The University Of Nairobi

College of Architecture and Engineering
School Of Built Environment
Department Of Architecture And Building Science

BAR 613; Research Thesis

Sustainable Built Forms In Upper Highland Climate. A Case Of Molo

A Research Thesis Submitted By
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B02/0883/2013

“

...all living species must either adapt their physiology through selection or mutations, or find other defences against the impact of the environment.

~Olgyay, 1963~

Declaration

This thesis is my original work and has not been presented in any other University or Institution for the purpose of awarding a degree to the best of my knowledge.

Author: ..... Date .....

KARUGA JULIUS MBURU

This thesis is submitted in partial fulfilment of the examination requirements for the award of the Bachelor of Architecture degree, in the Department of Architecture and Building Science at the University of Nairobi.

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MR. NORBERT MUSYOKI

Chairman: ..... Date .....

MR. MUSAU KIMEU

Dedication

TO MY FAMILY

for the love and support
and
without whom this milestone would be impossible.

Acknowledgement

In the course of my investigation, I have incurred many debts of gratitude for the support through this time and I fully acknowledge each and every person that informed my thesis in any way, great or small.

I raise my head to the heavens and humble myself before the Lord. Only you know my heart and only you know the journey.

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Abstract

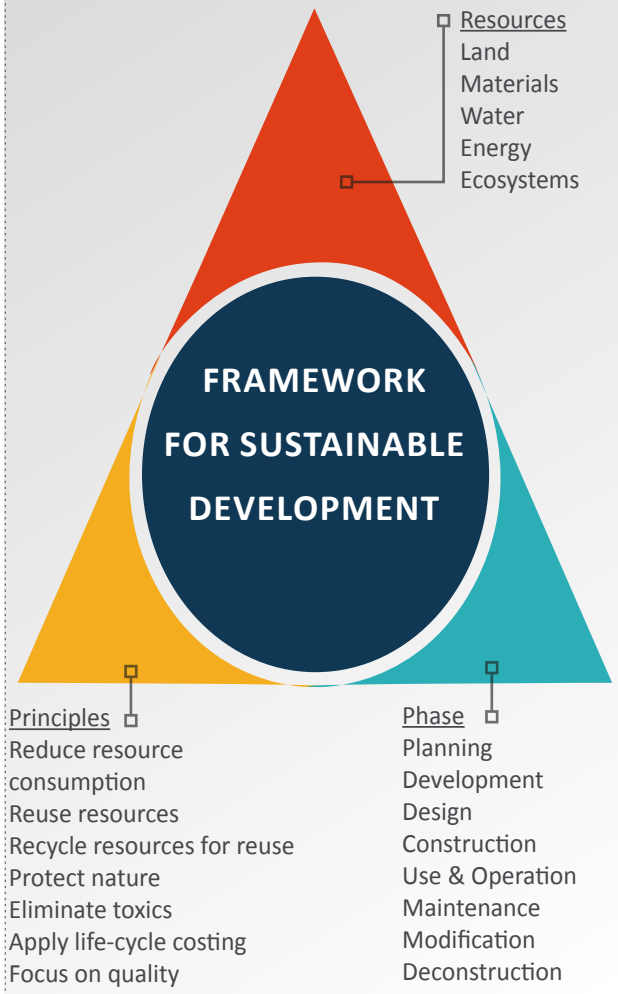
Upper highland regions are generally cool areaswhich is caused by their high altitude of over 2000m above sea level, with night tempatatures dropping to about 8^0 C. This poses a potential human thermal comfort problems to the inhabitants of these regions. Architects disigning for these areas should therefore ensure that their buildings are thermally comfortable, for the sake of the users.

This study has its main aim of investigating the thermal performance of institution buildings in upper highland climate as well as establish design principles to be adopted in these areas.

The objectives are: to investigate principles of design in Upper highland climate, with regard to thermal comfort, to investigate and examine thermal performance of selected institution buildings in Molo town, to generate recommendable design strategies for buildings in upper highland climate with regard to achieving thermal comfort.

CHAPTER ONE

INTRODUCTION



>>Figure 1.1 **INFO-GRAPHIC IMAGE FOR SUSTAINABLE DEVELOPMENT WITHIN BUILT ENVIRONMENT.**

Source; Building Construction Illustrated, Francis D.k Ching. (Author Modified) November, 2018.

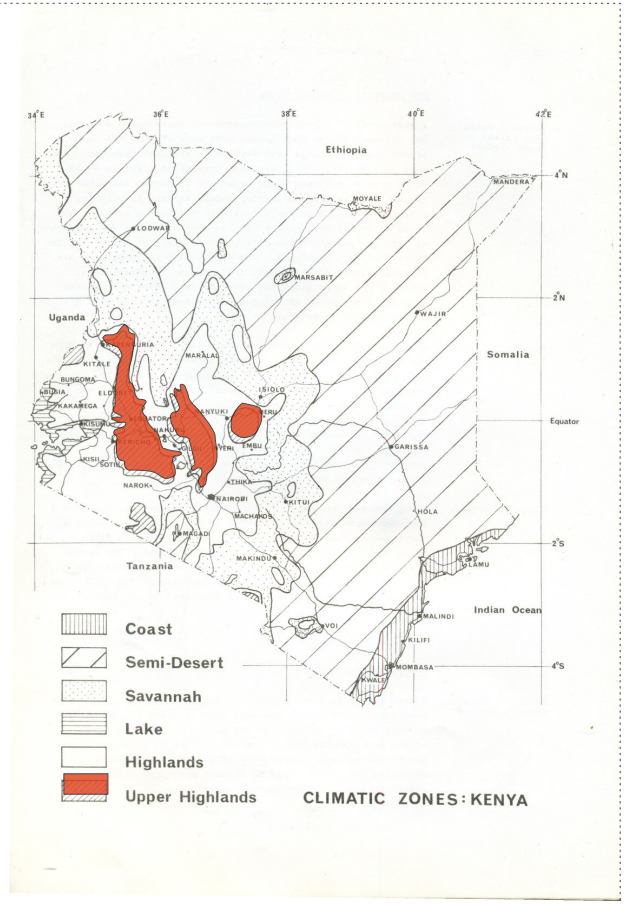
1.0 Introduction

1.1 Background of Study

In the countries of the industrialised world, buildings account for a substantial proportion of gross energy consumption. In providing services such as space heating, lighting, ventilation and air conditioning, buildings may account for up to 50% of total energy consumed. As the Third World countries embrace industrial technology, there is danger that they will also become profligate in their demand of energy.(Dean Hawkes, 2002).

The nature of the problem of building energy demand has sparkled the need for creating awareness in order to curb the issue of climate change. This has pushed sustainability into becoming a significant issue shaping how the construction industry operates. According to (Francis D.K. Ching, 2014), sustainability is broad in scope, affecting how we manage resources as well as build communities, and the issue calls for a holistic approach that considers the social, economic, and environmental impacts of development and requires the full participation of planners, architects, developers, building owners, contractors, manufacturers, as well as governmental and non-governmental agencies.

In seeking to minimize the negative environmental impact of development, sustainability emphasizes efficiency and moderation in the use of materials, energy, and spatial resources (See Figure 1-01). Building in a sustainable manner requires paying attention to the predictable and comprehensive outcomes of decisions, actions, and events throughout the life cycle of a building, from conception to the citing, design, construction, use, and maintenance of new buildings.



>>Figure 1.2 **MAP SHOWING CLIMATIC ZONES OF KENYA;**

With Upper Highland Climatic Zones of Kenya Highlighted.
Source; Charles Hooper, Design For Climate. 1975.

1.2 Problem Statement

Areas within the tropics have arguably the most favourable climatic conditions for building design. This may be due to the minimal or lack of extreme climatic conditions in majority of the habited area. Kenya is located in this region between latitudes 5º North and 4º South with the altitudes ranging from 0m to 5000m above sea level. The habitable areas fall between 0m at the coast to 2750m above sea level in the highland regions of Mt Kenya.

Mombasa, at an altitude of 50m above sea level has an annual mean temperature of 27^0 C while Eldoret at an altitude of 2100m above sea level has an annual mean temperature of 16.8º C. This is due to the positive lapse rate which holds that for every 1000m rise in altitude, there is a 4º C drop in temperature.

However, as a result, high altitude regions in Kenya experience temperatures that are below human comfort. A case in point is Mau escarpment in Rift Valley region with altitude of about 2500m above sea level. Towns like Molo, Eldoret and Kapenguria which are located in this areas experience cool temperatures during the day. The temperature level drop significantly during the nights and could drop as low as 8º C thus potentially posing a human thermal comfort problem.

According to (Charles Hooper's book Design For Climate 1975), these highland areas experience Upper Highland climate (Figure. 1.02). They are generally cold, where heating in buildings is necessary for most of the year. Humidity is fairly high due to high altitude and night temperatures are way below human comfort.

The environmental considerations during design at the early stage should effectively integrate

>>Figure 1.3 **IMAGES A & B SHOW THE EMERGING TRENDS OF BUILDINGS IN MOLO TOWN.**

Source; Author. Oct 2018

the building into the environment sustainability. Vitruvius states, in his book, De Architectura, that:

"For a style of buildings ought to be different in Egypt and Spain, in Pontus and Rome, and in countries and regions of various characters. For one part of the earth is oppressed by the sun; in another part the earth is far removed from it; in another it is affected by its moderate distance."

However, a casual observation in these regions reveals a worrying reality. The current global trends and effects of globalisation have heavily influenced the way people build in this area (see figures), regardless of its unique climatic conditions. Poor choice of materials and technology, among other factors have rendered the internal temperature within buildings unbearable especially in cold nights and seasons. This poor choice of building envelops allow heat transfer from the inside of buildings, therefore compromising human thermal comfort.

This study will seek to investigate the environmental design considerations of built forms in Molo Town. It seeks to establish the suitability and adaptability of modern buildings to the climate of this area, and finally to develop principles of design that are favourable for Upper Highland Climate.

>>Figure 1.4 **DIFFERENT BUILDING FORMS IN MOLO TOWN.**

A. Highland Hotel workers Quaters; build in 1924
B. Family Bank,Molo
C. New Commercial building

Source; Author. Oct 2018

1.3 Aims and Objectives

The principle aim is to study the transformation of building forms within Molo area by comparing the current emerging building trends of built forms with those of the past: with focus on sustainability.

1.3.1 Research Objectives

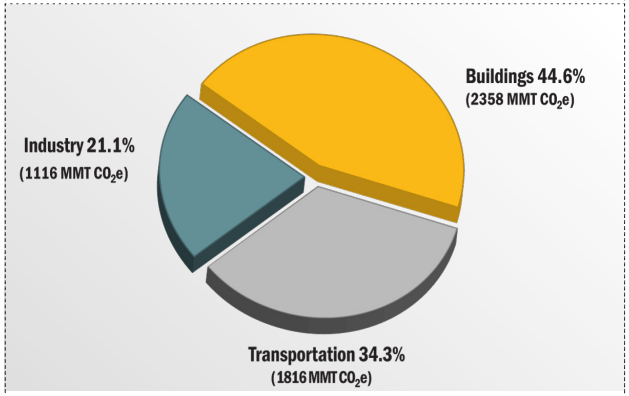
i. To examine and identify the strategies that can be employed in upper highland climate to achieve thermal comfort .
ii. To study and analyse different built forms (developed within a time-line) that are found in Molo area in relation to thermal comfort.
iii. To establish design guidelines and how the identified typologies can be enhanced to meet thermal comfort needs in upper highland climate.

1.3.2 Research Questions

i. What are the strategies that can be employed in upper highland climate to achieve thermal comfort?
ii. In what ways do the existing built forms in Molo respond to the local climate, especially thermal comfort?
iii. What are the recommended design guidelines and how are the identified built typologies be enhanced to meet thermal comfort needs in upper highland climate?

>>Figure 1.5 **IMAGE SHOWING THE CONSEQUENCE OF CLIMATE CHANGE ON ENVIRONMENT.**

Source; http://dwomlink.info/climate-change-pictures.html



>>Figure 1.6 **CARBON (IV) OXIDE EMISSION BY SECTORS.**

The Building Sector Consumes About A Third Of The Total Energy Consumption Worldwide.

Source; https://www.weforum.org

1.4 Justification of Study

With the whole world facing the biggest threat of its modern times, 'Climate Change', many countries are aiming at transforming the building industry into being more environmentally responsible. Using the right strategies of design, such as proper orientations and built forms, understanding the context and climate etc.. architects are presented with the opportunity of reversing and curbing the threats of climate change.

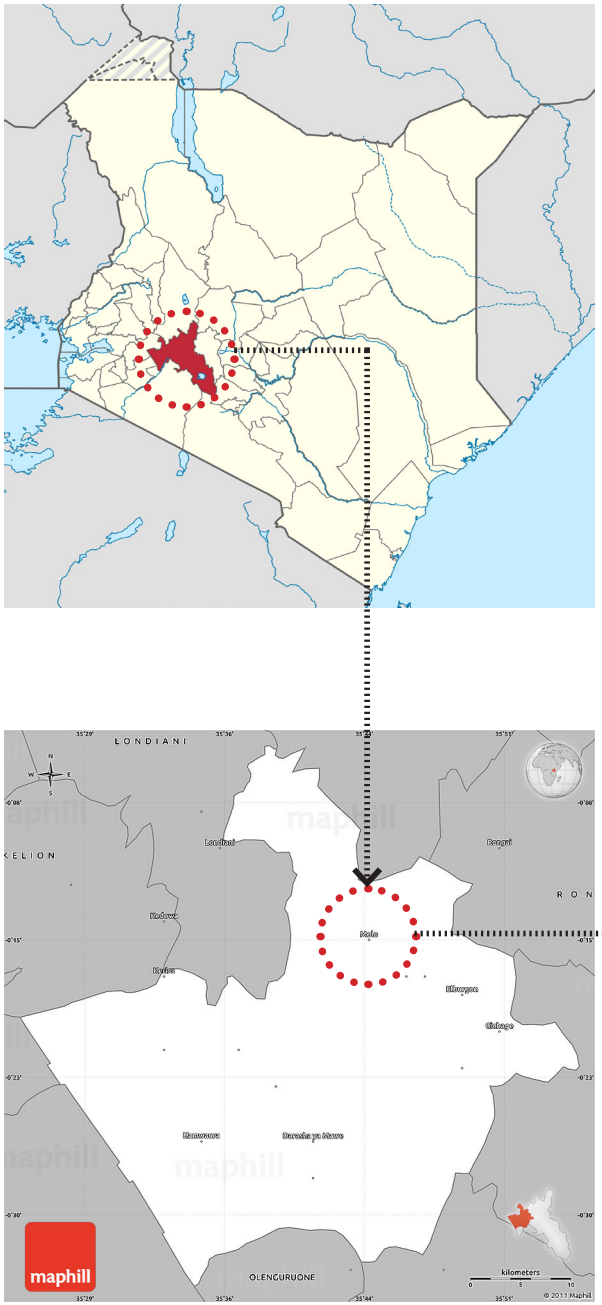
It is generally acknowledged that the building sector consumes about a third of the total energy consumption worldwide. This figure may vary according to the typology and the location of the building. Buildings consume nearly 40% to 50% of all global energy and pollute the environment primarily through the use of fossil fuel during their operational phase. (Prof. Federico M. Butera, 2014).

This therefore shows the importance of carrying out a research on climate responsive design, where there is a need to come up with a contemporary model of built form, not only in upper highland climate, but also in many other growing urban centres in Kenya.

1.5 Significance of Study

The findings of this study are intended to provide a further insight to designers and developers on the design of buildings for human thermal comfort in cold climate of Kenya, otherwise referred to as Upper Highland Climate.

Being among the coldest places in Kenya, the study of the performance of different built typologies in the highlands of Molo will provide important information for proper sustainable design in such climates.



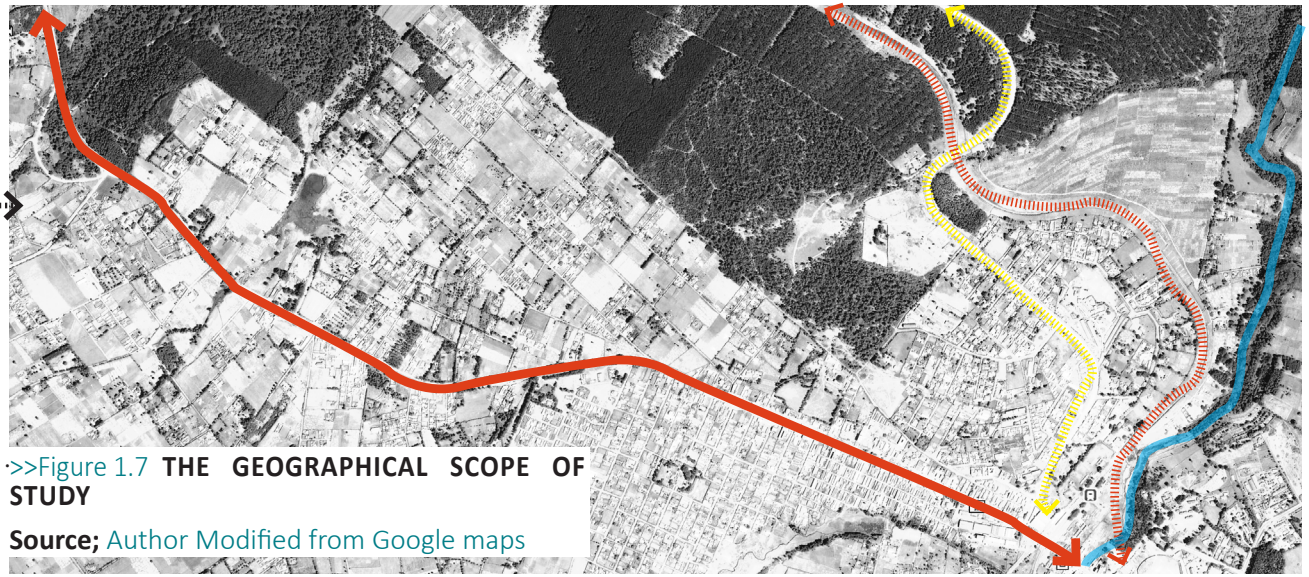
The study will concentrate on recommending sustainable modern design parameters to be employed in cold climate and subsequently, contribute to the debate on how to build in such climatic conditions.

1.6 Scope and Limitation

In a very broad field of sustainable design, this research focuses on climate responsive design strategies employed in cold highland regions. It entails evaluation and analysis of such strategies employed within Molo town in Kenya, and other areas which experience this climate

Geographically, this study focuses on Molo town, Nakuru County, See figure 1.7. There is need for the town to grow in a sustainable way given its location to ensure that its development does not negatively affect the environment.

This study is limited to sustainable design principles that have been used to maintain thermal comfort in the area under study. Various climatic elements such as air temperatures, air humidity, precipitation, sky condition, solar radiation and air movement are discussed and analysed. The research is also limited to time and financial constraints, availability of data for analysis and accessibility of sample case studies chosen to conduct this research.



>>Figure 1.7 **THE GEOGRAPHICAL SCOPE OF STUDY**

Source; Author Modified from Google maps

>>Figure 1.8 **INFO-GRAPHIC IMAGE FOR THE ORGANISATION OF STUDY.**

Source; Author, November, 2018.

1.7 Organisation of Study

The study is organised as follows;

Chapter One: Introduction...

This chapter serves as the introduction of the thesis and highlights the problem statement, aims and objectives of the study, research questions, justification and significance of the study,the scope and limitations and also the research methodology used to undertake the study.

Chapter Two: Literature Review...

Chapter two critically reviews the studies done in the past in the light of thermal design strategies and identifies arguments for and against it, which establishes the author's point of view on how it can be localized and be employed in Upper Highland climate.

Most important, this chapter enables the author to establish variables that can be used to measure design's response to this climate. The two basic parameters for thermal design being temperature and solar geometry, the main variables that measure responsive design are established in this chapter as human comfort, site planning, house plan, structure and materials, openings and ventilation.

These parameters vary for each climatic region and this chapter establishes the ideals of these variables for Upper Highland climate. These ideals will be later used as benchmarks to establish the thermal performance of learning buildings in the area of study.

Chapter Three: Research Methodology...

Chapter three will highlight the methods of data collection, sources that the author engages in carrying out the research. It will include a brief explanation of why a chosen method will be used, how it will be executed and of what significance it will be to the author in getting the materials for study.

Chapter Four: Data Collection And Analyses.
This chapter will basically contain detailed analysis of the research findings of the local case study buildings in Molo town. The chapter will also contain recorded climatic data of the selected buildings after the investigations. Findings and comprehensive analysis of the selected learning institution buildings in the study area will be documented.

Chapter Five: Conclusion And Recommendations
This final section of the research thesis gives the deductions and recommendations. It highlights the conclusions deduced from the findings of the investigation.

1.8 Definition Of Terms

Sustainable Development is development that meets the needs of the present without compromising on the ability of future generations to meet their own needs.

Sustainable Design is the principle of designing the built environment and its services to comply with the principles of social, economic and ecological sustainability.

Climate Responsive Architecture takes into consideration seasonality, the direction of the sun (sun path and solar position), natural shade provided by the surrounding topography, environmental factors (such as wind, rain fall, humidity) and climate data (temperature, historical weather patterns, etc.) to design comfortable and energy efficient buildings.
It aims at achieving occupant thermal comfort with little or no recourse to non-renewable sources by incorporating elements of the local climate effectively (Yannas, 2003).

Passive design strategies refers to the use of the natural environment to moderate the internal climate of a building. It relies on ambient energy sources, such as wind and solar energy to regulate the internal climate.

Upper Highland climate- This type of climate is generally has high precipitation of not less than 1250mm a year, with low temperatures and high seasonal and diurnal temperature ranges and the humidity is very high with lower solar radiation.

Passive climate control- is the use of natural environment to moderate the internal climate of a building. It relies on ambient energy sources, such as wind and solar energy to regulate the internal climate.

Active climate control- refers to the conservation of electricity into energy to regulate the internal climate of a building.

Thermal comfort- is the state of mind that expresses satisfaction with the surrounding environment. Human thermal comfort cannot be measured in terms of psychological factors only; hence it majorly involves the maintenance of the thermal balance between the human body and the environment.