A PARAMETRIC APPROACH TO OPTIMIZE SOLAR ACCESS FOR ENERGY EFFICIENCY IN HIGH-RISE RESIDENTIAL BUILDINGS IN DENSE URBAN TROPICS

Nadeeka Jayaweera

178001H

Thesis submitted in partial fulfilment of the requirements for the degree

Doctor of Philosophy in Architecture

Department of Architecture

University of Moratuwa

Sri Lanka

April 2022

Declaration page

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Name of the supervisor: Dr. R.M.K.U. Rajapaksha

Signature of the supervisor: UOM Verified Signature

Date: April 06 2022

Name of the supervisor: Dr. M.M.I.D. Manthilake

Signature of the supervisor: UOM Verified Signature

Date: 07/04/2022

Abstract

Solar access in buildings is a topic predominantly investigated in the urban contexts at higher latitudes and to a much lesser extent in the tropics. Existing research focuses on ensuring unobstructed solar access, whereas, in the tropics, unobstructed solar access is avoided in buildings due to external heat gain. In addition, most regulations for high-rise residential buildings in the tropics are inadequate to ensure sunlight exposure for residents. Four research objectives were formulated in this study to investigate the definition, typology, planning and architectural issues of solar access in high-rise residential buildings in dense urban tropics.

This study investigated the shading effect of the urban context on solar access in terms of energy savings and daylight in high-rise residential buildings in the tropical city of Colombo, Sri Lanka. The methodology consisted of three phases. In Phase I, three simulation models of 11, 21 and 31 floors (SM1, SM2, and SM3) were developed based on the archetypal high-rise residential building characteristics in Sri Lanka.

In Phase II, the study demonstrated a parametric urban context for the simulation models utilizing simulation software *Rhino3D* and the *Grasshopper* interface. *Archsim* and *DIVA4* plugins were used to simulate the effects of the urban context on spatial daylight autonomy (sDA), annual energy use for cooling, and annual day-time lighting energy use. A multi-objective optimization process applying the Pareto-front identified the thresholds for optimum solar access.

Phase III of the study investigated the daylight and energy performance of external shading scenarios of a high-rise residential building in a dense urban context.

This study defined the optimum solar access for a perimeter zone in a high-rise residential building that achieves 75 sDA $_{(300lx|50)}$ with corresponding annual energy savings of 28%-36% in the east-west and 8%-12% in the north-south directions. The prescribed building setback curves for ensuring optimum solar access were validated with three calibrated case studies located in Colombo, Sri Lanka. All case studies demonstrated 50% of interior spaces (living rooms and bedrooms) with 55 sDA $_{(300lx/50)}$ and annual energy savings of 26-31% in east-west and 8%-15% in the north-south direction. The Floor area ratios (FAR) calculated for optimum building density for SM1, SM2, and SM3 were 4.2, 6.5, and 8.4, respectively.

The best performance external shading scenario in the vertical façade of the 11-floor Simulation model 2 (vertical and horizontal shading on the nineteenth floor, horizontal shading only for the eleventh floor, and no shading for the second floor) satisfied 75 sDA $_{(300lx|50)}$ at all floors with corresponding energy savings of 16%-20%. The best performance scenario was applied to a 17-floor case study building located in Colombo, Sri Lanka. The simulation results indicated that 58% of the spaces had over 75 sDA for both Baseline and Best performance scenarios, while an increase in energy savings of 1%-3% was found in the Best performance scenario compared to the Baseline scenario of the case study.

This research study redefined solar access for the tropics, prescribed building setbacks for optimum solar access and informed optimum building density for the high-rise residential building typology. The study also identified the best performance external shading scenario for a high-rise residential building façade in the urban context. The research outcomes established in this study provide a much-needed platform to initiate the dialogue on solar rights in dense urban tropics.

Keywords: tropics, urban context, high-rise residential; energy savings, daylight, parametric

Dedication

I would like to dedicate this thesis to my parents.

Acknowledgement

I would like to express my sincere gratitude towards my supervisors, Dr. R.M.K.U Rajapaksha and Dr. M.M.I.D. Manthilake for their guidance for my research from the inception.

This research study was conducted under the purview of a MoU, which was signed between the University of Moratuwa and the Condominium Management Authority of Sri Lanka to promote sustainable development of high-rise residential buildings in Sri Lanka. I would like to thank Prof. A. Jayawardane, former Vice-Chancellor of the Moratuwa University and Mr. C. Wijeweere, former Chairman of the CMA, signatories to the MoU. In addition, I would also like to acknowledge Mr. J D N C Dissanayake, Deputy General Manager (Regulatory), and other staff members of the CMA for their assistance given during the survey of high-rise residential buildings. I am also grateful to the Senate Research Council of the University of Morautwa for the National Development Grant (SRC/2017/ND/01), which provided the financial assistance to enable the objectives of the MoU. My special thanks go to Prof. Stephen Lau of the University of Hong Kong for arranging my visit to the National University of Singapore to broaden my exposure. I am also very grateful to Prof. R. Halwathura, chairman of the progress review committee for his guidance during the progress reviews. I would also like to thank Dr. S. Cooray, Director of the Higher Degrees Committee of the Architecture Faculty and Dr. W. Gamage, Research Coordinator for the Department for their support. I would like to thank Mr. S. Mendis, Mr. J. Senavirathne, Mr. P. Obadage, Ms. A. Mahanama, Ms. J. Nadaraja and Mr. S. Rodrigo for their assistance in collecting field data for this research study. I am also grateful to Mr. C. Masakorala, technical officer at the Department, and the Supplies Division of the University of Morautwa for their assistance to purchase equipment for this study. I would also like to thank the staff members of the Periodicals Section of the Library of the University of Moratuwa for their assistance in obtaining much-needed reference materials. Finally, I would like to thank my family and friends for their patience and support during the research study.

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List of Abbreviations

Abbreviation	Description
ASE	Annual sunlight exposure
ASHRAE	American society of heating, refrigerating and air-conditioning engineers
CBDM	Climate based daylight modelling
CMA	Condominium management authority of Sri Lanka
CV (RMSE)	Coefficient of variation of root mean square error
FAR	Floor area ratio
LEED	Leadership in energy and environmental design
NMBE	Normalized mean bias error
sDA	Spatial daylight autonomy
UDA	Urban development authority of Sri Lanka
UDI	Useful daylight illuminance
URA	Urban redevelopment authority of Singapore
UVA	Unobstructed vision area
VDF	Vertical daylight factor