

**URBAN AIR QUALITY AS A FUNCTION OF STREET DESIGNS;
STRATEGIES FOR COLOMBO TRANSPORTATION NETWORK
WITH SPECIAL REFERANCE TO GALLE ROAD**

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA



University of Moratuwa, Sri Lanka
Electro A Dissertations
www.lib.mrt.ac.lk

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

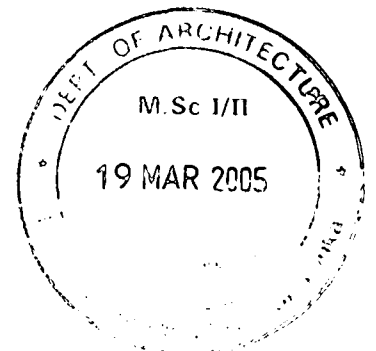
72"05"
42(049)

85515



University of Moratuwa

M.M.M. WEERASINGHE
March 2005



85515

85515

DECLARATION

I declare that this dissertation represent 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.

Signed: ***UOM Verified Signature***



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

M.M.M. Weerasinghe

Signed, Supervisor:

UOM Verified Signature

Dr. Rohinton Emmanuel

ACKNOWLEDGEMENTS

I'm great full to my supervisor Dr. Rohinton Emmanuel and my year masters, Archt. Jayanth Silva and Archt. Gamini Weerasinghe for their encouragement, consultant, guidance and critical evaluation through my research work.

I also wish to convey my thanks to the Dean of the faculty, Prof. Nimal de Silva, Head of the department Architect Vidhura Sri Nammuni, subject coordinator Dr Upendra Rajapakse, Senior lectures Dr. Harsha Munasinghe and Architect Prasanna Kulathilake.

I owe much thanks to Mrs. Bimalka Perera who rendered me great help by arranging instruments, analyzing chemicals and giving necessary guidance.

I extend my especial thanks to National Building Research Organization (MBRO), Atomic Energy Authority, University of Colombo, Department of Architecture, Department of Earth Recourses, and University of Moratuwa for supplying necessary instruments and facilities.



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

I also wish to convey my thanks to the people of Mount-Lavinia and Wadduwa for helping me to do the experiments.

Finally, I would like to thank my family, especially my parents and all other friends who constantly encouraged me in this endeavour.

ABSTRACT

The city of Colombo is gradually being choked to death by air pollution, especially vehicular related pollution. Poor air quality deteriorates human health, buildings and materials and even creates global environmental problems. The consideration and necessary attention towards cleaner air has been overshadowed by market forces in cities like Colombo. Much like most of developing cities, Colombo's city structure was influenced by colonial characters. These built forms have no bearing on natural, cultural and economical forces of the country. In addition, existing street network and space allocation is not enough to cater the ever rising transportation. As a result, transportation releases a considerable amount of pollutants to the air.

The study analyses the ambient air quality of CMR. Mount Lavinia Junction and Wadduwa were taken as the major sites, and analyses some variable factors in the city which could mitigate air pollution. At last the study is arrived at a set of conceptual street design strategies and guide lines to improve the air quality of the CMR.



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

CONTENTS

ACKNOWLEDGEMENT	iii
ABSTRACT	iv
CONTENTS	v
LIST OF FIGURES	vii
LIST OF TABLES	viii
LIST OF GRAPHS	ix
LIST OF ABBREVIATIONS	x

INTRODUCTION	1
Goals and Objectives	3
Scope and Limitations	3
Methodology	4

CHAPTER 1.0- URBANIZATION IN RELATION TO CITY FORM AND TRANSPORTATION

1.1 Historical Aspects of Urbanization in Colombo	5
1.2 Urban Form in Relation to Transportation	7
1.3 City Character and transportation	9
1.4 Land Use and Transportation	10
1.5 Spatial Structure and City Performance	11
1.5.1 Aspects of Urban Spatial Structure	11
1.5.2 Spatial Structure and Transport Efficiency	14
1.5.3 Spatial Structure and Pollution	14
1.5.4 The Global Trend in Urban Spatial Structure	15
1.6 Urbanization and Transportation in Colombo	15
1.6.1 Transport-ills in Colombo	18
1.6.2 Transport Planning and Traffic Management	19

CHAPTER 2.0-URBAN AIR QUALITY

2.1 The Urban Pollutants	20
2.2 Energy Consumption vs. Pollution	21
2.3 Vehicular Emission as Major Contributor	23
2.4 Air Pollution In cities	24

2.4.1 Trends of Air Pollution in the World	24
2.4.2 Trends of Air Pollution in Colombo	27
2.5 Impacts of Urban Air Quality	32
2.5.1 Health impacts	32
2.5.2 Environmental impacts	34
2.5.3 Physical impacts	35
2.6 Urban Air Quality standards	36
2.6.1 Background of Air Quality standards	36
2.6.2 Need of Air Quality standards	37
2.6.3 Air Quality trends in Sri Lanka	37
2.6.4 National Policy on Air quality management	38
2.6.5 Air Quality Standards	39
2.7 Air Pollution Mitigation	41

CHAPTER 3.0-METHOD AND MATERIALS

3.1 Site Selection Rationale	45
3.2 Measurements Protocol	48
3.3 Method of Analysis	51

CHAPTER 4.0-RESULTS AND MAJOR FINDINGS

4.1 Effect of Number of Vehicles vs. RPM	53
4.2 Effect of Temperature vs. RPM	54
4.3 Effect of RH vs. RPM	54
4.4 Effect of THI vs. RPM	55
4.5 Effect of Wind Speed vs. RPM	55
4.6 RPM of High – Risk busy town vs. Low-Risk suburb	56
4.7 Hourly Measurements of TSP	57
4.8 Sub Element Analysis	58
4.9 Conclusion	60

CHAPTER 5.0- MITIGATION STRATEGIES AND PROPOSED CONCEPTUAL STREET DESIGN GUIDE LINES AND STRATEGIES FOR THE CASE STUDY SITE.

LIST OF FIGURES

- Figure 1.2.1. The Concentric-Zone model
- Figure 1.2.2. The Multiple Nuclei model
- Figure 1.2.3. The sector model
- Figure 1.5.1.1. Average Population Densities in built up areas in 46 Metropolitan areas
- Figure 1.6.1. Galle road as a major urban street
- Figure 2.3.1. Different processes of vehicular emission
- Figure 2.4.2.1. Growth in fuel consumption by Road users.
- Figure 2.4.2.2. Emissions of petrol vehicles in Colombo
- Figure 2.4.2.3. Emissions of diesel vehicles in Colombo
- Figure 2.5.2.1. Bleaching of corals due to temperature rising
- Figure 2.5.3.1. Air pollution increases the corrosion of culture heritages.
Taj Mahal
- Figure 3.1.1. Mount Lavinia ,Location map
- Figure 3.1.2. Mount Lavinia , Arial view
- Figure 3.1.3. The site at Mount Lavinia
- Figure 3.1.4. Wadduwa ,Location map
- Figure 3.1.5. The site at Wadduwa
- Figure 3.2.1. Air quality measurements at sites
- Figure 5.1. Pedestrian route network shaded (with “Erf”-like environments and arcades)
- Figure 5.2. Use/Design North- South running narrow and shady streets as major routes
- Figure 5.3. Safe and continuous cycle route network
- Figure 5.4. Multy- utilizing streets which have people, vehicles and activities together
- Figure 5.5. Separate lines for different users in different speeds
- Figure 5.6. Locate water bodies near streets

LIST OF TABLES

- Table 1.6.1. Specific charactering of Colombo sub division
- Table 1.6.1. Land use pattern in Colombo
- Table 2.2.1. Energy consumption by sector
- Table 2.2.2. Estimated active Sri Lanka vehicle fleet in 2000 and 2005
- Table 2.4.1.1. World automobile production
- Table 2.4.1.2. Overview of air quality in 20 mega cities.
- Table 2.4.2.4. Total Hydrocarbon Emissions, Kt./y
- Table 2.4.2.1. Total Hydrocarbon Emissions, Kt./y
- Table 2.4.2.2. Total Carbon Monoxide (CO) emissions, Kt/y
- Table 2.4.2.3. Nitrogen Oxides Emissions, Kt/y
- Table 2.4.2.4. Sulphates emission (SO_x), Kt/y
- Table 2.4.2.5. Particulate Matter Emissions (PM) Kt/y
- Table 2.4.2.6. Particulate Matter Emissions by Type of Gasoline Vehicles % of Emissions of Gasoline Engine Vehicle
- Table 2.4.2.7. Benzene Emissions, Kt/y of Moratuwa, Sri Lanka
- Table 2.5.1.1. U. S. EPA dose – response estimates for PM 10 and PM 2.5
- Table 2.6.5.1. National Ambient Air Quality Standards (USEPA)
- Table 2.6.5.2. Proposed standards for main air pollutants in Sri Lanka (1994)
- Table 2.6.5.3. Environmental Quality Standard for Toxic Compounds relating to the protection of Human Health
- Table 3.2.1. Types of instruments used for the research
- Table 4.1. Data collected at Mount Lavinia Junction using Gravimetric Dust Sampler
- Table 4.2. Calibration data of the Gravimetric Dust Sampler with Gent air sampler and High volume Air Sampler
- Table 4.6.1. RPM data Mount Lavini and Wadduwa.
- Table 4.7.1. Hourly TSP data collection at Mount Lavinia Junction
- Table 4.7.2. Hourly Normalized TSP levels and other parameters at Mount Lavinia Junction
- Table 4.7.2. Hourly Normalized TSP levels and other parameters at Mount Lavinia Junction
- Table 5.1. Conceptual street design strategies and guide lines for the case study site; Mount Lavinia

LIST OF GRAPHS

- Graph 4.1.1 Vehicle count vs. Calibrated RPM at Mount-Lavinia Junction
- Graph 4.2.1 Temperatures vs. normalized RPM at Mount- Lavinia junction
- Graph 4.3 .1 Relative humidity vs. normalized RPM at Mount-Lavinia junction
- Graph 4.4.1 Effect of temperature – humidity Index (THI) vs. normalized RPM at Mount Lavinia Junction
- Graph 4.5.1 Effect of wind speed vs. RPM at Mount Lavinia Junction
- Graph 4.7.1: Hourly TSP data variation at Mount Lavinia Junction



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

LIST OF ABBREVIATIONS

CO	Carbon Monoxide
CO ₂	Carbon Dioxide
HC	Hydro Carbons
NO _x	Nitrogen Oxides
PM	Particulate Matter
PM ₁₀	Particulate Matter with the size below 10 microns
PM _{2.5}	Particulate Matter below 2.5 microns
RPM	Reparable Particulate Matter
SO ₂	Sulphur Dioxide
TSP	Total Suspended Particulate Matter.



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