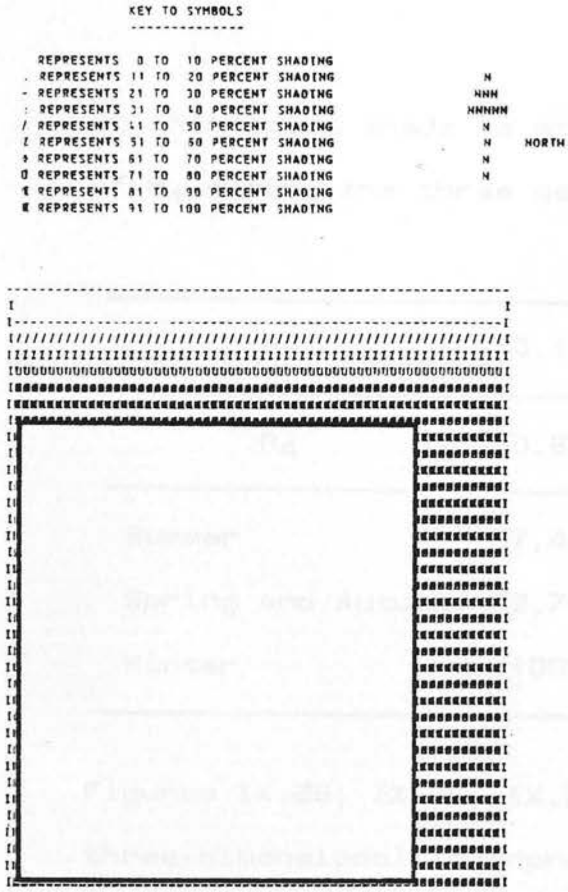


A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive

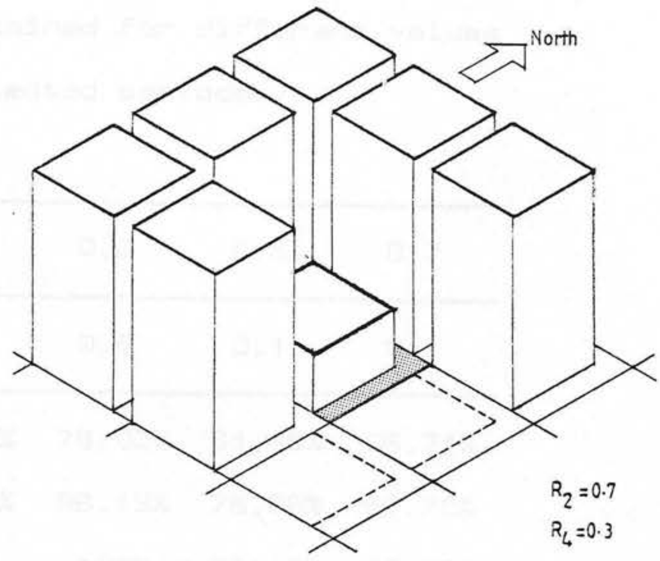


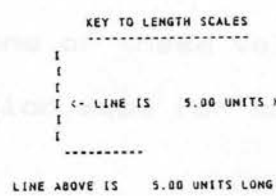
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

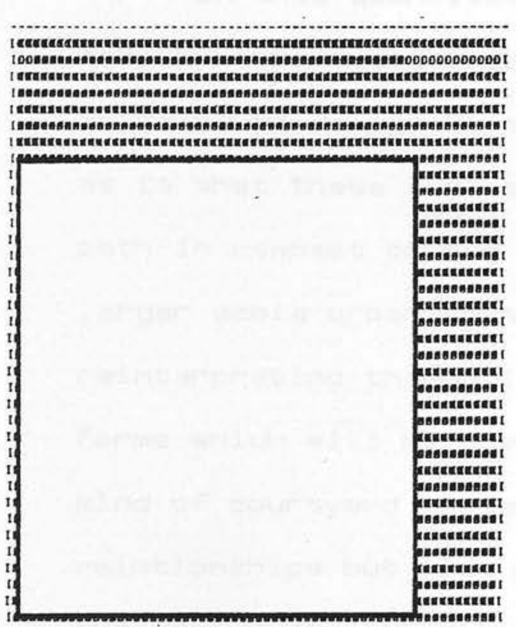
Figure IX.23 The proportions of a group of courtyards of varied heights expressed by the ratios R_2 and R_4 and their average shading distribution in urban space in summer, spring and autumn, and winter



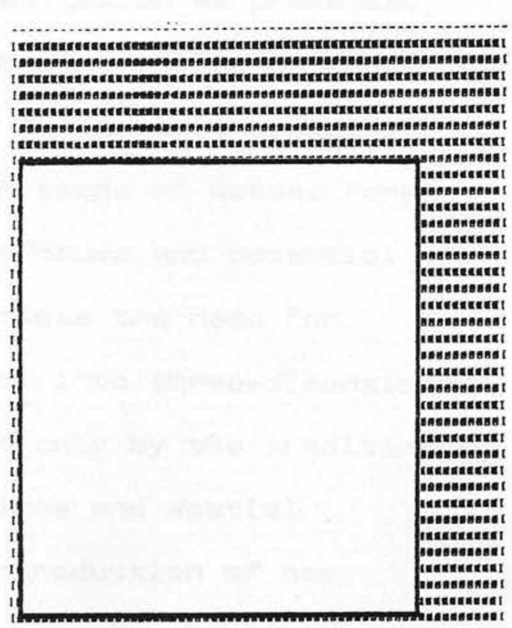
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive







A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX.24 The proportions of a group of courtyards of varied heights expressed by the ratios R_2 and R_4 and their average shading distribution in urban space in summer, spring and autumn, and winter

at which good shade is attained for different values of R_1 during the three selected periods.

R_1	0.1	0.3	0.5	0.7
R_4	0.6	0.6	0.1	0.1
Summer	87.43%	78.03%	61.45%	68.71%
Spring and Autumn	99.79%	98.19%	76.36%	90.72%
Winter	100%	100%	99.16%	99.93%

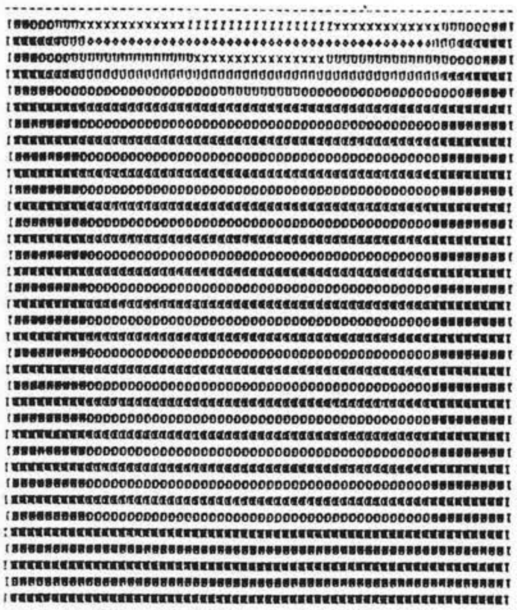
Figures IX.25, IX.26, IX.27 and IX.28 illustrate the three-dimensional interpretations of these values and their average shading distribution maps for summer, spring and autumn, and winter.

In this quantitative investigation we presented form by ratios and ended up with some choice of what we think of as 'good' ones, but the question remains as to what these figures mean in terms of actual forms both in respect of the courtyard house and potential larger scale urban form. Here rises the need for reinterpreting these figures back into three-dimensional forms which will be governed not only by the traditional kind of courtyard house proportions and spatial relationships but also by the introduction of new businesses and activities. For example, the

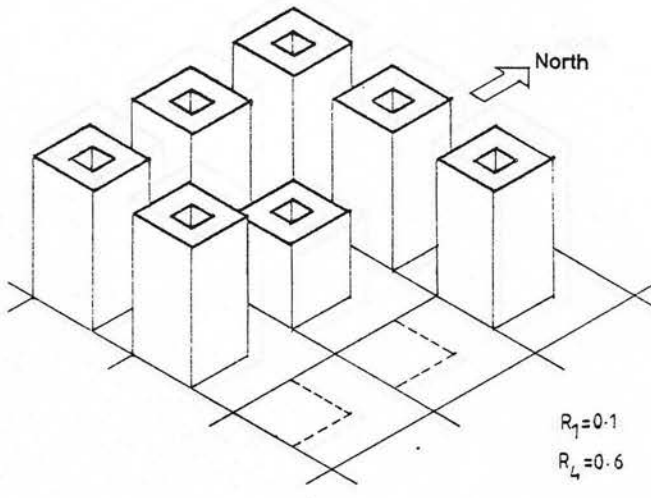
KEY TO SYMBOLS

```
--------------
  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING
- REPRESENTS 21 TO  30 PERCENT SHADING
: REPRESENTS 31 TO  40 PERCENT SHADING
/ REPRESENTS 41 TO  50 PERCENT SHADING
I REPRESENTS 51 TO  60 PERCENT SHADING
+ REPRESENTS 61 TO  70 PERCENT SHADING
0 REPRESENTS 71 TO  80 PERCENT SHADING
¶ REPRESENTS 81 TO  90 PERCENT SHADING
■ REPRESENTS 91 TO 100 PERCENT SHADING
```

NORTH

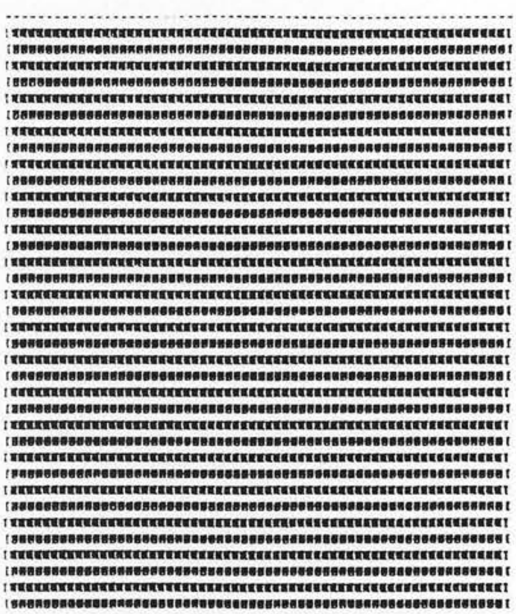


A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

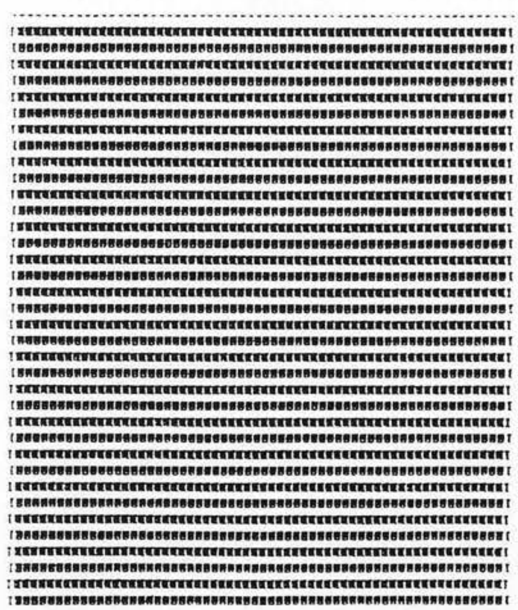


KEY TO LENGTH SCALES

```
-------------------
I
I
I
I <- LINE IS    2.00 UNITS HIGH
I
I
----------

LINE ABOVE IS   2.00 UNITS LONG
```



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



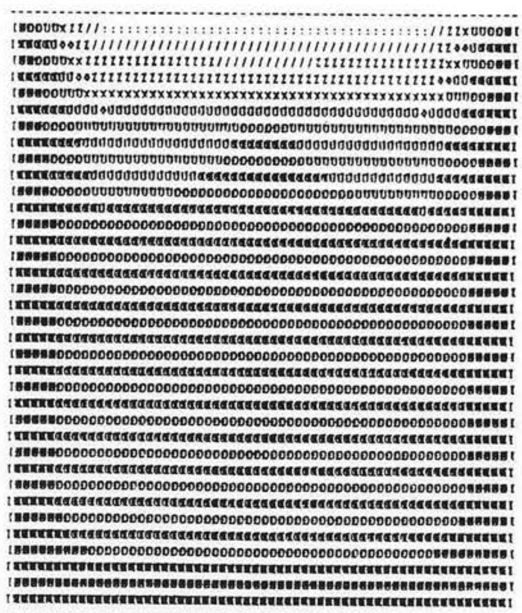
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX·25 The proportions of a group of courtyards of varied heights expressed by the ratios R_1 and R_4 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

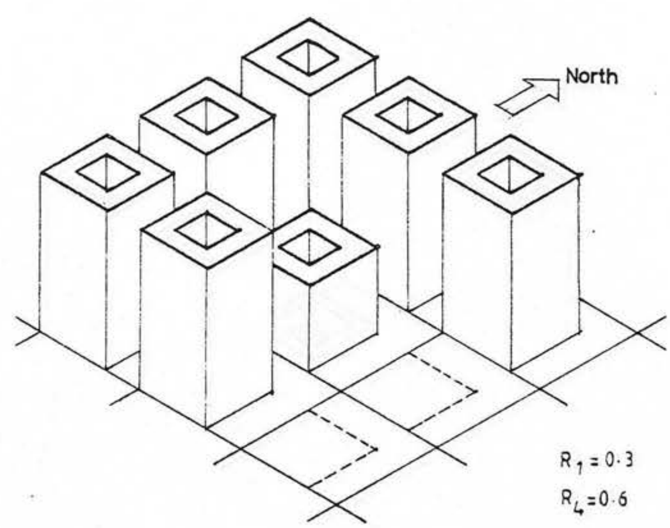
KEY TO SYMBOLS

  REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
I REPRESENTS 51 TO 60 PERCENT SHADING
+ REPRESENTS 61 TO 70 PERCENT SHADING
O REPRESENTS 71 TO 80 PERCENT SHADING
* REPRESENTS 81 TO 90 PERCENT SHADING
* REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



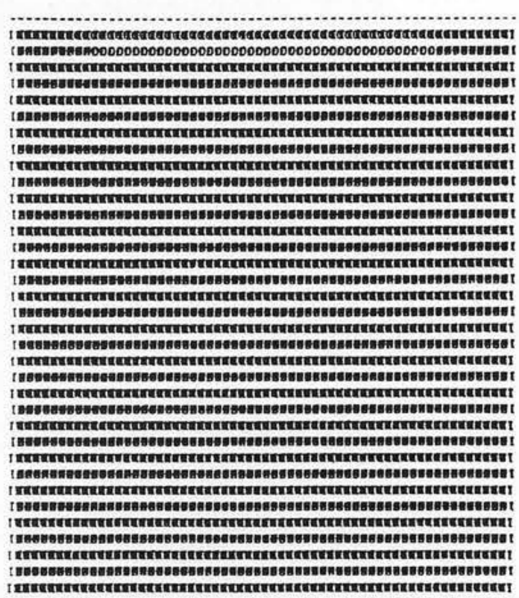
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive



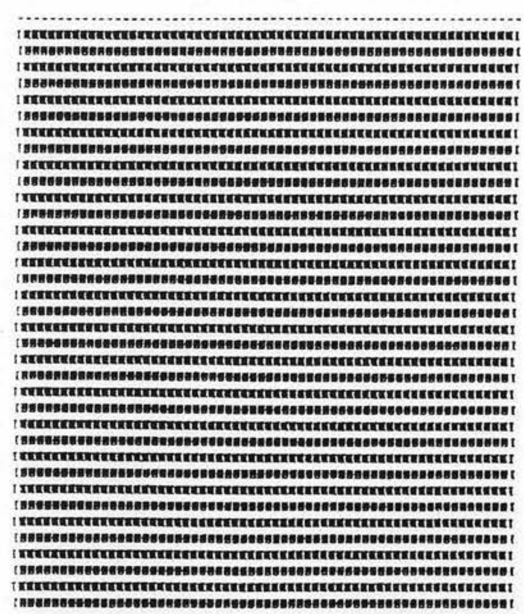
KEY TO LENGTH SCALES

<- LINE IS 6.00 UNITS HIGH

LINE ABOVE IS 6.00 UNITS LONG



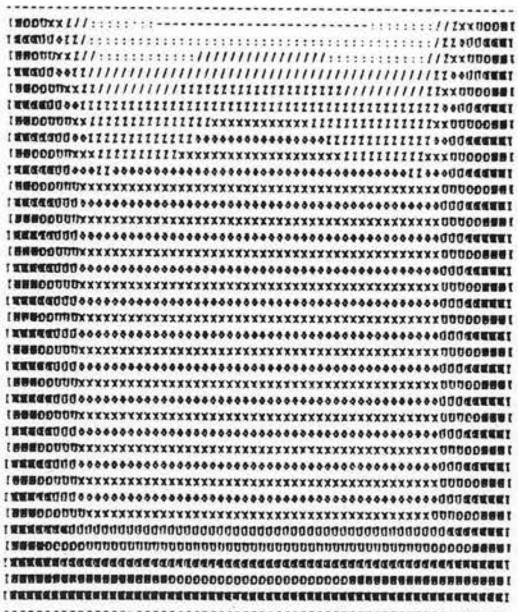
A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



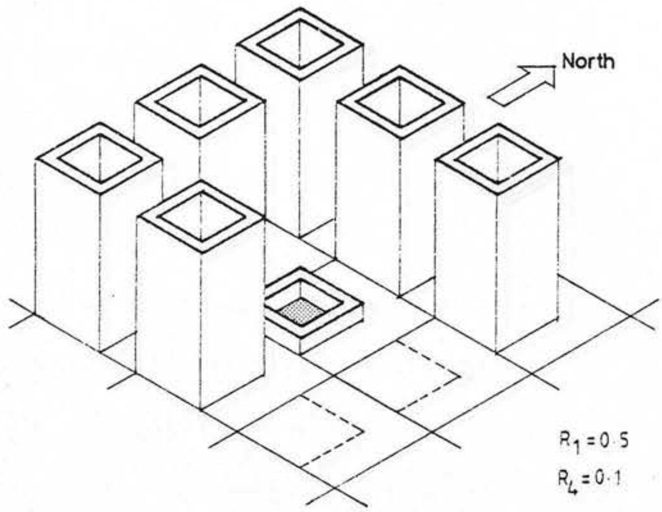
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX·26 The proportions of a group of courtyards of varied heights expressed by the ratios R_1 and R_4 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

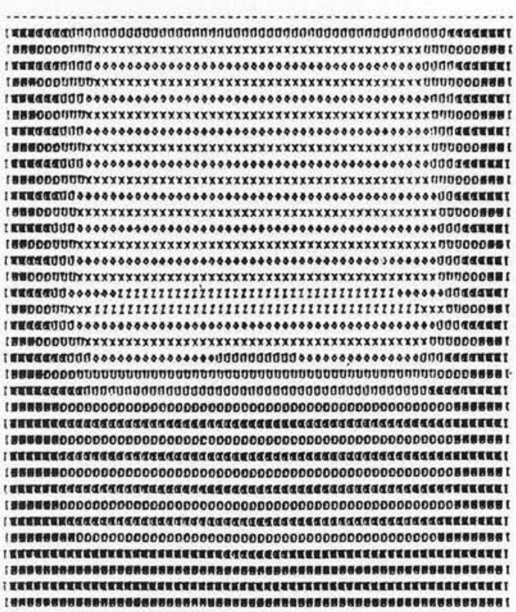
```
        KEY TO SYMBOLS
        --------------

  REPRESENTS  0 TO  10 PERCENT SHADING
. REPRESENTS 11 TO  20 PERCENT SHADING          N
- REPRESENTS 21 TO  30 PERCENT SHADING         NNN
: REPRESENTS 31 TO  40 PERCENT SHADING        NNNNN
/ REPRESENTS 41 TO  50 PERCENT SHADING          N
I REPRESENTS 51 TO  60 PERCENT SHADING          N      NORTH
+ REPRESENTS 61 TO  70 PERCENT SHADING          N
0 REPRESENTS 71 TO  80 PERCENT SHADING          N
X REPRESENTS 81 TO  90 PERCENT SHADING
B REPRESENTS 91 TO 100 PERCENT SHADING
```



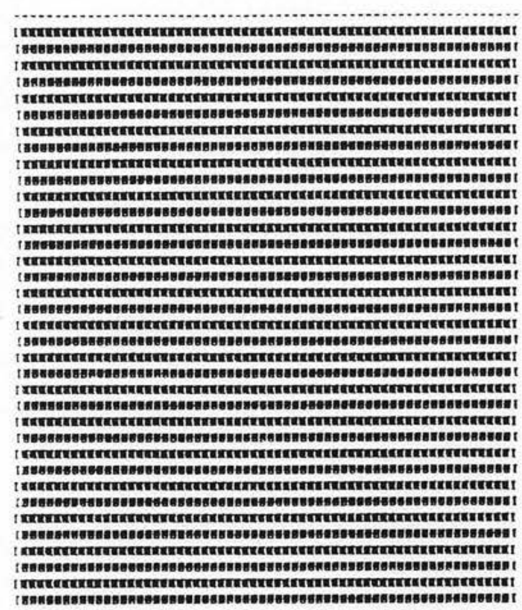
A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive




```
      KEY TO LENGTH SCALES
      --------------------
I
I
I
I <- LINE IS   10.00 UNITS HIGH
I
I
 ----------

LINE ABOVE IS   10.00 UNITS LONG
```



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



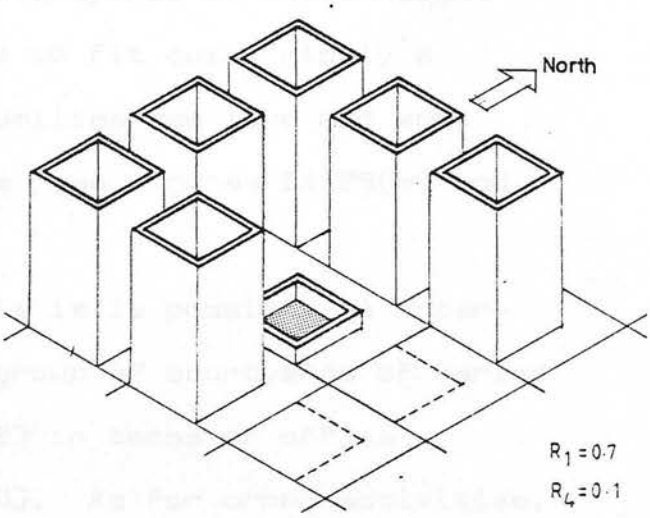
A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

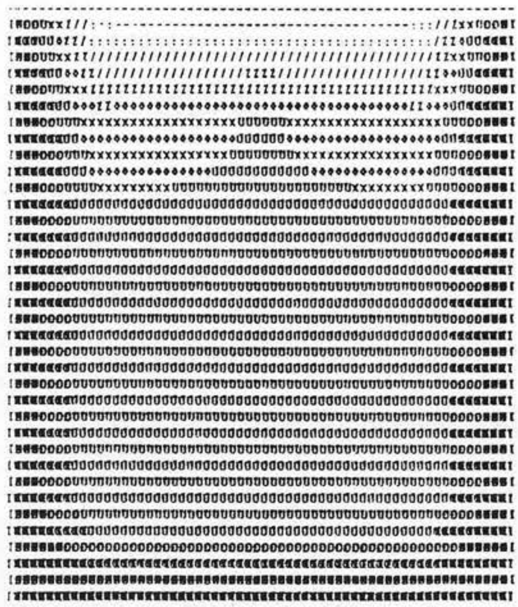
Figure IX·27 The proportions of a group of courtyards of varied heights expressed by the ratios R_1 and R_4 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

KEY TO SYMBOLS

- (blank) REPRESENTS 0 TO 10 PERCENT SHADING
- . REPRESENTS 11 TO 20 PERCENT SHADING
- - REPRESENTS 21 TO 30 PERCENT SHADING
- : REPRESENTS 31 TO 40 PERCENT SHADING
- / REPRESENTS 41 TO 50 PERCENT SHADING
- Z REPRESENTS 51 TO 60 PERCENT SHADING
- + REPRESENTS 61 TO 70 PERCENT SHADING
- 0 REPRESENTS 71 TO 80 PERCENT SHADING
- # REPRESENTS 81 TO 90 PERCENT SHADING
- ■ REPRESENTS 91 TO 100 PERCENT SHADING

NORTH



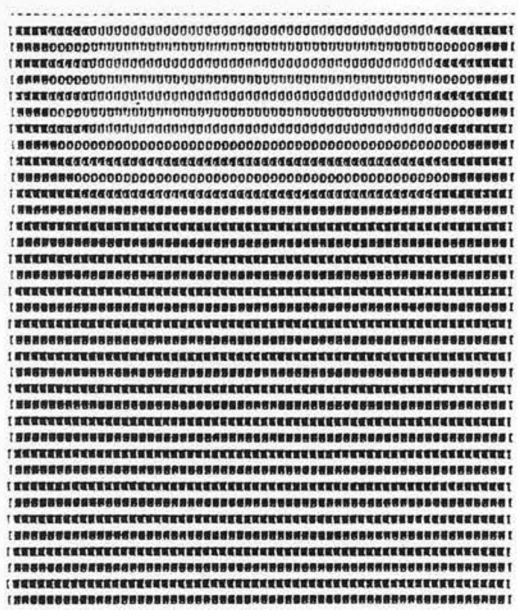


A map of the average shading between the hours of 700 and 1700 over the period 8-June to 6-July inclusive

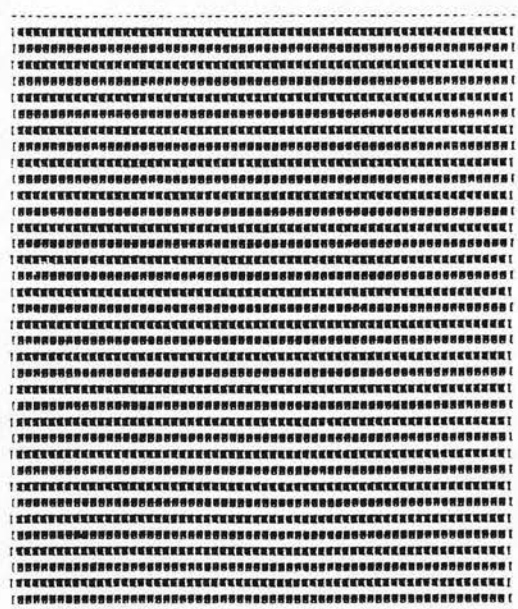
KEY TO LENGTH SCALES

<- LINE IS 14.00 UNITS HIGH

LINE ABOVE IS 14.00 UNITS LONG



A map of the average shading between the hours of 700 and 1700 over the period 7-Mar. to 4-Apr. inclusive



A map of the average shading between the hours of 700 and 1700 over the period 8-Dec. to 5-Jan inclusive

Figure IX·28 The proportions of a group of courtyards of varied heights expressed by the ratios R_1 and R_4 and their average shading distribution within the courtyard space in summer, spring and autumn, and winter

proportions of a group of courtyards of equal height shown in Figure IX.15 seems to fit quite nicely a housing pattern in which families can live and work within their dwelling units (see Figures IX.29[a] and IX.29[b]).

At a much larger scale it is possible to interpret the proportions of a group of courtyards of varied height given in Figure IX.23 in terms of office buildings [see Figure IX.30]. As for urban activities, it might be interesting to imagine the proportions in Figure IX.27 giving some sort of characteristics typical of the size and shape of commercial centres [see Figure IX.31].

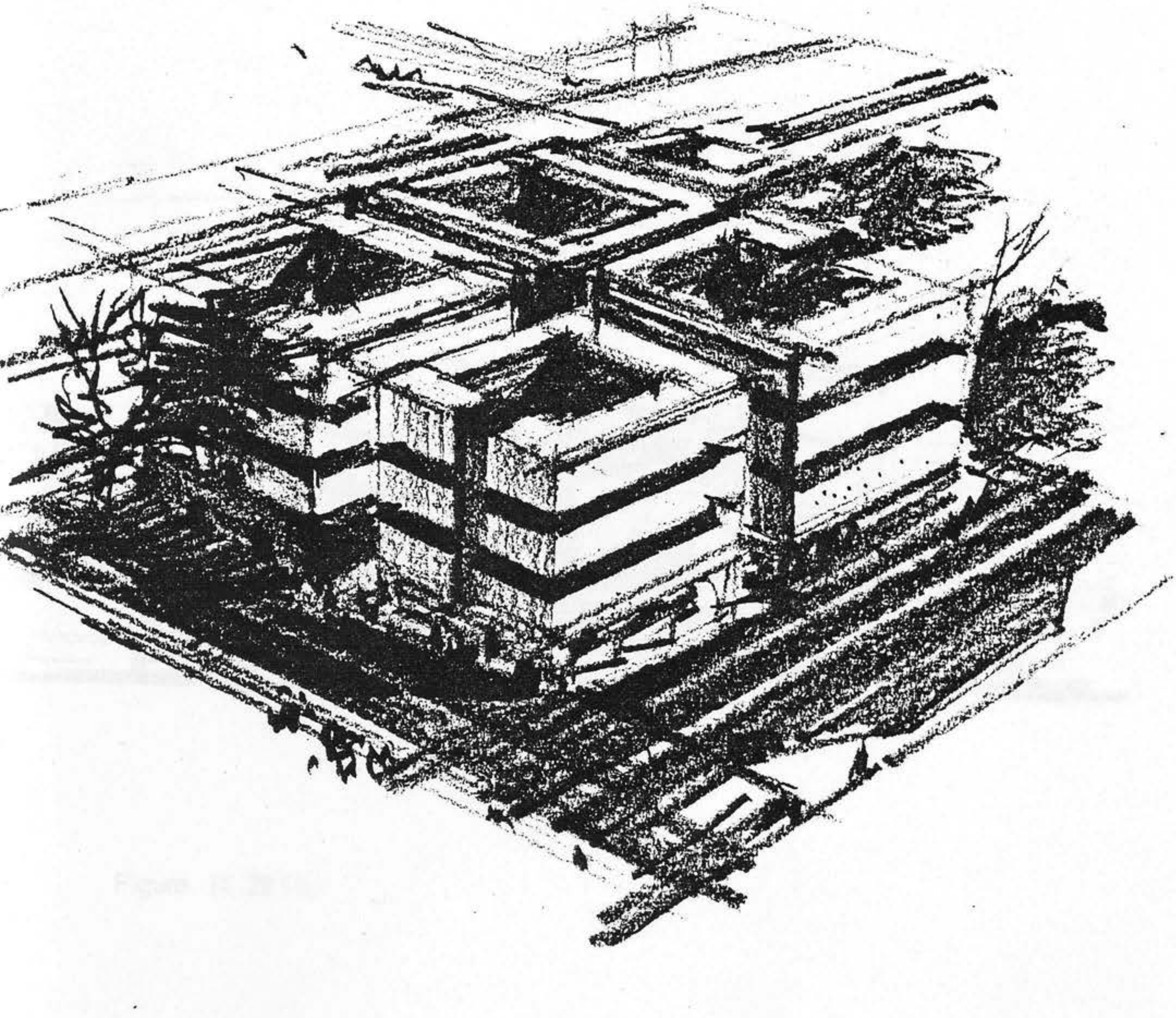


Figure IX.29 (a)

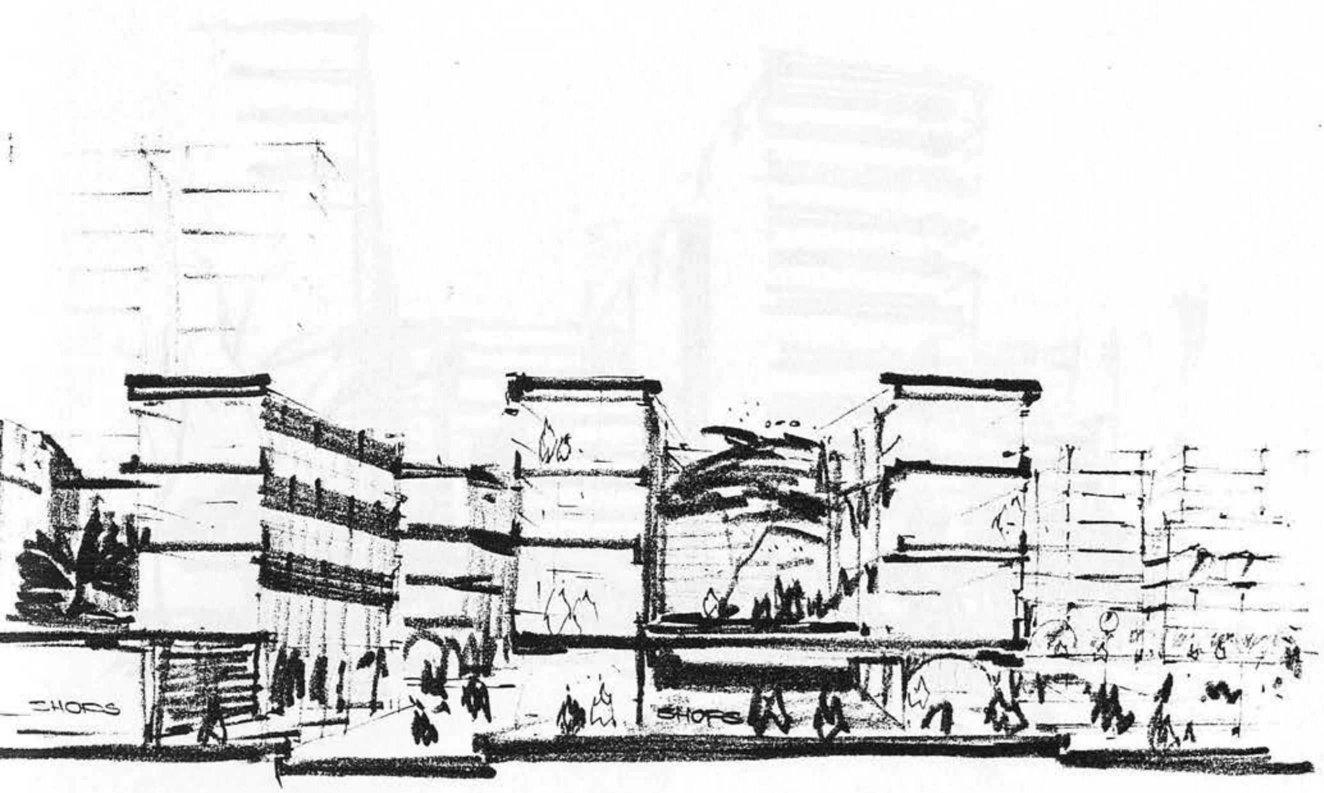


Figure IX.29 (b)

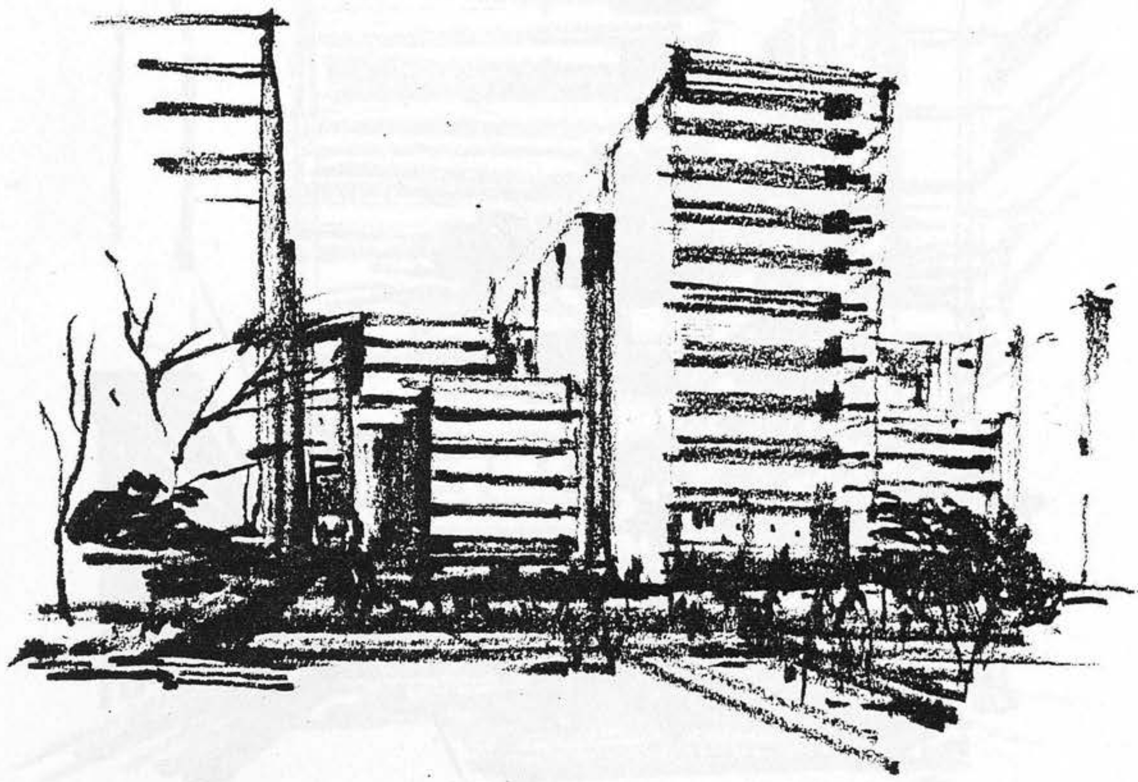


Figure IX.30

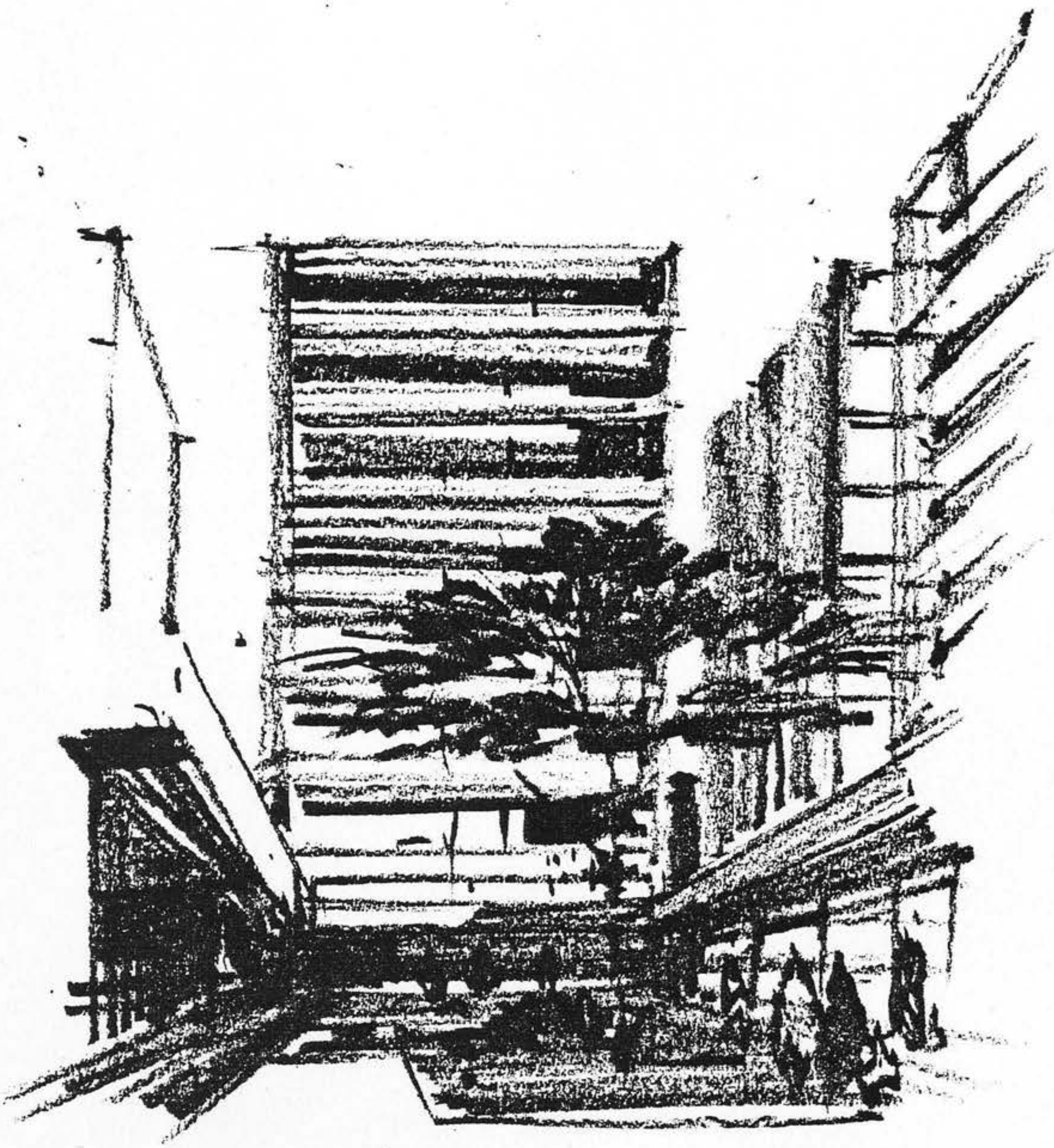


Figure IX-31

CHAPTER X

THE MEETING OF QUALITY AND QUANTITY

CHAPTER X

THE MEETING OF QUALITY AND QUANTITY

X.1 Introduction

This chapter considers briefly the ways in which the qualitative considerations of the phenomenon of shade might come together with the quantitative ones.

Section X.2 summarizes the different stages in the present study and shows how a particular concern about the phenomenon of shade in the tropical urban environment led eventually to the generation of a particular courtyard.

Section X.3 emphasizes the necessity of synthesizing quality and quantity both in design and in research.

X.2 From Particular Concern to Particular Form

The argument for a process of design initiated by qualitative concerns started in Chapter II where we found that shade, along with all other natural phenomena, must be first understood in terms of qualities. It was also argued that shade, in the living concrete reality, is a 'place' to which man's relationship is none other than 'dwelling'. With this placeness of shade it was possible to see this phenomenon in a much wider context where shade transcends these abstract predicted patterns and gets tied to urban built forms and activities and their physical and behavioural manifestations.

The phenomenological analysis revealed that the very existence of shade stems primarily from its meanings and values all of which in fact give rise to physical and behavioural expressions common to the tropical urban environment.

Our emphasis upon the qualitative aspects of shade [see the discussions in Chapters II, III and IV] can be regarded as a response to 'particular' concerns about the quality of phenomena which man encounters in his everyday dealings with the environment. Throughout these discussions it was clear that we were moving towards making a 'general' qualitative choice exemplified for the purpose of this work in the geometry of the courtyard form [see Chapter V].

With this general qualitative choice decided upon, there arose the need for picking out 'particular' courtyard forms whose shading performance would be better than others. This was achieved through the 'general' systematic quantitative investigation presented in Chapters VII and IX.

X.3 The Synthesis of Quality and Quantity

The present study was initiated by 'particular' concerns about the quality of phenomena and ended up with 'particular' courtyards generated from the 'general' systematic quantitative investigation.

The synthesis of a 'particular' concern about the quality of shade and a 'particular' courtyard which generates it would normally take place in a 'particular' design.

The benefits of such a synthesis in the design process are evident. Through it, it is possible to generate ranges of courtyard forms, evaluate their shading performances and define those particular forms which satisfy the socio-cultural demands and climatic constraints imposed. This of course makes a demand for an interplay between research and design which allows the designer to carry out the necessary modification to enhance his proposals. For example, the shading behaviour of a courtyard varies with the latitude of its locality; accordingly the courtyard situated in Kuwait [latitude 30^{o}] would be expected to be proportionally different from one located in Oman [latitude 20^{o}]; the designer therefore is under the necessity of returning to the systematic quantitative investigation in order to define a particular courtyard that responds to solar shading at particular latitude. Here, there are two things that must be taken into account: [i] from the point of view of shade, there are ranges of courtyard proportions that generate living shady places which are different from those optimum ones which just produce the abstract shaded spaces, and [ii] although courtyard forms having identical proportions would certainly have the same ratio of exposed to shaded areas, which is scale free, they will surely manifest different behavioural patterns, i.e., the communal and private characters of the courtyard are influenced by its largeness and smallness [see Chapter V].

The designer's task is to allow this meeting between qualitative concerns and quantitative description to take place in design. This of course would involve a wide range of his activities at the drawing board where his ideas move constantly between quality and quantity to form the spatial and temporal basis for his proposals.

The qualitative approach adopted in the present study seems to warrant further use and development because of the insights it may give into similarities and differences in behaviour of other natural phenomena and their meanings and values in different urban environments.

Of course, the average shade investigated here can give only general indications. In a particular design it would be worthwhile pursuing a more detailed analysis of the quantitative distribution of shade in space and time within the courtyard in relation to expected activities. It hardly seems worthwhile trying to do this for the generalized courtyard.

There is also the question of the extent to which shady places are conditioned by reflected radiation and thus the choice of the surface treatments as well as of forms. But this again is a refinement which would be hard to pursue fruitfully in a generalized study.

The main part of this investigation has been to argue for and demonstrate a fruitful form of relationship between design and research - not to produce specific guidelines for the products of design but rather guidance for the process.

CHAPTER XI

CONCLUSIONS

CHAPTER XI

CONCLUSIONS

The present study is concerned with the attainment of a better understanding of the phenomenon of shade in the tropical urban environment, and is directed towards the development of an approach to design dominated by such qualitative understanding.

It has been argued that the problem of shade is not so much one of prediction as it is of choosing the appropriate form upon which shade is conditional. The discussion in Chapter I emphasized that shade is not only physical, but is primarily phenomenal, i.e., it has meanings and values.

The approach taken has been to make a two-level investigation of shade. The first was dominated by qualitative concerns, where we were able to analyze phenomenologically the meanings and values of shade in living tropical urban settings, and derive from them principles of form which culminated in the qualitative choice of the courtyard as a viable and relevant form. At the second level we took this qualitative choice and moved into a systematic quantitative investigation of its shading characteristics.

The findings fall into three main areas:

The first is related to environmental research where the quantitative and qualitative approaches have a tendency to diverge to the point that the consideration of one means the elimination of the other. The epistemological question concerning shade emphasized the complementarity of quality and quantity, and asserted the necessity of combining them so as to satisfy behavioural and physical demands. However, the argument also emphasized the primacy of the qualitative aspects of shade, while at the same time allowed its quantitative description to have its proper place in research.

The second area is related to environmental and architectural design, where the understanding of 'space' is often confined to abstract notions about manipulable 'emptiness' which the designer makes use of in order to shape and quantify his proposals. As an alternative, a phenomenological approach to man and his environment allows things to be seen in their 'spatiality' rather than in 'space'. In this manner, a process of design initiated by qualitative concerns was proposed as a way to deepen the designer's awareness of the environment as a living place rather than as abstract space.

The third area is linked to the use of the computer program (SHADE). It was argued that there is a need to reduce complexity and ease the routine systematic, and potentially excessive, content of the quantitative investigation of shade. This was achieved through the qualitative choice of the courtyard which was prompted both by the practical necessity of picking a form for investigation and by the argument for choosing the form on qualitative grounds.

A mathematical model simulating the interaction between solar shading and groups of courtyard forms was developed for evaluating the time-averaged distribution of shade on the ground. The underlying objectives in developing the model were twofold: [i] allowing a quantitative investigation to be carried out into the effects of geometrical parameters of the courtyard form and its surroundings on the shading of the ground surface of the courtyard and urban spaces; and [ii] providing the designer with useful information for practical application relating to ranges of courtyard forms and their corresponding shading performances.

Taking the city of Abu Dhabi as a typical example of the prevailing climatic conditions in the Gulf region, and using the computer program SHADE, wide ranges and combinations of form parameters were studied over three selected periods of the year between the hours of 7.00 a.m. and 5.00 p.m. On this basis, the relationships between the time-averaged distribution of shade on the ground and the parameters of the courtyard form and its surroundings were analyzed in Chapter IX.

In a study dominated by qualitative concerns, the derivation of optimum forms based upon the generation of maximum shade would have been irrelevant, and so the emphasis was placed on the provision of 'good' shade and 'best' forms to satisfy qualitative demands.

Although the model's output was limited to courtyard forms having square shaped plans in a grid-iron arrangement with a single orientation, the results nevertheless provide a general indication of alternative possibilities for manipulating the geometrical parameters of this particular form for the quantitative evaluation of shade in relation to other socio-cultural and climatic criteria as well as an illustration of the research/design strategy which is being proposed.

The approach developed in this study can be seen in a much wider context. It is necessary to tame the increasing power, available to researchers and designers, of computer based quantitative analyses. With this potential power of quantitative investigations of a wide range of physical phenomena there is always the temptation to make use of simulations of building behaviour and performance which often end up with too much data and too few variables. The key question, in research terms, is how to avoid this unrestrained expansion of output, data and catalogues of form/performance relationship, and how to arrive at some kind of criteria to determine their direction and limits; whereas in design terms, the problem is how to avoid the computer dominating the design of the building using all sorts of optimal conditions which we presume to exist for all these physical variables.

The answer to both problems lies in looking, qualitatively, for the kinds of forms which seem to have the right kind of meaning as places, and then using the quantitative tools to investigate their performance and to tune their design.

Shade has been central to this work in a way which we hope to have some value both in terms of understanding its nature and through guidance which may be obtained from the computer outputs. However, the real weight of the thesis is to propose a way of looking at the relationship between the qualitative and quantitative aspects of the environment, and to argue for a process of design which builds upon quality and uses, wisely, quantitative tools.

Although we have been concerned with shade, the argument could equally be applied to a wide variety of other phenomena. It seems important to make this argument at the present time, not because people are less concerned with the qualitative but because quantitative techniques are growing more and more powerful.

APPENDIX

APPENDIX

THE CLIMATIC FEATURES OF THE UNITED ARAB EMIRATES: WITH PARTICULAR REFERENCE TO THE CITY OF ABU DHABI

A.1 General

All the Gulf States lie within a sub-tropical arid zone, where they are exposed to the influence of the Gulf and the Indian ocean, but are still outside the Monsoon area. The map of the Gulf region shown in Figure A.1 indicates the locality of the city of Abu Dhabi, and shows its latitude and longitude. Although the area is widely regarded as a hot arid zone, the fact is that the climate of the Gulf region has peculiar characteristics of its own. The main inland areas are extremely hot and dry, whereas the coastal zone, in which the Gulf adjoins the large land mass of the Arabian peninsula, is exceedingly hot and humid. This coastal belt stretches for a few miles into the hot dry zone, creating quite different micro-climatic conditions within an area of a city.

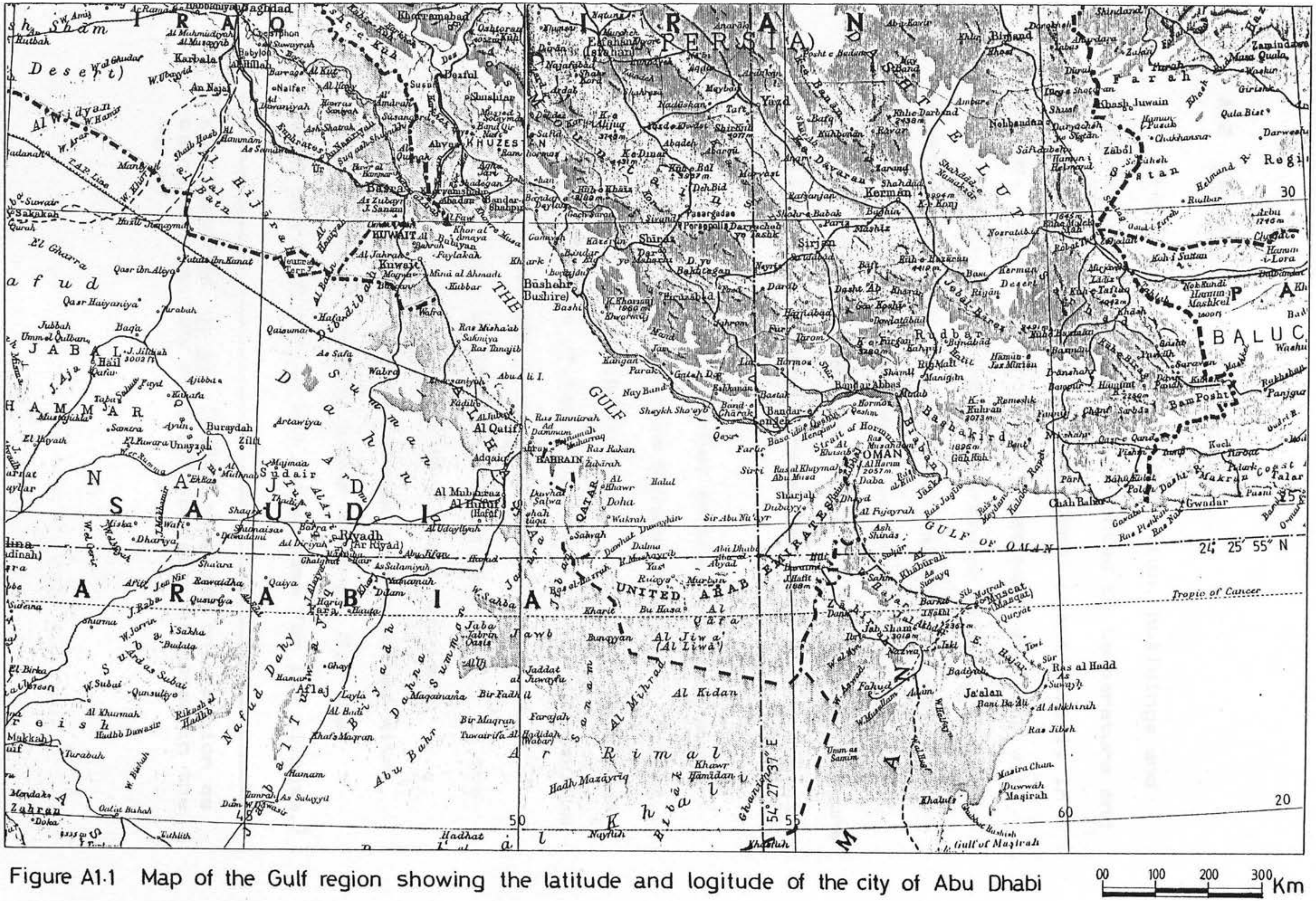


Figure A1.1 Map of the Gulf region showing the latitude and logitude of the city of Abu Dhabi

A.2 Temperature and Humidity

In addition to solar radiation, buildings and human environment are also affected by temperature and humidity. The climate of Abu Dhabi, particularly in summer, is characterized by great heat combined with high humidity. During the period of June to September high daytime temperatures with relatively hot and humid nights can prove most uncomfortable. However, there are considerable variation in the air temperature as well as in humidity between the desert and coastal areas.

There is also a marked contrast between summer and winter months; June to September are the hottest. Absolute maximum and minimum dry bulb temperatures as well as estimates of return periods of extreme maximum temperature for Abu Dhabi are given in table A.1.

Humidity, on the other hand, especially on the coast, is invariably high throughout the year, generally becoming more intense when combined with high temperature during summer months. For that reason the Gulf region has a bad name for its climate.[1]

---

[1] Koenigsberger et al. [1973] regarded this region as being amongst the most unfavourable climates in the world.

Abu Dhabi
Latitude : 24° 25' 55" N
Longitude : 54° 27' 37" E

TEMPERATURE C°

Absolute maximum dry bulb

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
1971	27.6	34.4	36.7	42.5	44.0	44.4	47.4	41.5	43.1	36.0	33.8	29.0	38.3
1972	29.3	28.6	37.0	35.5	43.5	45.2	45.5	44.8	43.4	38.9	35.2	28.8	37.8
1973	28.7	33.5	38.5	44.5	43.5	45.0	45.1	46.1	43.8	40.8	32.5	27.3	39.1
1974	29.0	33.6	37.8	42.0	42.7	47.3	45.8	46.0	42.5	40.5	35.0	29.6	39.3
1975	30.0	32.0	36.1	38.5	44.0	44.8	45.8	45.0	43.4	40.4	33.6	30.1	38.6
1976	29.2	30.7	34.3	40.3	43.0	43.5	44.2	45.2	42.9	38.9	33.3	29.4	37.9
1977	29.0	32.1	38.9	40.5	42.1	44.2	44.9	46.1	42.6	38.3	34.7	30.6	38.7
1978	30.1	32.7	39.8	41.7	41.9	44.6	44.8	45.5	43.0	39.6	36.7	31.3	39.3
1979	28.5	32.7	37.7	41.4	44.0	45.6	48.0	45.9	43.2	39.5	34.4	30.7	39.3
Mean	29.0	32.2	37.4	40.8	43.2	44.9	45.7	45.1	43.1	39.2	34.3	29.6	38.7
S/D	0.72	1.64	1.54	2.42	0.77	1.00	1.17	1.36	0.38	1.38	1.16	1.14	

Absolute minimum dry bulb

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
1971	8.8	10.7	11.2	16.3	16.0	22.1	23.8	26.0	20.4	17.8	15.4	11.2	16.6
1972	9.4	7.5	12.6	14.5	20.5	24.9	26.7	25.6	25.0	19.1	14.7	10.7	17.6
1973	7.9	8.9	14.7	15.6	22.2	23.6	26.5	27.6	25.0	18.1	14.7	9.6	17.9
1974	9.2	9.5	13.9	15.6	20.1	23.2	22.7	26.7	23.5	17.2	13.3	12.0	17.2
1975	10.6	10.8	10.3	13.3	22.0	23.3	26.1	25.6	25.3	16.7	16.9	10.0	17.6
1976	10.2	11.8	14.0	16.6	20.2	23.5	27.0	27.0	24.2	20.8	13.1	13.6	18.5
1977	10.4	12.2	15.5	16.1	23.0	25.2	26.2	26.6	25.5	21.9	15.6	14.9	19.4
1978	12.0	10.5	13.2	15.6	18.6	24.5	26.5	26.0	24.7	21.0	15.4	13.3	18.4
1979	9.1	10.8	12.8	16.4	18.0	25.6	24.0	26.5	25.0	21.0	13.0	10.7	17.8
Mean	9.7	10.3	13.1	15.5	20.1	24.0	25.5	26.4	24.3	19.3	14.7	11.8	17.9
S/D	1.13	1.37	1.54	0.99	2.11	1.07	1.47	0.62	1.49	1.89	1.24	1.69	

Estimated extreme maximum temperature return periods (C°)

10 years	25 years	50 years	100 years
48.0	48.9	50.0	51.1

Table A.1 Absolute maximum and minimum dry bulb temperatures and estimated extreme maximum temperature return periods for the city of Abu Dhabi (source : Dept. of Civil Aviation - Abu Dhabi, 1980)

For Abu Dhabi Table A.2 gives absolute maximum and minimum humidities, whereas the graphs shown in Figures A.2 and A.3 represent variations in mean dry bulb temperature and mean relative humidity at various times.[1]

A.3 Sunshine Duration

In Abu Dhabi skies are generally clear except during the relatively cooler months of December to March. Table A.3 shows mean daily and daily maximum sunshine hours as well as sunshine expressed as a percentage of maximum possible hours.

A.4 Solar Radiation

Solar radiation is another problem arising in the Gulf region. According to the worldwide measurements of solar radiation during both the International Geographical Year [1957-1958] and the International Quiet Sun Years [1964-1967] Ashbel [1970] has provided a number of maps representing world distribution of solar radiation [see Figures A.4 and A.5].

---

1 Meteorological data for Abu Dhabi is available from January 1970 to December 1979. The Meteorological instruments are situated on Abu Dhabi island at Lat. 24° 25' 55" and Long. 54° 27' 37"E.

Abu Dhabi
Latitude : 24° 25' 55" N
Longitude: 54° 27' 37" E

RELATIVE HUMIDITY %

Absolute maximum

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	100	100	100	99	100	96	96	97	88	100	98	94
1972	94	100	100	95	98	95	94	99	100	98	91	100
1973	100	99	99	90	92	91	91	100	100	100	98	100
1974	99	100	100	100	91	99	92	100	100	100	100	98
1975	99	99	100	94	100	93	93	92	100	96	97	96
1976	92	100	95	100	97	98	93	92	94	95	98	94
1977	93	100	99	93	98	98	93	93	100	100	91	100
1978	100	100	100	84	97	91	92	99	94	100	92	100
1979	100	98	91	92	91	98	96	97	98	99	96	95
Mean	97	99	98	94	96	95	93	96	97	99	96	97
S/D	3.20	0.68	2.97	4.93	3.46	2.95	1.63	3.16	4.01	1.83	3.23	2.53

Absolute minimum

Year	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	17	18	16	13	16	11	07	25	18	15	17	22
1972	32	19	17	10	11	10	12	09	13	20	22	34
1973	31	12	12	05	09	08	20	20	18	10	24	24
1974	28	21	15	12	13	03	06	15	13	14	22	29
1975	27	20	09	13	11	10	21	15	09	18	28	27
1976	23	29	25	13	11	14	23	15	09	15	19	33
1977	36	20	12	11	10	11	21	14	17	16	30	25
1978	37	15	10	13	11	17	17	13	13	16	18	27
1979	22	14	12	09	08	11	10	12	15	13	06	25
Mean	28	19	14	11	11	11	15	15	14	15	21	27
S/D	6.26	4.66	4.56	2.54	2.18	3.62	6.18	4.39	3.14	2.69	6.62	3.41

Table A.2 Absolute maximum and minimum humidity for the city of Abu Dhabi (source: Dept. of Civil Aviation-Abu Dhabi, 1980)

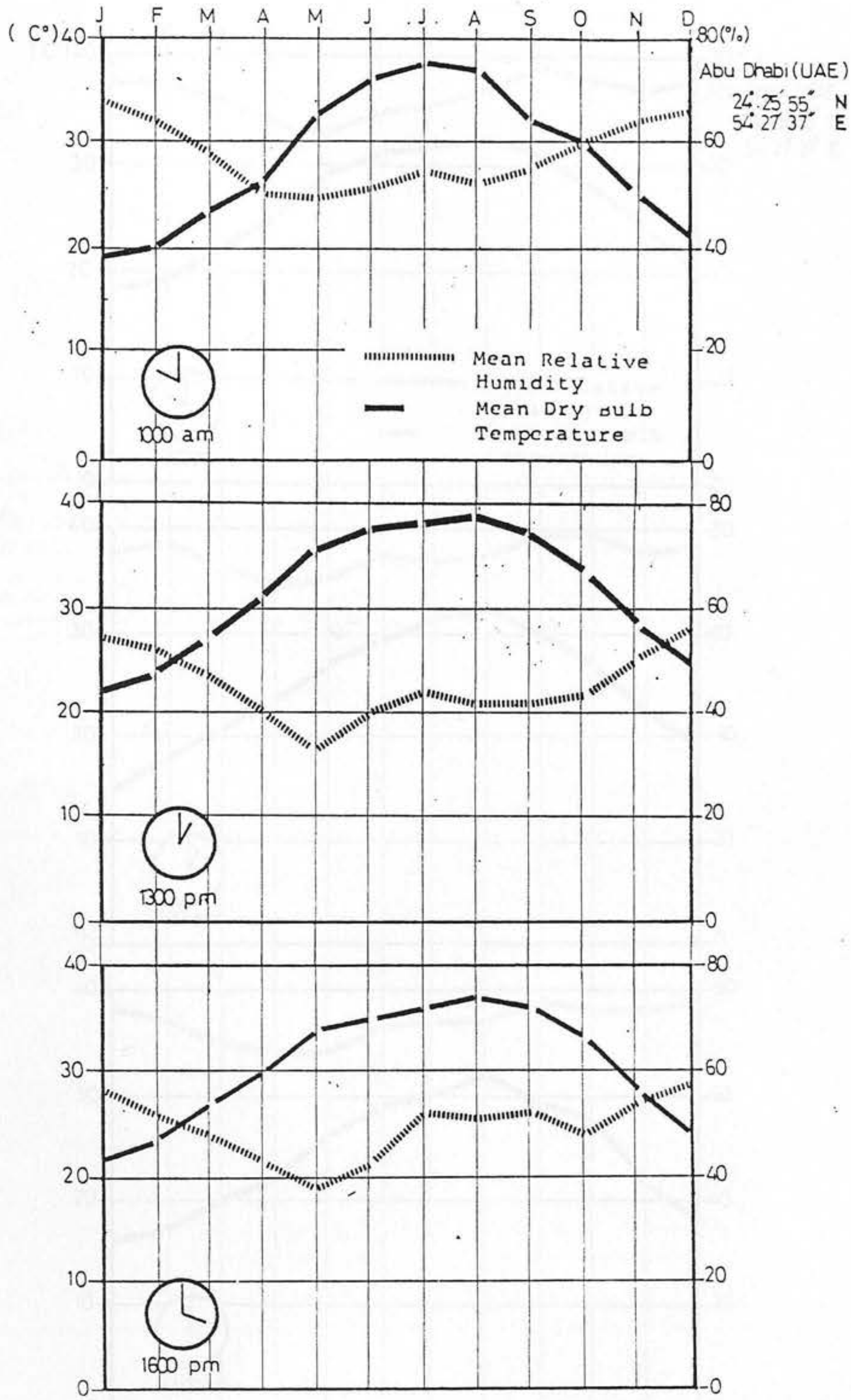


Figure A.2 Mean dry bulb temperature in C° and mean relative humidity as % at various times for the city of Abu Dhabi (source : Dept. of Civil Aviation - Abu Dhabi, 1980)

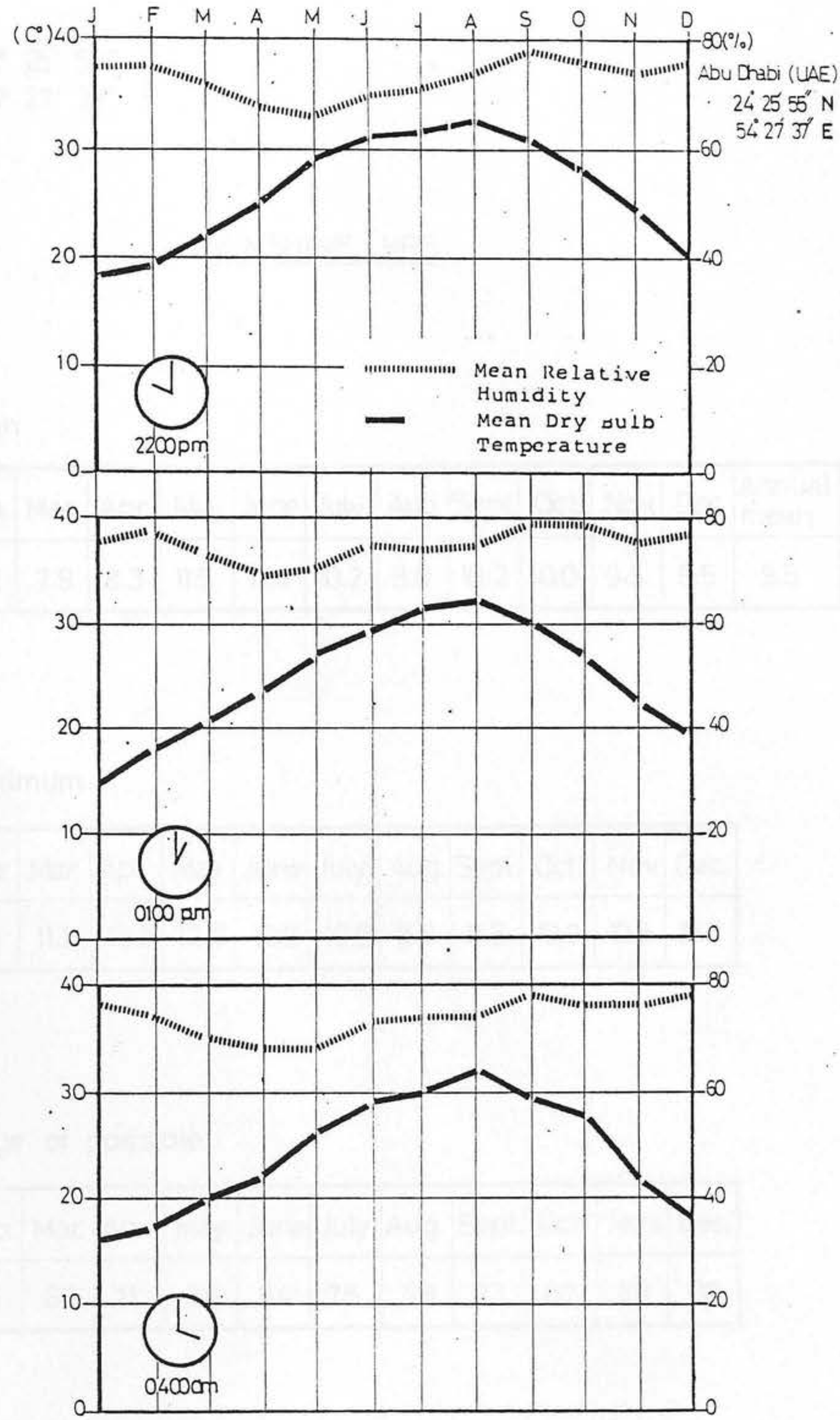


Figure A.3 Mean dry bulb temperature in C° and mean relative humidity as % at various times for the city of Abu Dhabi (source : Dept. of Civil Aviation - Abu Dhabi, 1980)

Abu Dhabi
Latitude : 24° 25' 55" N
Longitude : 54° 27' 37" E

SUNSHINE HRS

Daily mean

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
7.5	8.2	7.9	9.3	11.5	11.4	10.2	9.8	10.2	10.0	9.5	8.5	9.5

Daily maximum

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
10.4	11.3	11.1	12.3	12.8	12.8	12.8	11.9	11.5	10.9	10.5	10.8

Percentage of possiple

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
70	73	67	71	86	84	75	78	83	87	89	80

Table A.3 Daily mean and daily maximum sunshine hours and percentage of possiple sunshine for the city of Abu Dhabi
(source : Dept. of Civil Aviation - Abu Dhabi, 1980)

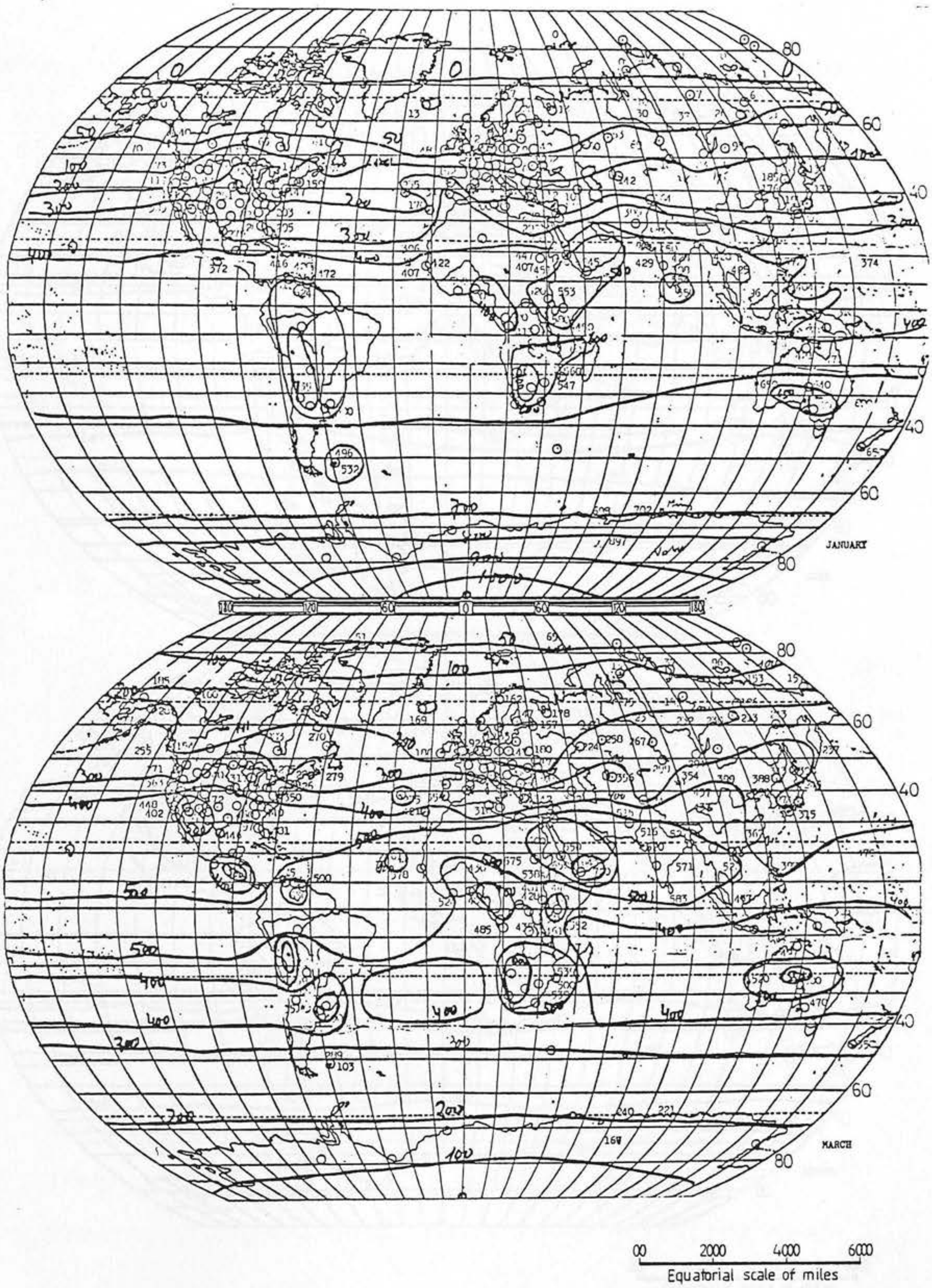


Figure A.4 Global solar radiation during Quiet Sun Years (1964-1967)
(source: Ashbel, D., 1970)

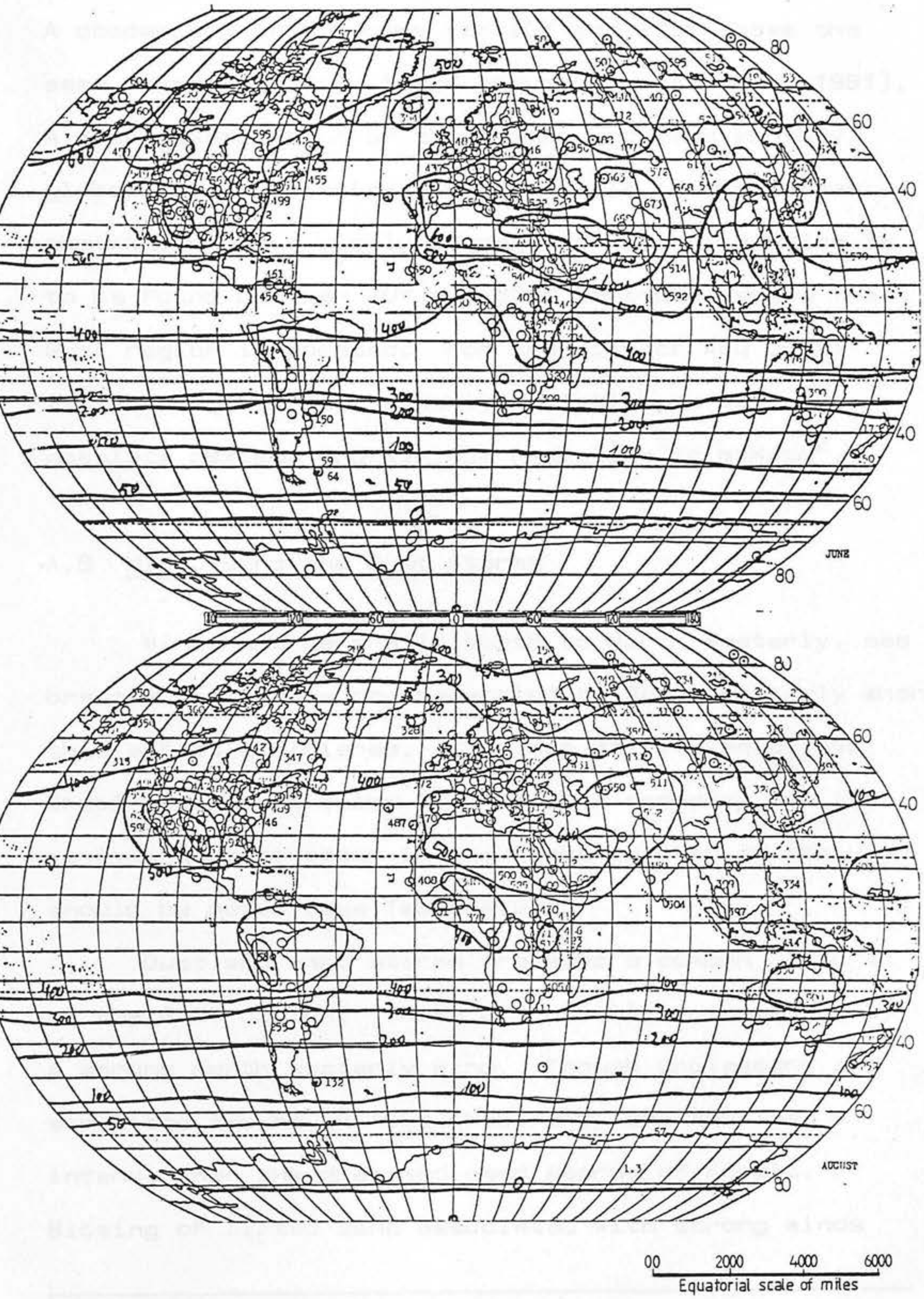


Figure A.5 Global solar radiation during Quiet Sun Years (1964 -1967)
(source : Ashbel, D., 1970)

A comparison of the maps for IGY and IQSY shows the same characteristics found previously [Asheble, 1961]. A close examination of these maps and mean monthly global solar radiation given in Table A.4 has shown that the highest yearly average of solar radiation is to be found between 20^{o} and 30^{o}N latitude, where the Gulf region is located. For the city of Abu Dhabi Table A.5 gives mean monthly radiation as well as absolute maximum and minimum radiation in mWH/cm^2.

A.5 Wind, Sand and Dust Storms

Winds are generally North to North Westerly, sea breezes during the day reverting to South Easterly when this effect diminishes. The mean daily wind at Abu Dhabi station is below 10 knots.[1] A tendency for the maximum gust to occur in the first quarter of the year should be noted [see Table A.6].

Dust and sand storms are also a common feature of the Gulf region. These are usually accompanied by a strong north westerly wind. Though unpleasant and sometimes severe in Abut Dhabi they are far less intense than the dust and sand storms of Kuwait. Blowing of lifted sand associated with strong winds

---

[1] All wind measurements are based on a height of 10 metres.

Latitude	January	March	June	August	Yearly average
85-N	0	30	650	200	100
80-N	0	75	580	220	120
70-N	15	150	400	260	180
60-N	40	200	430	300	220
50-N	85	250	480	470	300
40-N	160	280	600	590	370
30-N	280	450	740	670	530
20-N	360	530	570	550	600
10-N	500	600	500	500	500
00	500	500	500	450	500
10-S	480	480	500	450	480
20-S	600	550	430	450	470
30-S	700	600	330	400	450
40-S	500	380	180	260	400
50-S	450	280	80	150	300
60-S	510	230	20	70	210
70-S	560	180	00	10	160
80-S	610	130	00	00	110
90-S	700	120	00	00	80

Table A.4 Cross-section from pole to pole of the mean monthly global[1] solar radiation at the 40° E meridian during the I.G.Y. (cal / cm^2 / day) (source: Ashbel, D.,1961)

1. Global solar radiation is the total of direct and diffused radiation falling on horizontal surfaces

Abu Dhabi
Latitude : 24° 25' 55" N
Logitude : 54° 27' 37" E

RADIATION mWH/cm^2

Monthly mean

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
323	438	495	593	672	658	605	567	532	493	408	361	498

Absolute maximum

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
533	601	687	770	794	764	785	664	677	661	545	462

Absolute minimum

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
94	135	166	185	381	412	334	410	441	240	200	69

Table A.5 Radiation recorded at Abu Dhabi station in mWH/cm^2
(nine years of record, January 1971 to December 1979)
(source: Dept. of Civil Aviation - Abu Dhabi, 1980)

Abu Dhabi
Latitude : 24° 25' 55" N
Longitude : 54° 27' 37" E

WIND KTS

Daily mean

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
9	9	9	8	9	9	8	8	7	7	7	8

Maximum 10 minute duration

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30	33	42	34	29	34	32	38	24	26	25	25

Maximum monthly gust

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
37	45	60	41	38	37	37	54	34	36	32	33

Maximum gust (yearly)

Year	Velocity (KTS)	Month
1971	35	February
1972	45	March
1973	37	Jan., Feb. & June
1974	38	April
1975	54	August
1976	60	March
1977	41	February
1978	45	February
1979	49	March

Table A.6 Mean daily and extreme winds of at least 10 minute duration and extreme gusts recorded at Abu Dhabi station (all wind measurements are based on a height of 10 meters) (source : Dept. of Civil Aviation - Abu Dhabi, 1980) can cause damage to exposed surfaces.[1]

A.6 Rain

Rain is not a major factor in shaping the environment as the average annual total is relatively small. However, flash flooding can occur in towns during sudden storms because of lack of drains. This normally evaporates fairly rapidly. Autographic records are available for Abu Dhabi station from 1957; therefore, it has not been possible to produce intensity duration curves. Table A.7 gives monthly mean rain fall expressed as a percentage of annual mean rainfall for Abu Dhabi.

---

1 An unwary motorist who attempts to drive through one of these sand storms may well find his windscreen pitted all over and the paint removed from his number plates!

Abu Dhabi
Latitude : 24° 25' 55" N
Longitude : 54° 27' 37" E

RAINFALL

Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
29	26	19	13	Nil	Nil	Nil	07*	Nil	Nil	01	04

Table A.7 Monthly mean rainfall expressed as a percentage of annual mean rainfall (MMS)
(source : Dept. of Civil Aviation - Abu Dhabi, 1980)

* This figure is due mainly to a fall of 28 mms occurring on the 17th of August 1975.

BIBLIOGRAPHY OF REFERENCES

BIBLIOGRAPHY OF REFERENCES

Alexander, C. — Notes on the Synthesis of Form, Harvard University Press, Cambridge, Massachusetts, and London, England, 1964.

The Oregon Experiment, Oxford University Press, New York, 1975.

A Pattern Language, Oxford University Press, New York, 1977.

The Timeless Way of Building, Oxford University Press, New York, 1979.

Anderson, B. — Solar Energy: Fundamentaly in Building Design, McGraw-Hill Book Company, 1977.

Arnheim, R. — The Dynamics of Architectural Form, University of California Press, Berkeley and Los Angeles, California, 1977.

Ashbel, D. — New World Maps of Global Solar Radiation. During I.G.Y., Hebrew University, Jerusalem, 1961.

Bachelard, G. — The Poetics of Space, Beacon Press, Boston, 1964.

Brinkworth, B.J. — Solar Energy for Man, The Compton Press Ltd., Great Britain, 1972.

Brooks, C.E.P. — Climate in Everyday Life, Ernest Beram, London, 1950.

Burckhardt, T. — Art of Islam, Language and Meaning, World of Islam Festival Trust, 1976.

Cain, A., Afshar F. and Norton, J. — "Indigenous Building and the Third World", Architectural Design, 4, 1975, pp. 207-220.

Campion, D. — Computers in Architectural Design, Elsevier Publishing Company, Amsterdam-London-New York, 1968.

Consolazio, C.F., Johnson, R.E. and Pecera, L.J. — Physiological Measurements of Metabolic Function in Man, McGraw-Hill Book Co., Inc., New York, 1963.

Cowan, H.J., Gero, J.S. Ding, G.D. and Muncy, R.W. — Model in Architecture, Elsevier Publishing Company, 1968.

Egli, E. — Climate and Town Districts Consequences and Demands, Verlag für Architekture AG, Erlenbach-Zürich, 1951.

Fathy, H. — Architecture for the Poor, An Experiment in Rural Egypt, The University of Chicago Press, 1973.

Geiger, R. — The Climate Near the Ground, Harvard University Press, Cambridge, Massachusetts, 1965.

Giedion, S. — Space, Time and Architecture, Cambridge, Massachusetts, Harvard University Press, 1980.

Givoni, B. — Man, Climate and Architecture, Elsevier Publishing Company, 1969.

Gropius, W. — Scope of Total Architecture, Allen and Unwin, London, 1956.

Hall, E.T. — The Hidden Dimension, Doubleday and Company, Inc., Garden City, New York, 1966.

Halprin, L. — The RSVP Cycles, Creative Processes in the Human Environments, George Braziller, Inc., New York, 1969.

Heidegger, M. — Being and Time, Translated by John Macquarrie and Edward Robinson, Basil Blackwell, 1962.

Heidegger, M. — Poetry, Language, Thought, Translation and Introduction by Albert Hofstader, Harper & Row, Publishers, 1971.

The Question Concerning Technology, Translated with an Introduction by William Lovitt, Harper & Row, Publishers, 1977.

Knowles, R. — Energy and Form, An Ecological Approach to Urban Growth, The Massachusetts Institute of Technology, 1974.

Koenigsberger, Ingersoll, Mayhew and Szokolay — Manual of Tropical Housing and Building, Longman Group Ltd., London, 1974.

Lee, C. — Models in Planning, An Introduction to the Use of Quantitative Models in Planning, Pergamon Press Ltd., 1973.

Lippsmeier, G. — Building in the Tropics, Verlag Georg D.W. Callwey, München, 1969.

Lord, E.A. and Wilson, C.B. — "The General Principles Underlying the Interaction Between Buildings and their Environments", Building and Environment, vol.15, pp. 151-165, Pergamon Press Ltd., U.K., 1980.

Lynch, K. — The Image of the City, The M.I.T. Press, Cambridge, Massachusetts, and London, England, 1960.

Site Planning, The M.I.T. Press, Cambridge, Massachusetts, and London, England, 1962.

What Time is this Place? The M.I.T. Press, Cambridge, Massachusetts, and London, England, 1972.

Lynch, K. — A Theory of Good City Form, The MIT Press, Cambridge, Massachusetts, and London, England, 1981.

McHarg, I. — Design with Nature, The Natural History Press, 1969.

March, L. and Steadman, P. — The Geometry of Environment, RIBA Publication Ltd., 1971.

Markus, T., Whyman, P., Morgan, J., Whitton, D., Maver, T., Canter D., and Fleming, J. — Building Performance, Building Performance Research Unit, School of Architecture, University of Strathclyde, Applied Science Publishers Ltd., 1972.

Markus, T.A. and Morris, E.N. — Building, Climate and Energy, Pitman Publishing Ltd., 1980.

Martin, L. and March, L. — Urban Space and Structures, The Syndics of the Cambridge University Press, 1972.

Meyerhoff, H. — Time in Literature, Berkeley: University of California Press, 1955.

Nasr, S.H. — Knowledge and the Sacred, Edinburgh University Press, 22 George Square, Edinburgh, 1981.

Ne'eman, E. and WendyLight — Availability of Sunshine, Building and Environment, vol. 11, p. 103, 1976.

Nickels, S., et al., — [Editor] Finland, An Introduction, 1973.

Norberg-Schulz, C. — Intention in Architecture, The M.I.T. Press, Cambridge, Massachusetts, 1968.

Existence, Space and Architecture, Studio Vista Ltd., London, 1971.

Genius Loci, Towards a Phenomenology of Architecture, Rizzoli International Publications, Inc., 712 Fifth Avenue, New York, 1980.

Olgyay, A. and Olgyay, V. — Solar Shading and Shading Devices, Princeton University Press, 1956.

Olgyay, V. — Design with Climate - Bio-Climatic Approach to Architecture Regionalism, Princeton University Press, 1963.

Perin, C. — With Man in Mind, An Inter-disciplinary Prospectus for Environmental Design, the M.I.T. Press, Cambridge, Massachusetts, and London, England, 1970.

Phillips, R.O. — "Sunshine and Shade in Australasia", Department of Housing and Construction Experimental Building Station, Canberra, A.G.P.S., 1975.

Polanyi, M. — Personal Knowledge, Towards a Post-Critical Philosophy, Routledge and Kegan Paul Ltd., 68-74 Carter Lane, London, EC4, 1958.

Popper, K.R. — Objective Knowledge, An Evolutionary Approach, The University Press, Oxford, 1979.

Rapoport, A. — House Form and Culture, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1969.

Human Aspects of Urban Form, Pergamon Press Ltd., Headington Hill Hall, Oxford, England, 1977.

Rapoport, A. and Kantor, R.E. — "Complexity and Ambiguity in Environmental Design", AIP Journal, vol. 33, No. 4 (July), pp. 210-221.

Robinson, N. — Solar Radiation, Elsevier Publishing Company, 1966.

Rozelle, R.H. and Baxter, J.C. — "Meaning and Value in Conceptualizing the City", AIP Journal, vol. 38, No.2 (March), pp. 116-122.

Rushton, G. — "Analysis of Spatial Behaviour by Revealed Space Preference", Annals. Ass'n. of Arm. Geog. vol. 59, No.2 (June), pp. 391-400

Saini, B.C. — "Housing in the Hot Arid Tropics", Architectural Science Review, 5(1), pp. 3-12, 1962.

Building Environment, Angus and Robertson (Publishers) PTL Ltd. 2 Fisher Street, London, 1973.

Schumacher, E.F. — Small is Beautiful, A Study of Economics as if People Mattered, Blond & Briggs Ltd., London, 1973.

A Guide for the Perplexed, Jonathan Cape Ltd., 30 Bedford Square, London WC1, 1977.

Smart, W.M. — Spherical Astronomy, Cambridge University Press, 1977.

Smith, F. and Wilson, C.B. — "SHADE, the Optimisation of Micro Climate", Part A: Theory and Algorithms, Department of Architecture, University of Edinburgh, 1976.

"SHADE, the Optimisation of Micro Climate", Part B: User Manual, Department of Architecture, University of Edinburgh, 1976.

"The Shading of the Ground by Buildings", Building and Environment, vol. 11, pp. 187-195, Pergamon Press, U.K., 1976.

Sommer, R. — Personal Space, The Behavioural Basis of Design, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1969.

Spencer, J.W. — "Calculation of Solar Position for Building Purposes", Technical Paper No.14, Division of Building Research, CSIRO, Australia, 1960.

The'venaz, P. — What is Phenomenology, A Quadrangle Paperback Original, Chicago, 1962.

Tropical Advisory Service — Climatic Design, Report prepared for the Ministry of Public Building and Work, London, 1966.

Tuan, Y. — "Space, Time and Place: A Humanistic Frame", Timing Space and Spacing Time, Vol.1, [Edited by Carlstein, Parkes and Thrift], Edward Arnold [Publishers] Ltd., 25 Hill Street, London W1X 8LL, 1978.

Van Deventer, E.N. — "Sun Light and Shade Design", Build International, vol. 5, No. 4, July-August 1972, pp. 205-208.

Van Straaten, J.F. — Thermal Performance of Buildings, Elsevier Publishing Company, 1967.

Wilson, C.B. — "The Old Push and Pull: Two Problems in Design/Research Structures", Edinburgh Architectural Research, University of Edinburgh, 1973.

"Physical Relationships in Architecture" Cooperative Phenomena, [Edited by H. Harker and M. Wagner], Springer Verlag, Berlin-Heidelberg-New York, 1973.