

Towards Liveable Streets Urban Canyon Microclimate: An Empirical Study of Colombo

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

A Dissertation
Submitted to the Department of Architecture of the
University of Moratuwa in partial fulfilment of the
Requirements for the degree of
Master of Science
In
Architecture

72 "04"
72(043)

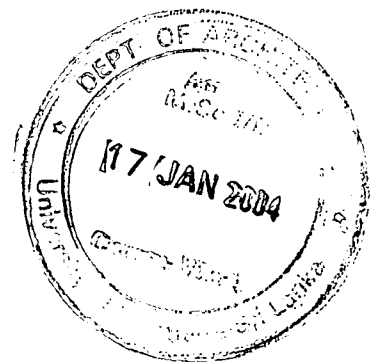
85445



University of Moratuwa

Silva G.R.H

January 2004



85445

85445 ii

DECLARATION

I declare that this dissertation represents my own work, except where due acknowledgement is made, and that it has not been previously included in a thesis, dissertation or report submitted to this University or to any other institution for a degree, diploma or other qualification.

UOM Verified Signature

Signed: .

(G.R.H Silva)



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

ACKNOWLEDGEMENTS

This study with many complexities and difficulties completed due to the assistance, guidance and encouragement given by all of the following persons, to whom I wish to extend my heart full gratitude.

Arch. Vidura Sri Nammuni Head, Department of Architecture University of Moratuwa, for his assistance in this study.

My Coordinator Arch. Prasanna Kulathilake, Senior lecturer, Coordinator M.Sc. Dissertations, Department of Architecture for comments and criticism which encouraged me to do this study.

I am deeply indebted to my tutor Arch. Dr. Indrika Rajapaksa Lecturer Department of Architecture for her guidance, valuable comments and unreserved help given to me for the completion of this task.

Arch. Dr. Rohinton Emmanuel, Senior lecturer, Department of Architecture, for his guidance, valuable comments and unreserved help given to me.



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations

The staff of Department of Architecture.

Mr. Chathura, Technical officer, for the given help on arranging the instruments.

Librarian and Staff, University of Moratuwa Library and University of Peradeniya Library, for the given help.

Mr. Padmasiri and his staff for their kind guidance and help on obtaining Data from the Metrological Department, Colombo.

O.I.C. 's Administration in Dehiwala, Wellawatte, Bambalapitiya, Kollupitiya and Pettah Police Stations for their assistance for possible arrangements in having the Defense clearance to carryout the Field study survey and photograph the high security zones within Colombo.

I'm also grateful to my seniors, Miss. Sathya Sajeewa and Miss. Nirosha Loyed and Mr Narain Perera for the assistance provided.

I offer my heartfelt thanks to my dearest friends Panawala, Bashwara, Champika, and my batch mates for their valuable support rendered in completion of this task.

Last but not least I express my deepest gratitude to my dearest parents, and my Sister for their support and for always being there to take my troubles in a most loving way.

**Towards Liveable Streets
Urban Canyon Microclimate:
An Empirical Study of Colombo**

CONTENTS

	Page No.
Declaration	i
Acknowledgements	ii
Table of Contents	iv
List of Figures	vii
Abstract	xii

INTRODUCTION

A. Significance	1
B. Objectives	4
C. Hypothesis	5
D. Method of Study	6
E. Scope and Limitations	7



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

CHAPTER ONE: URBAN DESIGN AND ITS EFFECTS ON URBAN CLIMATE
(LITERATURE REVIEW)

Introduction to the Chapter	8
1.1 Urban Climatology	9
1.1.1 Urban Temperature: The Heat Island Phenomenon	9
1.1.2 Urban Wind Field	13
1.1.3 Radiation and Sunshine	14
1.2 Urban Design Effects on Thermal Behaviour of Urban City	15
1.2.1 The location of a town within a Region	15
1.2.2 Size of cities	15
1.2.3 Density of the built- up area	16
1.2.4 Land coverage	17
1.3 Overall spatial pattern of the urban heat islands in equatorial regions	20
1.3.1. Characteristics of urban heat islands in equatorial regions	21
Concluding Remarks	23

CHAPTER TWO: LIVEABLE STREET: ESSENTIAL SPACE OF URBAN DESIGN IN EQUATORIAL CLIMATES

(LITERATURE REVIEW)

Introduction to the Chapter	24
2.1 Public Realm as “ <i>the</i> ” Essential Space	25
2.1.1 Street as an Architectural Entity	25
2.1.1.1 Sense of enclosure	26
2.1.1.2 Sense of direction	26
2.2 Street as the Key Public Domain	27
2.2.1 Outdoor Activities	28
2.2.2 Life between Buildings	31
2.3 Thermal Comfort: The Key Facilitator of Physical Comfort	32
2.3.1 Thermal Comfort- Theoretical Basis	33
2.3.2 Architecture and Thermal Comfort	34
2.4 Thermal Comfort in equatorial urban outdoors	38
2.4.1. Location considerations within equatorial regions	39
2.4.3. Layout of the streets networks	39
2.4.4, Urban density and building heights in equatorial regions	40
Concluding Remarks	42



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

CHAPTER THREE: URBAN CANYON GEOMETRY (*Literature Review*)

Introduction to the Chapter	43
3.1 Urban Design Effects on Thermal Behaviour of Urban Canyon	
3.1.1 Aspect Ratio	44
3.1.2 Sky View Factor (SVF)	46
3.1.3 Radiation	48
3.2 Urban density and the characteristics of urban wind field	49
3.2.1 Perpendicular wind	51
3.2.2 Parallel wind	54
3.2.3 Oblique wind	54
3.3 Canyon geometry impacts on thermal comfort in equatorial regions	56
Concluding Remarks	61

CHAPTER FOUR: URBANIZATION TRENDS OF COLOMBO AND ITS EFFECTS ON URBAN CLIMATE

Introduction to the Chapter	62
4.1 Equatorial Climates	63
4.2 Climatic Characteristics of Sri Lanka	64
4.2.1 Climate Change Predictions in Sri Lanka	67
4.3 Colombo: Urbanization and Heat Island	68
4.3.1 Urbanization the city Of Colombo	68
4.3.2 Historical Trends in urban climate in the Colombo Metropolitan region	71
4.3.3 Colombo city as an Urban Heat Island	74
4.4 Problems related to Colombo City Microclimate	75
Concluding Remarks	77

CHAPTER FIVE: CASE STUDIES

Introduction to the Chapter	78
5.1 Approach to the Research	79
5.1.1 Site Selection	79
5.1.2 Development of a typology	81
5.2 On-site measurement and its variations in relation to an independent source	
5.2.1 Site traverse	83
5.2.2 Analysis techniques	85
5.3 Canyons Shading Patterns	86
5.3.1 North- South Oriented Urban Canyon	86

CHAPTER SIX: ANALYSIS AND URBAN DESIGN IMPLICATIONS

6.1 Analysis	94
6.2 Urban Design Implications	104
6.2.1 The East-West Street	105
6.2.2 The North-South Street	

6.3	Development of a "Human Zone"	111
6.3.1	North – South Oriented Urban Canyon	113
6.3.2	East- West Oriented Urban Canyon	116
 CONCLUSION		119
BIBLIOGRAPHY		124
Appendices		



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF FIGURES

Fig: No		Page
1.1	Sketch of a Urban Heat Island Profile	9
1.2	Urban Canopy and Boundary Layer over cities	13
1.3	Schematic illustration of the effect of topography on local wind exposures	14
1.4	Measured air temperatures at UCLA during 57 days spread over a year in sites with different ground cover	15
1.5	Measured surface temperatures of the sites	19
1.6	Crystal down town centers in San Francisco	19
1.7	many smaller cities especially in the developing world will retain their spontaneous layout in human scale	20
1.8	Metilli in the Algerian Sahara home of the Chamba	20
2.1	Sense of enclosure - Galle Road, Bambalapitiya	26
2.2	Sense of Direction	26
2.3	Streets – The Public Realm	27
2.4	Necessary activities - under all conditions	28
2.5	Optional activities - only under favorable exterior conditions	29
2.6	Social Activities on Streets	29
2.7	Graphic representation of the relationship between the quality of outdoor spaces and the rate of occurrence of outdoor activities	30
2.8	Mind Map – Relationship between	33
2.9	Vitruvian Tri-partite of climate balance	34
2.10	Interlocking fields of environment	34
2.11	Bio climatic chart	34
2.12	Seven point Numerical Scale	35
2.13	Boundaries of outdoor temperature and humidity	37
2.14	Climatic boundaries in terms of the outdoor maximum daily temperature	37
3.1	schematic distribution of the impinging solar radiation	
	a) an open flat country	44
	b) a built-up area with H / W ratio of about 1	44
	c) a high-density urban area with H / W ratio of about 4	44
3.2	In urban areas –the fraction of sky visible	47
3.3	SVF=1 in an open site or on a roof top	47

3.4	Height, Width and Length of a canyon	50
3.5	Wind direction perpendicular to the Long Axis	51
3.6	The flow pattern associated with air flow over building arrays of increasing	51
3.7	Threshold lines dividing flow into three regimes as functions of the building (L/H) and canyon (H/W) geometry	52
3.8	Single vortex pattern	53
3.9	Two vortices regime in deep canyons.	53
3.10	Wind flow direction parallel to the Long Axis	54
3.11	wind speed near ground level in front of a high-rise building is increased helping in diluting street-level air pollutants	58
3.12	Graphical Illustration of the changes in the vertical wind velocity profile over urban, suburban and open rural areas	60
3.13	air temperature measurement, owing two days in three streets of very different width ranging from a wide Avenue to a very narrow alley in Seville, Spain	60
4.1	climatic regions of the World	63
4.2	Important sun positions on Sri Lanka	66
4.3	Future expecting rain fall values- Sri Lanka	68
4.4	City of Colombo	68
4.5	Population Densities –Colombo	70
4.6	public outdoor relation space proposals	70
4.7	Location map of weather stations in the Colombo metro region	72
4.8	Thirty-year diurnal variations in temperature during the hottest month in CMR	72
4.9	a) Historical trends in Heat Index - Colombo Weather station	73
	b) Historical trends in Heat Index - Rathmalana Weather station	73
	c) Historical trends in Heat Index - Katunayake Weather station	73
4.10	Givoni's Bioclimatic recommendations based on Colombo's typical climate.	75
4.11	Colombo City - urban structure	75
5.1	Colombo Map – The research area	80
5.2	Classification of basic canyons in relation to canyon height	81
5.3	No of floors and approximate height of basic Canyons	81
5.4	survey of Canyons - Colombo	82
5.5	Hobo –HT	83

5.6	a) SVF- Symmetrical Canyons	85
	b) SVF- Asymmetrical Canyons	85
5.7	The Eastern Pedestrian Walkway	86
5.8	shallow canyon	87
5.9	Typical Canyon - Galle Road	87
5.10	Sunshine Hours above Eastern Pedestrian Walkway of the Canyon - Galle Road	87
5.11	Sunshine Hours above Western Pedestrian Walkway of the Canyon	88
5.12	Shadow Pattern comparison of Shallow, Intermediate and Deep Urban Canyons on Galle Road, Colombo	90
5.13	Categorization of canyons and availability	91
5.14	Percentage width of shadow in relation to the Canyon width, on Shallow Canyon of Galle Road @ 10.00 am during the Year	92
5.15	Percentage width of shadow in relation to the Canyon width, on Shallow Canyon of Galle Road @4.00 pm during the year	93
6.1	Correcting the measured data according to the trend pattern of that particular period	95
6.2	Research Area <small>University of Moratuwa, Sri Lanka</small>	95
	THI variation on the North-South Oriented Street- Galle Road	96
6.3		
6.4	Overall THI variation - Galle Road	96
6.5	THI variation on the East-West Oriented Street, Lotus Road and Olcott Mawatha	97
6.6	Overall THI variation -Lotus Road	97
6.7	Overall THI variation - Olcott Mawatha	98
6.8	Analysis of Selected Typologies	99 -
(a b c ...		103
6.9	Arcades ,York Street , Colombo	106
6.10	Mulberry Street, with Narrow sidewalks and slow pedestrian traffic Little Italy	106
6.11	11 Narrower, tree-shaded streets	106
6.12	Buildings that present a friendly face to the street have porches and trees	107
6.13	Shaded by means of the canyon height Broad Street, Philadelphia	108
6.14	Broad Street, Philadelphia	109

6.15	Street section-Hawkers pavement shelter	109
6.16	Section through a riparian arterial.	110
6.17	Along a riparian greenway, an artificial stream provides habitat and biofiltration of surfacewater.	110
6.18	Human Zone 1.5m in width, 2.00m high Space on walkway adjoined to the built mass	111
6.19	Horizontal shading device and Shadow Angle (β)	112
6.20	Vertical shading device and Shadow Angle (Φ)	113
6.21	Plan ; North –south Oriented Canyon	113
6.22	Typical section; North- south oriented Canyon	114
6.23	Plan; East-West Oriented Canyon	116



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk



Abstract

Urban Design;

Designing an Urban setting, it self can perceive as a single architectural process, not only an individual building, but also the way buildings are related each other and its three-dimensional composition represents the total image of the city. Performances of these solid-void compositions directly effected to thermal behaviour of the city.

The metropolization phenomenon at Colombo has provoked deep changes in the field of "Urban design". As well, as changes in thermal comfort levels and the energy balance, leading to an altered atmosphere of the urban area,

In Colombo, higher relative humidity values and moderation in wind speed, the daily (diurnal) variation in temperature and diminishing diurnal temperature variation would indicate a growing UHI problem. The phenomena of Urban Heat Island can create unpleasant microclimatic conditions at the pedestrian level. Pedestrian walkways are the key pubic domain of Equatorial towns and cities, where the greatest amount of human contact and interaction taken place.

Shading can create a comfortable level, avoids the direct solar radiation. Vegetation in particular tall trees can create a cooling effect, lower temperature and increase relative humidity.

The aim of this study is to investigate the effect of Orientation, built mass, tall trees with a wide foliage canopy and water bodies, on the climatic parameters, at the pedestrian level in street canyons, Colombo metropolitan. The research was conducted in either-side pedestrian walkways of two major public realms selected based on its Orientation. Each street canyon consisted with areas of deep, shallow and intermediate canyons, tall dense trees planted, street canyon relatively lacking in tall trees, directly effected water bodies etc.

One pair of walkways was located parallel to and, the other perpendicular to, the coastline. Data collected in two days of December 2003: Temperature and relative humidity, by a HOBO-HT data logger, in a well cross-ventilated radiation shield at seven feet height on each pavement,

Traverse walking along canyon, by which temperature and relative humidity were, measured using the mobile data logger at midday and night, in Dec 18th and 22nd.

The results show that during the day hours the temperature values in the canyons with vegetation were up to 2 THI values lower than those measured in the canyons without trees and it was up to 4 THI values lower in Gall face Green, where directly affected by the Ocean.

Wind speed in the canyons placed perpendicular to the coastline, was generally higher than in the canyons located parallel to the coastline and blocked by rows of building from the sea breeze, which is a characteristic of Sri Lankan western shoreline. But the effect of vortex phenomena caused by perpendicular winds, can clearly experienced in N-S oriented deep canyons,

Wind speed in canyons without trees was generally higher that in canyons with threes due to the windbreak and friction effects of the trees in the latter. The existence of shading devices above the pavements and tall dense trees in an urban environment could result in two opposite climatic effects. Shading devices moderate the air temperature and surface temperatures, preventing the direct solar radiation. In addition, trees act as moderators in both temperature and relative humidity levels towards comfortable levels.

This research shows imperative need of interferences, of climatized architectural impiceations in the case of street canyons and adjoined pedestrian walkways at the Colombo Metropolitan.