



EiABC

Ethiopian Institute of Architecture,
Building Construction and City Development
የኢትዮጵያ የኤርኪትክሮር ፣ ህንፃ ግንባታ እና ከተማ ልማት ኢንስቲትዩት
Addis Ababa University
አዲስ አበባ ዩኒቨርሲቲ

Constraints and Opportunities in the Application of Green Building Principles in the Professional Building Practice in Addis Ababa

A thesis Submitted to

Chair of Environmental Planning and Landscape Design

Submitted in Partial Fulfilment of the Requirement for the Degree of Master of science in Environmental planning and landscape design

Author: Nura Mohammedata

Advisor: Hailu Worku (Prof.)

Ethiopian Institute of Architecture, Building Construction, and City Development,
Addis Ababa University

Addis Ababa, Ethiopia

October, 2018

Addis Ababa University
School of graduate Studies

This is to certify that the thesis prepared by **Nura Mohammedata**, entitled: ***Constraints and Opportunities in the Application of Green Building Principles in the Professional Building Practice in Addis Ababa*** and submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental planning and Landscape design complies with the regulations of the university and meets the accepted standards with respect to the originality and quality.

Name and Signature of members of the Examining Board

Hailu Worku (Prof.)

Advisor

Signature

Date

Hiyaw Terefe (PhD)

External Examiner

Signature

Date

Dagnachew Adugna (PhD)

Internal Examiner

Signature

Date

Fisseha Wegeyehu (PhD)

Chair Person

Signature

Date

Declaration

I **Nura Mohammedata**, declare that this study is my original work towards Executive Masters of **Master of Science in Environmental Planning and Landscape Design** and has not been submitted for any Degree or Diploma in any University. To the best of my knowledge, all source of materials used for the study have been duly acknowledged. I have undertaken the study independently with the guidance and support of the research advisor.

Signature _____

Nura Mohammedata

Acknowledgment

After my almighty God, I would first like to express my sincerest gratitude to Prof. Hailu Worku for his guidance and valuable advice. All the respondents and interviewees involved in this study are gratefully acknowledged for their valuable time and insightful sharing. I would also like to thank my family and friends for their understanding and patience. Lastly, a special thanks and my deepest appreciation is given to Ezana Getaneh and Hlina Wondwossen for their warmest support and helpful hands throughout my study. Thank you all.

Table of Contents

List of Figures	i
List of Tables	iv
List of Acronyms	v
Abstract	vi
Chapter I	1
1. Introduction	1
1.1. Background of the study	1
1.2. Statement of the problem	2
1.3. Objective of the study	4
1.4. Research Question	4
1.5. Significance of the study	5
1.6. Scope of the study	5
1.7. Limitations of the study	6
1.8. Organization of the study	7
Chapter II	8
2. Literature Review	8
2.1. Building Practice	8
2.2. The process of transformation to green building practice	8
2.2. Green buildings Practice	10
2.3. Principles of green buildings	11
2.4. Green building councils and rating system	14
2.5. Benefits of green buildings	16
2.6. Challenges of green buildings	18
2.7. Strategies for promoting green buildings	20
2.8. The main actors' influencing the development of green buildings	21
2.9. Vertical greeneries	23
2.10. Vertical greenery and Leadership in energy and environmental design (LEED) rating system	25
Chapter III	27
3. Research methodology	27
3.1. Selection Criteria of study buildings	27
3.2. Study Design	27
3.3. Case Study Method	28
3.4. Sample and Sampling procedure	28
3.5. Data type and source	30
3.6. Data collection method	30

3.7. Data analysis method.....	32
3.8. Data Presentation	32
3.9. Research design	33
3.10. Methodology Summary	34
Chapter IV	35
4. Existing situation and Analysis of the Selected Buildings.....	35
4.1. Overview of Buildings in Addis Ababa	35
4.2. Existing situation and Analysis of the Selected Buildings.....	37
4.2.1. Gullele Botanic Garden	38
4.2.2. International Community School (ICS).....	47
4.2.3. Lideta Mercato Building.....	55
4.2.4. Hope University Library.....	64
4.2.5. Varnero Apartments	70
4.2.6. CMC Apartments.....	75
4.2.7. Yeka Sub-City Administration Building	81
4.2.8. Ye Enat Building.....	87
4.2.9. K Kare Building	93
4.2.10. Lion House Building	97
Chapter V	103
5. Data Analysis and Presentation	103
5.1. Analysis of the selected buildings	103
5.1.1. Sustainable sites	104
5.1.2. Water efficiency.....	105
5.1.3. Energy Efficiency and Atmosphere	107
5.1.4. Material and Resources	109
5.1.5. Indoor environmental quality.....	112
5.2. Challenges and Opportunities in implementing Green building principles	117
5.2.1. Respondents profession and Professional experience.....	117
5.2.2. Familiarity with green building concept.....	117
5.2.3. Application and difficulty of green building principles	118
5.2.4. Economic Challenges	120
5.2.5. Awareness and education challenges	122
5.2.6. Industry and organizational challenges.....	123
5.2.7. Opportunities in implementing green building practice	124
5.3. Strategies for application of green building practice	125
Chapter VI	127
6. Summary of Findings and Discussion.....	127

6.1. Building practice in Addis Ababa and efforts of application of green building principles	127
6.1.1. Gaps between green buildings and surveyed buildings concerning Sustainable site	127
6.1.2. Gaps between green buildings and surveyed buildings concerning water efficiency	128
6.1.3. Gaps between green buildings and surveyed buildings concerning energy efficiency	129
6.1.4. Gaps between green buildings and surveyed buildings concerning material and resources.....	130
6.1.5. Gaps between green buildings and surveyed buildings concerning Indoor Environmental quality.....	131
6.2. Challenges and opportunities in implementing green building principles	132
6.3. Appropriate strategies for application and implementation of green building practice	134
6.3.1. Public Awareness and Education	134
6.3.2. Economic and Financial incentives	139
6.3.3. Green building rating system	140
6.3.4. Green building related research.....	140
6.3.5. Policies and Regulations.....	141
6.3.6. Design and development of vertical greenery.....	142
Chapter VII	148
7. Conclusion and Recommendation	148
7.1. Conclusion	148
7.2. Recommendation	149
7.2.1. Design and Construction Recommendation	150
7.2.2. Recommendation for main actors of green building	152
7.3. Areas of further Research.....	154
Reference	155
Annex	i

List of Figures

Figure 1: Organization of the study	7
Figure 2: Evolution of Green Buildings	9
Figure 3: LEED credit Categories	16
Figure 4: Location of selected buildings.....	29
Figure 5: Research Design	33
Figure 6: Methodology Summary.....	34
Figure 7: Addis Ababa Urban Expansion.....	35
Figure 8: Plant species around the building.....	39
Figure 9: Gravel infiltration trench (left), ditch channeling the stormwater to the surrounding green (middle), type of pavement (right)	40
Figure 10: Green Roof of the building.....	40
Figure 11: Water efficient fixtures (left) and wastewater treatment (right)	41
Figure 12: Solar energy for boiler (left), LED lights (middle), Artificial lighting during the day (right) ...	42
Figure 13: Exterior materials (left), Interior materials (middle) and Waste disposal bin (right).....	43
Figure 14: Naturally lighted and ventilated circulation (left), Wooden sun breakers (middle) and Dampness in the toilets (right)	45
Figure 15: Ground and first floor plan of GBG (Top to bottom)	46
Figure 16: Green cover of the compound (left), Rain water from balcony irrigating green area (middle) and concrete pavement (right)	48
Figure 17: Green wall and Green roof of the building (from left to right)	49
Figure 18: waterless urinals, dual flashing, and auto-shutoff sinks (left to right)	49
Figure 19: Exterior materials (left), Interior materials (middle) and Waste disposal bin (right).....	51
Figure 20: Aluminum sun breakers (left), Skylight for the basement (middle) and naturally lighted and ventilated circulation (right)	52
Figure 21: Acoustic panel fins (left), louvre windows and folding doors (middle) and outdoor recreational area in every floor (right)	53
Figure 22: Ground floor and Typical floors from first to fourth (top to Bottom)	54
Figure 23: Rainwater released to the surrounding (left), Street at the rear side of the building (middle) and Recreational area rooftop (right)	56
Figure 24: Exterior and interior materials of the building (left to right)	58
Figure 25: The inclined atrium (artificial lighting during the day) and natural lighting through the perforated wall (left to right)	59
Figure 26: Dampness problem (left), open down to the main entrance (middle) and shops inside the building (right)	60
Figure 27: Lideta Mercato floor plan from ground floor to terrace	63
Figure 28: Pavement around the building (left), the effect of the recurring flooding in the basement (middle) and prevention method for the flooding (right).....	65

Figure 29: Green roof of the library and the surrounding green area (left to right)	65
Figure 30: Exterior materials and Interior materials (left to right).....	67
Figure 31: Open down with a greenery (left), Bamboo sun breakers (middle) and Skylight for ventilation and lighting (right)	68
Figure 32: Opening for ventilation and lighting (left), Limited operable windows (middle) and water leakage from the green roof (right)	69
Figure 33: Ground and first floor plan of Hope University Library.....	70
Figure 34: Surrounding green area and tile pavement (left) and Rainwater released to different layers of green areas (right).....	71
Figure 35: Green wall and the green area on the roof of the parking (left to right).....	72
Figure 36: The front side of the building studied (left), Water leakage in the parking garage with green roof (middle) and Part of the compound (right)	74
Figure 37: Varnero apartment floor plan: ground, first to fourth typical and fifth floor (top to bottom)..	75
Figure 38: Green area at the back of the building (left), rain water released to the surrounding green (middle) and concrete pavement and front green spaces (right)	77
Figure 39: Exterior material of the building and waste dumping site (left to right).....	78
Figure 40: Open down, naturally ventilated and lighted staircase, Dampness and microbial growth and green area in the ground floor of the open down (from left to right)	80
Figure 41: Typical ground floor of CMC	80
Figure 42: Taxi and bus stop at the entrance (left), Front side green area (middle), Rain water released to the ditch and green area at the back of the building (right)	82
Figure 43: Exterior materials (left), Interior materials (middle) and Artificial lighting used during the day even when not necessary (right).....	83
Figure 44: Open down all the way to the ground floor with skylight (left), Dampness in the building (middle) and well-lighted circulation (right)	84
Figure 45: Ground floor plan, first floor to seventh floor typical and eighth to eleventh floor typical (top to bottom)	87
Figure 46: Rainwater through downpipe to main drainage line(left), Ground level greenery and cobble stone paved walkway (middle) and Balconies with potted plants(right)	88
Figure 47: Exterior and Interior materials in the building 9Left to right)	90
Figure 48: Dormer windows on the roof (left), large windows on the front face (middle) and high indoor activity (right).....	91
Figure 49: Floor plan from ground to fourth mezzanine (top to bottom)	92
Figure 50: Parking area (left), Advertising lighting used inside the building (middle) and Artificial lighting during daytime and fans (right)	94
Figure 51: Exterior and interior materials used in the building (left to right)	95
Figure 52: Front facade of the building (left), Asphalted parking, waste disposal area and river at the back (middle) and Indoor potted plant (right).....	99

Figure 53: Different partitions affecting the lighting in the building unit and utilization of artificial lighting during the day	100
Figure 54: Naturally lighted circulation, Dampness in the toilets, closed curtain on the front side due to harsh sun (left to right)	101
Figure 55: Sketch floor plan of the ground and typical first to tenth floor (top to bottom)	102
Figure 56: Building function and ownership	103
Figure 57: Access to service and transport and Alternative Transportation	104
Figure 58: availability of open and green areas, green roof and green wall	105
Figure 59: Use of water efficient fixtures.....	106
Figure 60: Water Usage	106
Figure 61: Energy usage.....	107
Figure 62: Energy efficient lighting and Renewable energy	108
Figure 63: Type of wall used in the selected buildings	109
Figure 64: Roof and Floor materials	110
Figure 65: Waste Management.....	112
Figure 66: lighting mean score.....	113
Figure 67: Air quality mean score	114
Figure 68: Thermal Comfort	115
Figure 69: Efficiency and health problems due to IEQ	116
Figure 70: Respondents profession and Professional experience	117
Figure 71: Familiarity with green building concept.....	118
Figure 72: In-cooperated green building principles.....	119
Figure 73: Difficulty of green building concept.....	120
Figure 74: Economic Challenges	121
Figure 75: Awareness and education challenges	122
Figure 76: Industry and organizational challenges	123
Figure 77: Strategies for application of green building practice.....	126
Figure 78: Location map of the action area	142
Figure 79: Types of green facade designed	143
Figure 80: Designed mesh system green façade	144
Figure 81: Designed Wire or Rope System 3D and section	144
Figure 82: Roof catchment and storage plan and section	145
Figure 83: Selected Species	146
Figure 84: Constructed rope system vertical greenery (left), Constructed mesh system greenery (middle) and Fiber glass water storage for irrigation (right)	147

List of Tables

Table 1: Mean Scores for economic challenges	121
Table 2: Mean score for education and awareness challenges.....	122
Table 3: Mean score for Industry and organizational challenges	123
Table 4: Major opportunities according to practitioners	125
Table 5: Mean score for strategies for application of green building practice	126
Table 6: Cost breakdown of the vertical greenery	146

List of Acronyms

AC	Air Conditioner
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Built Environmental Efficiency
CFC	Chlorofluorocarbon
DGNB	German Sustainable Building Council
EiABC	Ethiopia Institute of Architecture, Building construction and City Development
GB	Green Building
GBCA	Green Building Council of Australia
GBG	Gulele Botanic Garden
GIZ	German Society for International Cooperation
HCB	Hollow Concrete Block
HVAC	Heating, Ventilation and Air Conditioner
HoA-REC&N	Horn of Africa Regional Environmental center and network
ICS	International Community School
IEQ	Indoor Environmental Quality
LEED	Leadership in Energy and Environmental Design
UN	United Nation
U.S.	United State
USGBC	United State Green Building Council
VOC	volatile organic compounds
WNCGBC	Western North Carolina Green Building Council

Abstract

Buildings make a significant contribution to environmental degradation and this have led to the emerging concept of “green buildings” which are designed to be energy and water efficient, use nonhazardous sustainable materials and provide healthy productive indoor and outdoor environments. This concept, however, is very new in Addis Ababa, which is currently undergoing a construction boom with a tremendous increase in the construction of buildings in recent years. Instead of taking advantage of the ideal climatic conditions, most buildings in the city use the glass facades causing glares and increasing energy consumption. Lack of greeneries and use of low albedo construction materials and impervious surfaces is trapping heat which will lead to the formation of urban heat islands. As a result, there is a need to enhance the environmental performance of these buildings through the application of green buildings principles for greater sustainability efforts before the problem becomes irreversible. With that, this thesis assess the nature of selected buildings based on the green building principles in order to understand the gap, its challenges, opportunities and proper approaches for application and implementation in Addis Ababa with a concentration on the design and development of vertical greenery because vertical greeneries contribute to securing up to 18 credits under the LEED rating system by dealing with most of the green building principles. A mixed approach that utilizes both qualitative and quantitative data was collected from primary sources through site survey, interview, questionnaires and secondary data through document review & case study to obtain the necessary information. By analyzing the data collected, it was found that most of the surveyed buildings have poor indoor quality sometimes contributing to occupant’s illness, rely on imported materials rather than using local and low impact materials, consume large amount of unnecessary energy and little consideration is given to water efficiency or the surrounding area. Based on the practitioners’ reply, the challenges for applying the concept of green building is lack of awareness about green building, lack of interest of developers, absence of government incentives and others while the best strategy according to the practitioners was public awareness campaigns to promote green buildings. Lastly, the thesis forwards the necessary recommendations based on the problems observed.

Key words: Green Building, Sustainable Building, Vertical Greenery

Chapter I

1. Introduction

1.1. Background of the study

All over the world, large amount of buildings are being built and their design, construction, maintenance and demolition have a tremendous impact on the environment and natural resources. According to the U.S. Green Building Council, buildings are among the heaviest consumers of natural resources and energy, thereby creating a significant portion of the greenhouse gas emissions that affect climate change. While industrial and transportation sectors produce 25% and 32%, respectively, of the U.S. CO₂ emissions from fossil fuel consumption, buildings, at 43%, account for the largest share of U.S. CO₂ emissions. (U.S. Green Building Council, 2008)

In view of these circumstances, green building movement which seeks to achieve balance between environmental, social and economic performance of buildings has gained momentum in recent years. As stated in (U.S. Green Building Council, 2008), the core idea of green building is the optimization of one or more of its principles such as Siting and Structure Design Efficiency, Energy Efficiency, Water Efficiency, Materials Efficiency, Indoor Environmental Quality Enhancement, Operations and Maintenance Optimization, and Waste and Toxics Reduction.

Green buildings use less energy, water and natural resources, further it creates less waste and provide healthier living environment compared to the conventional buildings. Green building strategies not only stand for sustainable materials in their construction (e.g. reused, recycled content or made from renewable resources) but also making use of natural processes (e.g. shading effects of trees, insulation capacities of green roofs and green facades, mitigation of urban heat due to evapotranspiration). Greening the exterior of buildings (walls and roofs) provides numerous ecological and economic benefits, including stormwater management, energy conservation and mitigation of the urban heat island effects, reducing air pollutants, increased longevity of building materials, as well as providing a more aesthetically pleasing environments in which to work and live. (Ottele, 2011)

In the developed world, there have been extensive studies on green buildings, as evidenced in the rapidly growing number of assessment tools (such as LEED United States, BREEAM United Kingdom, GBCA Australia, DGNB Germany and CASBEE Japan) developed to assist

the green building development in the last decades. However, in the developing world such as Africa, sustainable construction has not received sufficient attention despite being an important aspect of sustainable development (Adebayo, 2002).

According to the World Bank Development report of 2009, only South Africa has an established Green Building Council (GBC) but this is slowly changing with Morocco, Mauritius and Egypt being in the process of establishing their councils. (Malanca, 2010). Currently, the number of GBCs in Africa has increased including countries such as Ghana, Kenya, Namibia, Rwanda, Tanzania and Zambia but Ethiopia is yet to join these group.

Similar to the majority of developing African countries, the concept of green buildings is very new in Ethiopia. It is rare to find researches which address this topic except a master's thesis conducted by (Taeka, 2015) which focused on finding out the nature of the selected buildings based on the Green Building framework. Therefore, there is scarcity of research concerning the difficulties and prospects of applying these principles in Addis Ababa which is of prompt importance to bring about sustainable practices and techniques that minimize the negative effects of conventional buildings.

1.2. Statement of the problem

According to Taeka (2015), even though the proposal to improve the existing buildings of the capital are crucial in the Ethiopia's struggle to achieve sustainability, there are no implications that prove there are applications of remedial green building features onto the buildings of Addis Ababa.

Conventional buildings being a vital component of the urban environment largely contribute to the problems of urban areas. Buildings consume many of the natural resources and are responsible for many problems including 40% of the world's total energy use, 30% of raw materials consumption. 25% of timber harvest, 35% of the world's CO₂ emissions, 40% of municipal solid waste destined for local landfills, 50% of ozone-depleting CFCs still in use and has negative affect for watersheds, habitat, air quality, and community transportation patterns. (Woolley and Kimmins, 2000)

In Ethiopia, especially the capital Addis Ababa, there is a tremendous increase in the construction of buildings in recent years. As stated in Zegeye and Helawi (2012) the 'Dubai Fever', has reached Addis Ababa and the copy/paste of architectural strategies brings with it

myriad of serious problems. Instead of using locally available materials, more than 80% of the construction materials in Ethiopia, including steel and glass, are imported.

The glass towers symptomatic of 'Dubai fever' have a big impact on the energy consumption of the city and resultantly on the ecological footprint of the whole country. Instead of taking advantage of and designing for the ideal climatic conditions of Ethiopia, the glass facades force the necessity of technical cooling systems, depleting one of the goods that Ethiopia does not have: energy. (Zegeye and Helawi, 2012)

As stated in Bezawit (2013), commercial buildings accounts for around 25% of the total energy consumption in Ethiopia, which is a significant portion of the nation's energy use. In addition to this, the commercial sector is expected to be the most important electricity consumer in 2030 taking 42% of the estimated total sales.

The high energy consumption along with lack of greeneries around these buildings which are useful in evapotranspiration, reduction of rainwater run-off and absorbing carbon will lead to the formation of urban heat islands. In addition, the usage of low albedo construction material and impervious surfaces is trapping heat and glass is causing glares on adjacent areas. Internally, the space is constantly partitioned into smaller spaces using magnesium board and balconies are blocked to be used for other purpose limiting sufficient light into the building resulting in discomfort of occupants and decrease in their productivity.

According to data collected from Addis Ababa Municipality, in 2007 building permits were given to more than 416 buildings above G+4, 701 in 2008 and 720 buildings until May of 2009 giving us the overall idea of how the city is transforming. On the other hand, out of the thousands of buildings in Addis Ababa only two buildings are LEED certified green buildings, the Gullele Botanic Garden and NEC (Embassy of the United States of America). Even though many challenges including lack of knowledge, technology and lack of incentive on research and practice of green buildings stand in the way of its application in the city, the contribution of green buildings is undeniable.

Given the continued growth of urbanization and economic development in the city, pressure on the environment will continue to increase so enhancing the environmental performance of buildings through application of green building concept is essential for greater sustainability efforts. In addition, architects, developers, contractors, occupants and government officials need to have a better understanding for implementation of its principles.

Therefore, this thesis aims to fill this gap in green building area and its application in Addis Ababa by assessing the building practices of selected buildings in comparison with green building principles, its opportunities, challenges and possible strategies for its application and implementation with special emphasis on the design and development of vertical greenery so as to mitigate climate change and achieve sustainable development.

1.3. Objective of the study

The General objective of the study is to contribute to the enhancement of the transformation of the building practice to green building practice by assessing the nature of the buildings based on the green building principles in order to understand the gap, its challenges, opportunities and proper approaches for application and implementation in Addis Ababa.

The specific objectives are:

- To study the building practice and efforts of application of green building principles in selected buildings of Addis Ababa
- To identify the challenges and opportunities in implementing green building practice in Addis Ababa according to practitioners
- To identify appropriate strategies for application and implementation of green building practice
 - Design and development of vertical greenery

1.4. Research Question

The research has the following research questions:

1. What are the building practices in Addis Ababa? How does it relate to green building principles?
2. What are the opportunities that boost the green building practice?
3. What are the challenges restricting the application of green building principles in Addis Ababa?
4. What needs to be done in order to reduce the constraints and exploit the opportunities?

1.5. Significance of the study

This study provides valuable knowledge as it is one of the few studies to investigate the application of green building concepts in buildings of Addis Ababa. It is significant because it contributes to a better understanding of the concept and implementation of green building principles and its role for achieving sustainability in building design and construction.

Through its recommendations, it suggests ways of increasing adoption of sustainability concepts in buildings and can also be used as a useful reference for both industry practitioners and academics that are interested in green building developments. It increases the feasibility of these principles by identifying the cost and the best innovation in vertical greenery in local context. Lastly the study will influence the practice of consultants in the building industry in Addis Ababa.

1.6. Scope of the study

Spatially, the study is confined to selected buildings in Addis Ababa. Thematically, it examines the building practice against green building principles and its prospects and difficulties for application by incorporating knowledge of different disciplines including architecture, urbanization, sustainability, climate, and others. It focuses on the design and development of vertical greenery because, if at least 50% of the building is covered with a green roofs or wall, one LEED point each will be awarded for reducing heat islands and for stormwater management (Oberlander et al, 2002) and with quality green roof or wall design, one can earn as many as 18 LEED credits in the categories of sustainable sites, water efficiency, and energy and atmosphere (Kula, 2005).

In order to understand what qualifies as a “green” building or what it means to green a building, the LEED rating system is utilized as the benchmark because this rating tool has been used for certification of the two certified buildings in Addis Ababa, Gulele Botanical Garden and NEC (Embassy of United states of America).

Participants in this study are those who are involved in the design, construction and management as well as occupants of the selected study buildings and practitioners of the building industry.

1.7. Limitations of the study

The limitations encountered during this study are shortage of previously done research on Green Buildings and lack of properly documented baseline data especially on selected buildings' information. In addition, since the concept of green building is relatively new in Addis Ababa, there was some difficulties of communicating information. Moreover, the questionnaire for building occupants of ICS building was not conducted as the respondents are young students and were also on vacation during the study. Another limitation faced is that, the exact number of consultants in Addis Ababa was not identified as the office responsible was not responsive hence other methods such as internet was used to identify 85 consultants.

1.8. Organization of the study

The thesis is divided into six chapters.

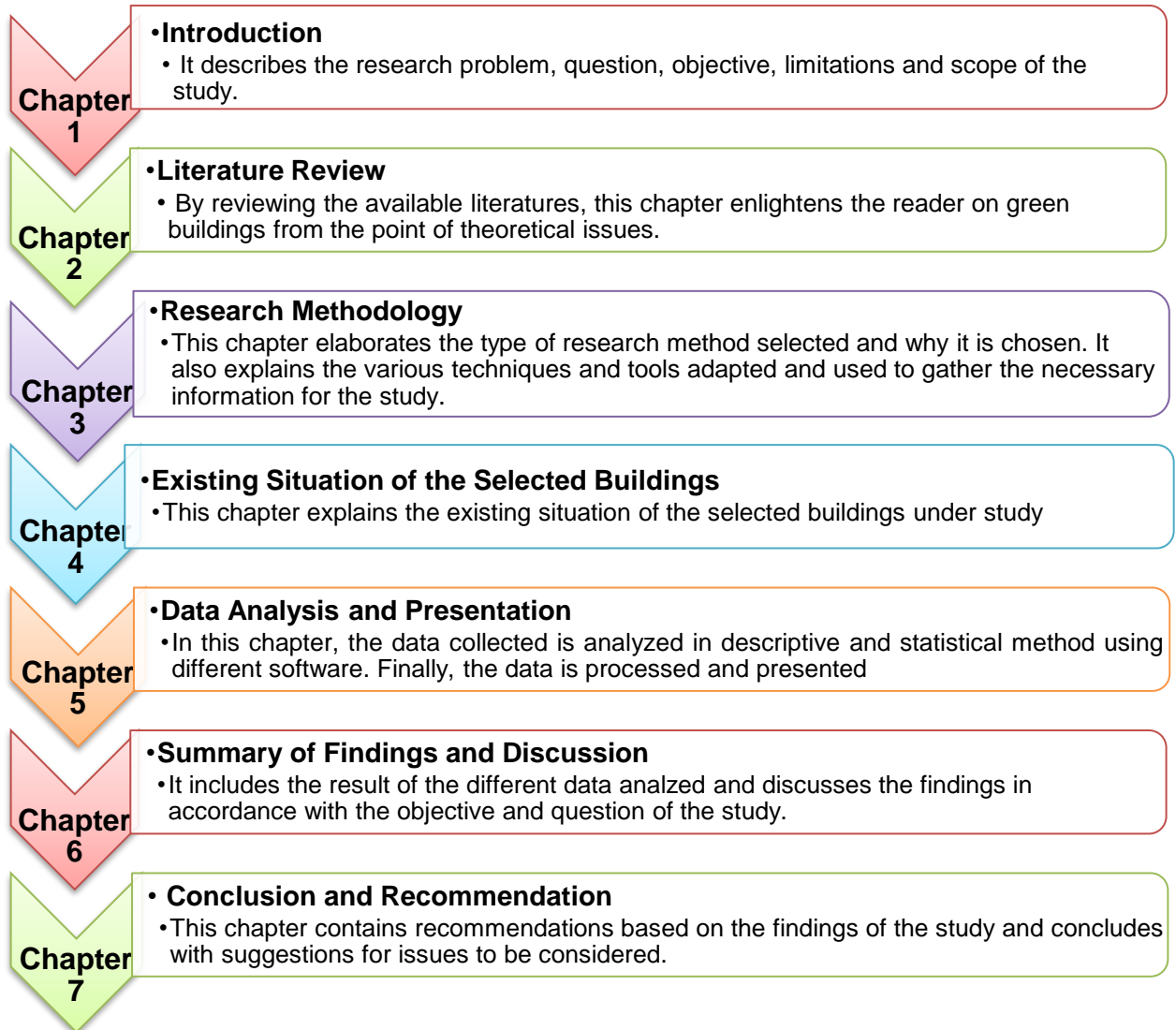


Figure 1: Organization of the study

(Source: Computed by the researcher, 2017)

Chapter II

2. Literature Review

This chapter discusses the literature that was reviewed. The literature review will start by explaining the concept of green buildings, how it came to be and its principles. Secondly there is a discussion on the benefits of green buildings and its challenges. Green building practices are discussed with a focus on vertical greenery. There is a focus on green buildings, and Green Building Councils and what they comprise off. Furthermore, the concept of a green rating tool is discussed, followed by the different green rating tools and models that are applied globally.

2.1. Building Practice

Traditional building practice is that way of building which makes serious use of the familiar symbolic forms of a particular culture of a particular people in a particular place. Traditional building practice is the term used to categorize methods of construction which use local anethetically available resources and traditions to address local needs. Some believed that, by using local practices, such as using local materials in construction, building costs will decrease, hence being economically more advantages.

However, the emerging trend of modernization and the urgent need for infrastructure and housing projects has caused a hasty shift from the traditional to modern buildings. The concept of modernism in building practice is difficult to define despite being clearly conceived in opposition to late 19th century historicism, and rejecting historical precedents and traditional methods of building. (Ching et al., 2011). Characteristics of modern architecture include functional requirements of the structure, lesser ornaments used and eliminations of dispensable details, and the application of the concept of “form follows function”. Modern building practice showed strong preferences for industrial building materials and production. For decades, modernism became the dominant structure for institutions and corporate buildings even up to the recent period. (Yellamraju, 2010)

2.2. The process of transformation to green building practice

The concepts of sustainable development and green building are not new. Looking at the building and construction history, this can be traced back several thousands of years, for example looking at how the Indians selected to place their dwellings so that they could draw

benefits from the sun or how the Romans aligned their dwellings along a certain direction to trap the sun in the winter. These showed buildings should work with the nature instead of against it and thereby have a sustainable energy performance. It has for a long time been important to people on our planet in the endeavor towards maintaining a sustainable society. (Yellamraju, 2010)

However, with the emergence of heating and air conditioning systems in the twentieth century, there was a tremendous shift in the way buildings were designed. Designer did not take the external climate conditions into their considerations anymore, as they become dependent on HVAC systems to do this job. Modern buildings became isolated from the external environment and started consuming energy created by burning fossil fuels, like coal and oil. Buildings became one of the major sources of consumption of energy in the world.

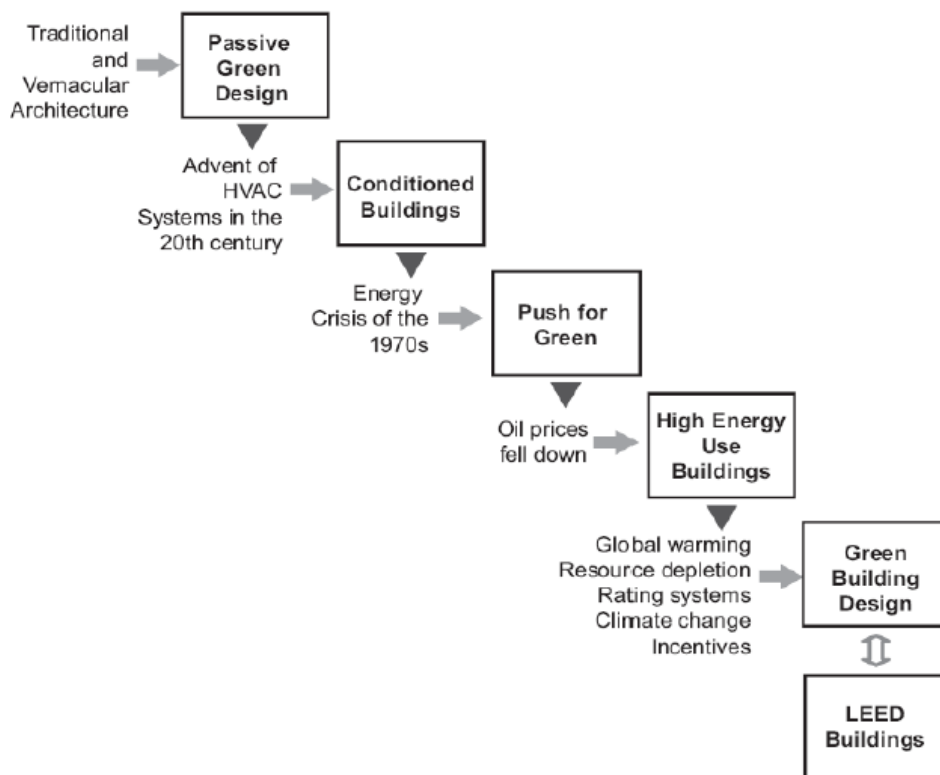


Figure 2: Evolution of Green Buildings

(Source: Yellamraju, 2010)

The green building movement can also be associated with the rise in environmental awareness among the general public as well as the governmental response to the environmental movements in the form of policy initiatives. For example, as stated by (Potbhare, 2008), the four milestones that triggered green building movement in the U.S. are:

- **Milestone I-Silent Spring by Rachael Carson (1962):** The book had started a nationwide debate on the unrestricted use of the Dichloro-DiphenylTrichloroethane (DDT) and other pesticides by the government. The public awareness created by this book can be referred to as the first nationwide environmental movement in the history of U.S.
- **Milestone II-OPEC oil embargo (1972):** the embargo had lasted only for six months but it had created an environment of crisis in terms of energy security. The government had issued many immediate measures such as tax benefits for the development of alternative sources of energy.
- **Milestone III-Brundtland Commission (1987):** The primary mission of the commission was to address the growing concerns about the accelerating deterioration of the human environment and natural resources.
- **Milestone IV-Formation of USGBC (1993):** To address sustainability, the U.S. government decided to target the construction sector, as it was one of the major consumers of the energy resources, contributors to the greenhouse gas emissions and also was a direct medium of public interaction.

2.2. Green buildings Practice

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland report, 1987)

This definition of sustainability is wide so under this definition of sustainability subsets have been developed, such as green building and sustainable construction. These concepts offer a possibility to look at buildings and buildings life span. Different definitions of green building according to different sources are explained below:

- Briefly the green building concept can be seen as part of a movement that wants to put more emphasis on sustainability in the construction of buildings. (Haselbach, 2010)
- Green buildings are buildings where an attempt is made to minimize the energy consumption and to protect and conserve water resources. There is also a lot of focus on optimizing the maintenance and operational practices in the building. Along with this, is the attempt to reduce the environmental impact the materials used in a building causes from a life-cycle perspective. All of this should lead to a green building that

which is environmentally sound and where the impacts on the human health are minimized. (Yudelson, 2010)

- Green building (also known as green construction or sustainable building) refers to a structure and using process that is environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. This requires close cooperation of the design team, the architects, the engineers, the suppliers, the contractors, and the client at all project stages. (Ji and Plainiotis, 2006)

According to Zuo and Zhao (2014), similar with that of sustainability, green buildings have three aspects including:

- a. Technical and environmental Aspect:** traditionally, the focus of green building is placed on environmental aspect of sustainability which takes into account issues such as energy efficiency, water efficiency, resource efficiency and greenhouse gas emission reduction.
- b. Social aspects:** In the construction context, social sustainability mainly covers the quality of living, occupational health and safety, and future professional development opportunities. In building context, social sustainability means providing a healthy and safe environment to all stakeholders, e.g. construction personnel, users and operators.
- c. Economic Aspects:** there are social and economic requirements of green buildings such as access, education, inclusion, cohesion, affordability, economic value, impacts to local economy, indoor health, cultural perception and inspiration. The benefits of energy retrofitting initiatives are reflected not only on the cost savings derived from improved energy efficiency but also the potential value added to the property. This helps to reduce the payback period of investment for energy efficiency measures.

Therefore, a green building could take either a narrow definition (e.g. purely environmental sustainability) or broad definition (i.e. adopting triple bottom line approach).

2.3. Principles of green buildings

The seven fundamental principles of green buildings according to different sources such as (El Yamany et al, 2016) and (Johnson, 2005) are:

I. Optimize Site Potential

Sustainable buildings start with proper site selection, including consideration of the reuse of existing buildings. The location, orientation, and landscaping of a building affects the local ecosystems, transportation methods, and energy use characteristics of the building. Smart growth principles should be incorporated in the project development process, whatever the scale of development. Whether designing a new building or retrofitting an existing building, site design must integrate with sustainable design to achieve a successful project.

II. Optimize Energy Use

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment. It is essential to reduce demand, increase efficiency, and utilize renewable energy. The use of passive measures such as orientation, air tightness, solar shading, thermal mass, and natural ventilation, must be considered from the outset; it must work with the natural environment, rather than against it, to reduce operating energy use, designers also use details that reduce air leakage through the building envelope (the barrier between conditioned and unconditioned space). They also specify high-performance windows and extra insulation in walls, ceilings, and floors.

III. Protect and Conserve Water

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site. The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing. Wastewater may be minimized by utilizing water conserving fixtures such as ultralow flush toilets and low-flow shower heads.

The use of non-sewage and grey water for on-site use such as site-irrigation will minimize demands on the local aquifer. Fresh water is an increasingly scarce resource. A sustainable building should reduce, control, and/or treat site runoff, use water efficiently, and reuse or recycle water for on-site use when feasible.

IV. Use Environmentally Preferable Products

A sustainable building must be constructed of materials that minimize life-cycle environmental, social and economic impacts such as climate change, resource depletion, and human toxicity and have been produced in a responsible and ethical way. Sustainable materials have a reduced effect on human health and the environment and contribute to improved worker safety and health, reduced disposal costs, and achievement of sustainability targets. Unfortunately, these products may have a slightly higher capital cost but we must always consider this against the whole life cost and the whole life value of the building legacy.

V. Enhance Indoor Environmental Quality (IEQ)

The Indoor Environmental Quality of a building has a significant impact on occupant health, comfort, and productivity. Among other attributes, a sustainable building maximizes day lighting; has appropriate ventilation, acoustic and moisture control; and avoids the use of materials with high Volatile Organic Compounds and ionizing radiation emissions.

VI. Resources conservation and Sustainable Waste Management

Conserving resources is a cornerstone of green building techniques. There are many ways to conserve resources during the building process. For example, selecting materials that have at least some recycled content can conserve natural resources and virgin materials. Minimizing construction waste can ease the impact on landfills and resources. Construction waste management practices start with onsite waste separation and source reduction, and end with reusing of the materials (on site or off site) and recycling.

VII. Optimize Operational and Maintenance Practices

No matter how sustainable a building may have been in its design and construction, it can only remain so if it is operated responsibly and maintained properly. Ensuring operations and maintenance (O&M) personnel are part of the project's planning and development process will help retain the green criteria designed at the onset of the project. Every aspect of green building is integrated into the O&M phase of a building's life. The addition of new green technologies also falls on the O&M staff. Although the goal of waste reduction may be applied during the design, construction and demolition phases of a building's life-cycle, it is in the O&M phase that green practices such as recycling and air quality enhancement take place.

2.4. Green building councils and rating system

Green Building Council (GBC) is non-profit, member-based organizations that look to transform building industries towards sustainability by encouraging the adoption of green building best practices. At present there are numerous green building councils around the world that are in different stages of development, and there are 20 Green Building Councils that are fully recognized. (Malanca, 2010)

Green rating systems are tools that help to ensure that sustainable buildings, communities and projects are developed in an integrated manner and that the appropriate experts are involved in the process. Rating systems were primarily developed to assess, or measure specific aspects of a building, regarding sustainability goals. Once measured, buildings could be more easily compared with current and past building practices and other green buildings. (EmiratesGBC, 2012).

The British Research Establishment launched the first commercial green building rating tool in 1990, known as BREEAM (British Research Establishment Environmental Assessment Method). This was followed by LEED (Leadership in Energy and Environmental Design) in 2002, in the United States, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan, Green Star in Australia and several other country-specific tools in Asia and Europe. (Malanca, 2010)

2.4.1. LEED Rating System

LEED which stands for Leadership in Energy and Environmental Design is a voluntary certification program that organizations can choose to use. If the organization chooses to certify buildings, LEED certification is a third party that approves it in the end. The meaning with using a LEED certification is to diminish the buildings ecological footprint and to lower the operating costs of the building. The first pilot of the system LEED version 1.0 was launched in 1998 and this was only LEED for New Construction. Due to a lot of mistakes and shortcomings in the system discovered in the pilot program of LEED version 1.0, LEED version 2.0 was launch to the public short thereafter in March 2000. (Cassidy, 2003)

The LEED rating tool is based on U.S standards. Any building in the world can register for LEED certification using the LEED rating tool. LEED provides building owners and operators with a structure for identifying and implementing practical and measurable green building design, construction and operations that recognize projects that implement strategies for

improved environmental and health performance. The LEED rating systems are developed through an open, consensus-based process led by LEED committees, various groups of volunteers representing a cross-section of the building and construction industry. (USGBC, 2011)

LEED is today one of the biggest and most widespread classification systems with almost 35,000 projects participating in the certification spanning over 91 countries. (USGBC, 2011) However, BREEAM is still the certification with the most buildings certified.

2.4.1.1. LEED Credit System

In LEED-NC and LEED-CS there is a 100-point scale with additional 10 bonus points to earn. The points are only positive, which means that points only are added when doing something good and that there is no possibility to get negative points for doing something that is bad. The points are divided into the five major categories and the two bonus categories. Each category has one part that is mandatory to be certified in that specific category. These prerequisites are there to guide the customers and to enhance the credibility of the LEED certification. The prerequisites do not give any extra points; it is just mandatory. Thereafter are there subcategories that can be chosen to work towards to get more points. (USGBC, 2011)

There are four possible levels of certification that can be achieved by exceeding the following point thresholds:

- Certified 40 - 49 points
- Silver 50 - 59 points
- Gold 60 - 79 points
- Platinum 80 points and above

According to (USGBC, 2011), the seven categories of LEED are shortly described as follows:

- **Sustainable Sites (SS):** 26 points; this category accentuates the project's sustainability with the development of existing infrastructure but also aims to diminish the impact on the local ecosystem and the natural resources.
- **Water efficiency (WE):** 10 points; covers a buildings water usage.
- **Energy and Atmosphere (EA):** 35 points; this category covers the use of energy and how the origin of the energy. This is done by encouraging different kinds of energy strategies such as the use of renewable energy.

- **Materials and Resources (MR):** 14 points; is a category that promotes the choice of sustainable materials and how to handle waste.
- **Indoor Environmental Quality (IEQ):** 15 points; concerning questions like daylight and clean air.
- **Innovation and Design (ID):** 6 points; promotes the use of different innovations and designs that goes beyond what is covered in the categories above.
- **Regional Priority (RP):** 4 points; addresses the geographical placement of the building. This category is at the moment a template for international projects.



Figure 3: LEED credit Categories

Source: *green wizards: the building product management solution, 2014*

2.5. Benefits of green buildings

The development of green building brings influential economic, social and environmental benefits to the communities.

2.5.1. Economic Benefits

With a better and healthier environment provided for occupants, their working productivity is believed to be increased and this can bring positive impact to the economy. In addition, green

building is energy-efficient and environmentally designed which helps reduce the energy and maintenance costs. (WNCGBC, 2013)

According to economist, green building can save 30% of energy consumption than conventional buildings. The research report released by (Davis, 2007) showed that extra upfront cost is required for green office building than conventional office buildings. However, the cost of not going green is high as well, considering the carbon trade cost and rocket high energy price. The cost savings during the operation and maintenance stages will help to offset the upfront cost required for green building features.

Nowadays, people are concerned about environmental friendliness more than ever, green building thus can help businesses build up corporate image and reputation. Hence, the asset value of green building is higher than conventional building. According to (Wasiluk cited in (WNCGBC, 2013), sustainable commercial buildings have a competitive advantage over conventional buildings and are able to attract higher profile tenants, command above market rentals and thus increase capital values. In addition, a city providing outstanding green environs can attract investment and bring profits to the communities. (WNCGBC, 2013)

Green Building Council of Australia (2008), reported that sustainable buildings in Australia commanded 5% to 10% higher rents and had higher relative investment return and asset values of 10%.

2.5.2. Environmental benefits

From environmental perspective, green buildings help to improve the urban biodiversity and protect the eco-system by means of sustainable land use. Reduction of construction and demolition waste is a critical component of sustainable building design. Compared with conventional buildings, green buildings generally provide higher performance reflected from energy efficiency, water efficiency and carbon emission reduction.

Green building can minimize environmental impacts by reducing or minimizing pollution and waste. In addition, as green building emphasizes the importance of clean energy and environmental friendly materials, it also helps conserve our limited natural resources. (WNCGBC, 2013)

2.5.3. Social and human benefits

Humans spend a considerable amount of time inside buildings and benefit from green buildings. The indoor environmental quality (IEQ), including volatile organic compound emissions and other contaminants is another critical issue in buildings. Extensive studies have suggested that green building can achieve higher level of IEQ than conventional buildings, which helps to improve the health and productivity of occupants. As a result, the level of satisfaction of building users is enhanced. In fact, (Leaman and Bordass, 2007) study found that users of green building tend to be more tolerant than those of conventional building in terms of indoor environmental quality. Different studies have shown that users of green building are more satisfied with thermal comfort and visual comfort than those in conventional building.

Studies also found that the health conditions and level of productivity improve when occupants moved to green buildings. For instance, (Ries, Bilec, Gokhan and Needy, 2006) suggested that economic benefits of green building in terms of productivity and absenteeism should not be overlooked. Their study found an increase of 25% of productivity and the absenteeism is significantly reduced when occupants moved from a conventional building to a green building.

2.6. Challenges of green buildings

While the advantages of green buildings and sustainable development continue to show encouraging results, there are a number of challenges affecting the realization of their full environmental, economic and social potential. The challenges of green buildings are discussed below:

a. Higher costs for green construction practices and materials

Perception of higher costs and increased upfront capital for green buildings relative to conventional building designs can be an obstacle. In fact, however, the average premium for green buildings is slightly less than 2% or 0.2-0.46 dollars per m² of the cost of conventional building (Kats, 2003). A 2003 study conducted for the California Sustainable Building Task Force found that an initial 2% increase in upfront costs yields lifecycle savings of 20% of total construction costs (based on a 20-year building life). (Kats, 2003)

b. Technical difficulty during the construction process

Often, green technologies require complicated techniques and construction processes. Tagaza and Wilson (2004) suggested that one of the main challenges in green building is the technical difficulties experienced during the construction process. Similarly, design can be more complicated than that of a conventional building due to the evaluation of alternative materials and systems (Hwang and Tan, 2012).

c. Unfamiliarity with green technologies

Knowledge and familiarity about green building practices has spread relatively slowly across the industry. As more architects, engineers, planners, and builders engage in green practices, both time and cost savings will be reduced. Many studies have verified that green technologies pose certain challenges for developers, clients and contractors. Two reasons suggested by (Eisenberg, 2002) are insufficient knowledge or technical expertise and unfamiliarity with the products, materials, system, or design. A project manager has to deliver the project with the required performance specified by the client (Pettersen, 1999; Ling, 2003), and unfamiliarity with the performance of green technologies may affect the performance outcome.

d. Greater communication and interest required amongst project team members

To be successful, the project manager must manage a large number of suppliers, subcontractors and team members. Communication is especially critical for the green project in order to convey the sustainable practices expected from the team members. Interest amongst team members is important, (Tagaza and Wilson, 2004) found that the initial enthusiasm for separating waste materials amongst sub-contractors dissipated as the projects progressed and the recycling skips were found to contain a mix of materials.

e. More time required to implement green construction practices on site

Random checks and on-site visits by project managers are usually required to ensure that sustainable practices are implemented on-site (Tagaza and Wilson, 2004). This is essential because workers may tend to forego time-consuming sustainable practices when there are time pressures to complete a project.

f. Risk due to different contract forms of project delivery

(Tagaza and Wilson, 2004) reported that the success of developing and implementing a green design depended greatly on the type of contract selected for the delivery of the project. The type of contract used in green projects must incorporate the details of a fully integrated green

design. This creates a problem if the design is locked before being developed fully. Multiple changes of significant scale are likely if green features are incorporated at a later stage, resulting in a greater overall project cost (Hwang and Tan, 2012).

g. Building codes and incentive policies

Building codes and incentive policies can be instrumental in facilitating green building practices and technologies, and education and training programs can minimize misperceptions regarding the economics of green buildings design and construction.

h. Inadequate Urban planning

(Adebayo, 2002), argues that in many urban areas of Africa and especially in the cities, construction of buildings generally, but especially residential buildings have been carried out to occupy the entire site. The natural green system has been destroyed and compaction has taken place to a level that prevents air movement even after construction is completed. The existing natural environment has in many cases been destroyed beyond repair.

2.7. Strategies for promoting green buildings

According to Planning and Growth Management (2012), there are three approaches to promote green buildings: the prescriptive or regulatory approach, the incentive-based approach, and the promotional/educational approach.

The prescriptive or regulatory approach: involves setting rules requiring development be built to meet a specified level of environmental performance or certification under a third-party rating system. Meeting the specified standard becomes a condition of receiving a building permit, zoning amendment and/or development approval.

The incentive-based approach: involves providing bonuses, subsidies, or other incentives that make green building more attractive or feasible to a prospective developer, while stopping short of actually making it a requirement.

Educational/promotional approaches: these includes

- web pages dedicated to promoting environmental and energy efficiency initiatives
- online information, guides and checklists to homebuilders and businesses to help explain the advantages of standards such as Energy Star, LEED

- online calendars of local sustainability events and a directory of local businesses that provide goods and services such as recycled building materials, contractors who build green, and energy auditors, among others
- research to identify obstacles to green building

2.8. The main actors' influencing the development of green buildings

According to GIZ, (2010), the main actors and their respective roles in the development of green buildings are discussed below:

I. Building materials and construction industry

The construction industry is vast, diverse and complex. There are no comprehensive data on the types and size of companies engaging in green building. Improved information would help to reduce transaction costs, improving efficiency and competition, which would help the industry in general and also provide the foundations for improving sustainability. Recognizing the diversity of actors within construction and materials production, and the differing incentives and needs of SMEs and of large firms, is key to promoting a commercial market for green buildings.

II. Government (national and municipal)

Governments are a dominant force in the move towards green building where their main function is to help overcome market barriers caused by the discrepancy between the private costs faced in producing green buildings and the social costs of climate change and social gains of energy efficiency. Governments not only provide the policy and regulatory framework for the construction and building materials sectors but are also a major buyer of their services. Governments play an indirect role in promoting demand and developer activity by raising awareness and demonstrating the validity of the concept. By commissioning green buildings, governments can provide the local market with tangible experience of sustainable building practices.

III. Financial institutions

Financial institutions relevant to green construction range from responsible property investors or impact investors who have strong environmental imperatives (even requirements of environmental returns on investments), to commercial actors seeking market-rate returns on individual mortgages or large loans to property developers. Engaging financial institutions requires both data and also cost incentives to invest in green construction, but investment

decisions tend to be firmly rooted in short-term economic gains rather than in long-term savings in energy costs

IV. Non-governmental organizations, membership and consumer groups

Currently, there are some 60 GBCs around the world in various stages of development. The World Green Building Council (WGBC) is the umbrella organization with regional networks for Asia–Pacific, Europe, the Americas and Africa (Malanca, 2010). One of the main activities of most GBCs is the establishment of rating tools for green buildings. The US Green Building Council has attempted to transform the market by identifying critical research needs and fostering research activity. While continual improvement of the LEED rating systems depends on pending research, the context and benefits of funding, conducting and applying such research are much broader.

NGOs, civil society organizations (CSOs), consumer groups and the media can help to raise awareness of the benefits of green building. They can also monitor the performance of government and industry in creating and implementing relevant policy, private-sector adherence to regulations, and the impact on particular sectors of the population. Help can be provided through engagement with the public and private sector, facilitating leadership and bridging efforts to support public and private-sector activities

V. Research and educational institutions

Research organizations can help to address data gaps and contribute to monitoring and evaluation (M&E) work. Educational institutions can develop the skills required to build green practices into commercial activities, for example through vocational secondary and tertiary education and training for those working in the built environment.

VI. International organizations

There is a wide range of cross-country and global green building initiatives, alongside multiple programs and institutions addressing climate change and sustainable and inclusive development, all of which affect green building. The United Nations and national government partnerships have deployed regional-level approaches. UN Habitat established a five-country partnership in East Africa, sponsored by the Global Environment Facility (GEF), to focus on buildings' energy and resource efficiency through codes, policy, practice, housing finance, and across the building sector through reviewing the status quo (compiling data), then raising awareness and helping to leverage finance, as well as providing demonstration projects. The scheme is soon to be introduced in West Africa.

VII. Professionals

Architects, engineers, planners and contractors have to work together with local councils to determine and identify the limitations of the environment and developing designs that incorporate environmentally friendly practices such as solar heating, recycling of local materials, and minimizing the use of materials so as to have the least possible effect on the environment.

2.9. Vertical greeneries

Vertical greenery can be divided into two major categories: Green Facades and Green Living walls.

2.9.1. Green facades

Green facades are a type of vertical greenery system in which climbing plants or cascading ground covers are trained to cover specially designed to support structures. The plants are either grown in the ground or in elevated containers where they are water and fertilized. (Dunnett and Kingsbury, 2008)

Two green facades systems that are frequently used are

a. Modular trellis Panel System

This system makes advantageous use of a unique three-dimensional design that provides not only the horizontal and vertical supports necessary for plant propagation but also an element of structural depth that promotes greater plant density and support by effectively capturing plant material within its dimension.

The three-dimensional panel made from a powder coated galvanized and welded steel wire that supports plants with both a face grid and a panel depth. Each modular unit, sized at a standard width of 4 ft.(1.2m) and a length which can range from 6-14ft (1.8 - 4.2m) is comprised of a rectangular trellis panel offset from secondary vertical layer by a series of supplementary diagonal climbing supports which thread themselves upwards through horizontal members.

Panels can be stacked and joined to cover large areas, or formed to create shapes and curves, are made from recycled content steel and are recyclable. Because the panels are rigid, they can span between structures and can also be used for freestanding green walls. The wire truss configuration may be used as a freestanding fence spanning vertical structural member's

such as posts or columns thus operating as a vegetated screen or shade element once plants have been allowed to fully infiltrate its structure. (Elgizawy, 2016)

b. Cable and wire rope system

It uses either cable and/or wire-ropes net. Cables are usually designed for faster growing climbing plants whereas wire ropes nets are used for supporting slower growing plants that need support at closer interval. Those systems use high tensile steel cable, anchors and supplementary equipment. And many different sizes and patterns can be used as flexible vertical and horizontal wire-ropes to give variable shapes which enable the designer to create various patterns through cross clamps. (Elgizawy, 2016)

2.9.2. Green living walls

Constructed from vegetated panels, vertical modules or planted blankets that are fixed to structural framework or to a wall. Green living walls are made from steel framework, plastic, expanded polystyrene and synthetic fabric to support a variety of diversity and density of plant species. Living walls also called bio walls tend to require more maintenance such as fertilizer and water than green facades systems that are planted into the ground. Living walls are made with three parts: metal frame, a PVC layer and an air layer (don't need soil). (Elgizawy, 2016)

a. Modular green living wall system

According to (Elgizawy, 2016), this consists of panels that hold growing media to support the plant material. It has usually grown before, providing an instant effect after installation. Modular green living walls also require irrigation at different levels along the wall using gravity to move the water through the growing media: similarly, nutrients and fertilizing is carried out through this method. Modular systems are often grown before, providing an instant green effect upon completion of the installation.

Modular green living wall system can take several forms (for example, trays, vessels, planter tiles or flexible bags) requiring a different structure. It is usually composed of several interlocked parts, made of lightweight materials as plastic (for example, polypropylene) or metal sheet (for example, aluminum, galvanized steel or stainless steel). Modular living wall systems usually include a frame to hold the elements and a support for plants.

b. Vegetated mat walls system

As stated by (Elgizawy, 2016), this system is composed of two layers of synthetic fabric with pockets filled with the plant and growing media. The fabric walls are supported on a framework

and backed by a waterproof membrane against the building wall. Nutrients and water delivered through an irrigation system at the top of the wall. It is a hydroponic system fed by nutrients rich water, which is re-circulated from a manifold, located at the top of the wall, and collected in a gutter at the bottom of the fabric wall system.

2.10. Vertical greenery and Leadership in energy and environmental design (LEED) rating system

As stated by Sharp et al (2008), green walls can contribute to securing up to 18 credits under the LEED for new buildings, the summary is as follows:

I. Sustainable sites credits

SS Credit 7.1 Landscape Designs That Reduces Urban Heat Islands, Non-Roof (1 Point)

Reduce heat islands to minimize impact on microclimate and human and wildlife habitat. Exterior green walls reduce the solar reflectance of a structure and thereby impact the urban heat island effect, helping to moderate the city's temperature. The LEED rating system recommends "considering replacing constructed surfaces (i.e. roofs, walls, sidewalks, etc.) with vegetated surfaces such as green walls and open grid paving or specify high-albedo (light reflective) materials to reduce the heat absorption."

II. Water efficiency (WE) credits

WE Credit 1.1: Water Efficient Landscaping: Reduce by 50% (1 point)

Limit or eliminate the use of potable water, or other natural surface or subsurface water resources available on or near the project site, for landscape irrigation. A building can incorporate a collection system to store stormwater from the buildings site and roof surfaces to be used for irrigation of the green walls and other landscape features.

WE Credit 1.2: Water Efficient Landscaping: No Potable Water Use or No Irrigation (1 Point in addition to WE Credit 1.1)

Eliminate the use of potable water, or other natural surface or subsurface water resources available on or near the project site, for landscape irrigation. Using only captured, recycled water or non-potable water for irrigation will allow projects to achieve this additional credit. One could also design a green wall that does not require irrigation.

WE Credit 2: Innovative Wastewater Technologies (1 Point)

Reduce generation of wastewater and potable water demand, while increasing the local aquifer recharge. Green walls can be utilized as wastewater treatment media through a number of innovative techniques. The incorporation of compost tea from a composting toilet is another innovative use of a green wall to aid in reducing wastewater generation. This is not recommended for indoor air quality living walls.

III. Energy and atmosphere credits

The intent of this initiative is to realize opportunities to improve the performance of the building's envelope and increase the efficiency of the building systems. Should the commissioning authority deem a green wall to be a contributing factor to a building's reduced energy consumption it can contribute the following points.

EA Credit 1: Optimize Energy Performance (1-10 points)

Achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use. Green walls provide additional insulation and natural cooling mechanisms to a building, thereby reducing its reliance on mechanical systems in both the summer and winter months. A green wall can be an integral part of a building's cooling strategy.

IV. Innovation in design credits

Since they are not explicitly acknowledged throughout the documents the most likely way that a green wall can contribute to LEED Certification is through innovation in design.

ID Credit: Innovation in Design (1-4 Points)

To provide design teams and projects the opportunity to be awarded points for exceptional performance above the requirements set by the LEED-NC Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED-NC Green Building Rating System. Innovation in Design credits allow a green wall designer to think beyond the scope of the LEED rating system and create sustainable solutions to building challenges and earn additional credits under the system.

Chapter III

3. Research methodology

This section discusses the research design and methodology that is used in acquiring the necessary information to answer the research questions. It explains how the data consisting of secondary and primary data was retrieved, followed by description of the method for the interviews and how the analysis and presentation of the data was conducted.

3.1. Selection Criteria of study buildings

The study buildings were selected under these criteria:

- **Function:** commercial, residential, mixed use and offices
- **Age:** during Emperor Haileselassie era, Derg regime and currently built buildings
- **Construction Material:** aluminum cladding, HCB and other materials
- **Ownership:** Private, government, institutional and others
- **Availability of resources:** access to floor plans, utilities map and others

The reason for selecting buildings of different era is to understand the changes in the building design throughout those years as well as to understand the extent of retrofitting this building to achieve green building requirements.

3.2. Study Design

The research uses both descriptive and explanatory research methods. It is designed of site survey, interview, questionnaires, document review & case study to obtain the necessary information.

A mixed approach that utilizes both qualitative and quantitative data is used. The qualitative data include attitudes, opinions and experience of residents within the selected buildings concerning green building principles such as recycling, water efficiency, day lighting and energy efficiency. For quantitative method, parameters that define green buildings, determining the degree of greenness of the sampled buildings in Addis Ababa were statistically analyzed.

3.3. Case Study Method

This research utilizes the case study approach because it is useful to carry out an intensive study of a small number of buildings (the selected cases), for the purpose of understanding a larger class of similar units (the buildings in Addis Ababa).

i. Study cases

Professional Building practice in Addis Ababa: based on the selection criteria appropriate buildings in Addis Ababa are selected to review the building practice, its constraints and opportunities as well as recommend appropriate measures.

Case of application of green building principle: the research designs and develops green walls to increase the feasibility of green building principles by identifying the cost and best innovation in vertical greenery in the local context

3.4. Sample and Sampling procedure

Buildings for the field work were identified by means of purposive sampling. It is one type of non-probability sampling method in which the researcher relies on his or her own judgment when choosing the samples. A total of 10 relevant buildings in the Addis Ababa were selected to participate in the sample. Five respondents per floor (if it not owned by the same company) were selected in order to get the opinions of those on the North, East, West, South and middle portion of the building.

Respondents in the consulting offices were identified by means of simple random sampling and a total of 21 consulting offices representing 25% of the total identified 85 consultants were selected. Within each consulting office, three questionnaires were distributed for the architects, engineers and those in managerial position or design heads (who are also mostly architects) in order to get the opinions of all those who partake in any architectural projects. Therefore, a total of 52 filled questionnaires were collected.

Location of Selected Buildings

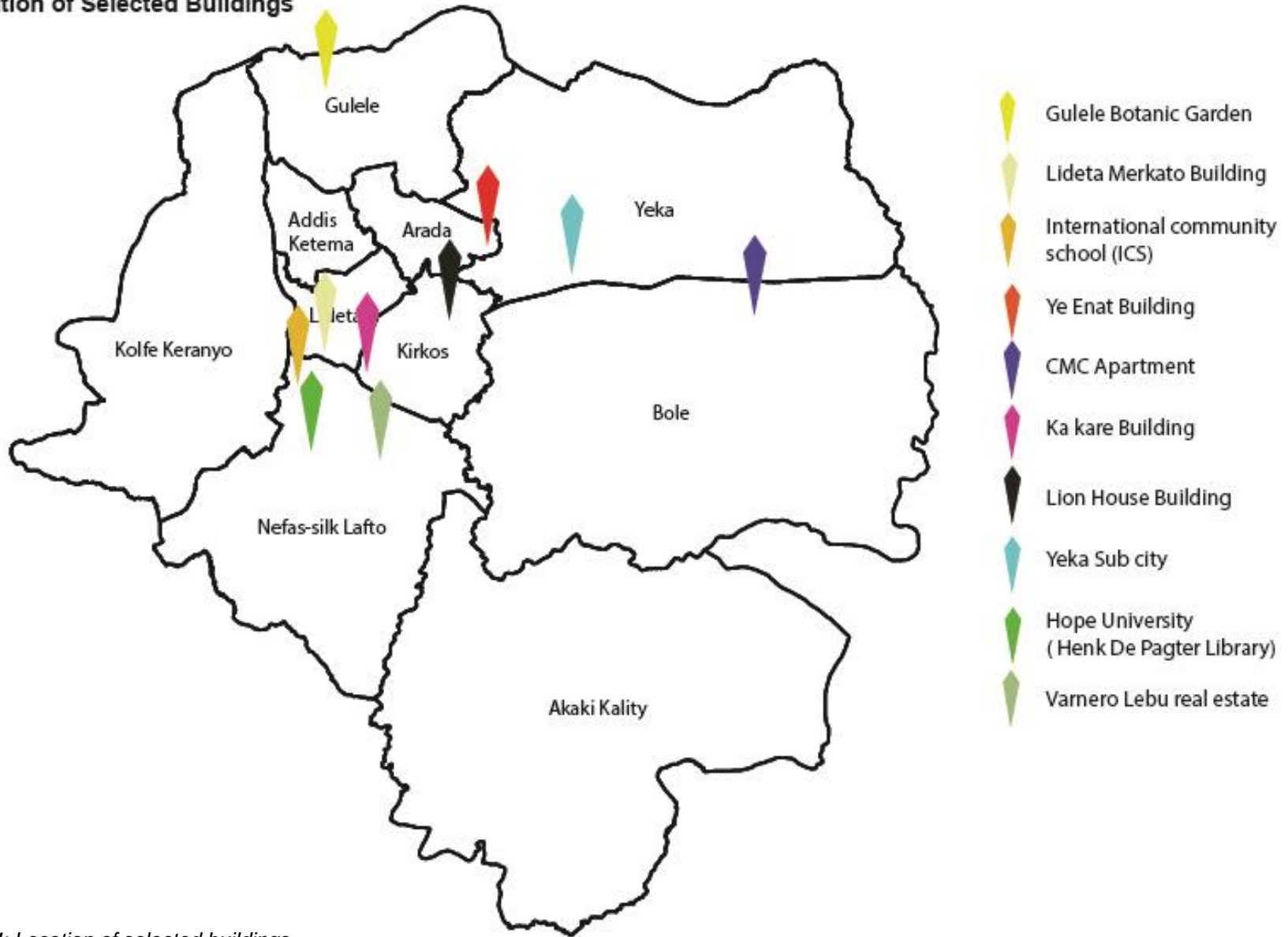


Figure 4: Location of selected buildings

(Source: Computed by the researcher, 2017)

3.5. Data type and source

The research used both primary and secondary data collection methods as a tool to gather the necessary information.

3.4.1. Primary Data

Primary data was obtained from residents and managers of selected buildings concerning their opinions, difficulties and needs with regard to water efficiency, energy consumption, recycling and indoor environmental quality.

Furthermore, primary data was emanated from questionnaires directed to consultants about their understanding of green building concept, its challenges and proper approach for its application.

3.4.2. Secondary Data

As a secondary data, national and international literature on the concept of green building was collected through internet sources, books and journals. Architectural plans, utilities, infrastructure maps were collected from different sources including building owners, consulting offices and contactors responsible for that particular building to better understand the existing situation of the selected buildings. For buildings in the Halieselassie and Derg Regime sketches were used in order to acquire the architectural plans.

3.6. Data collection method

All the data necessary to conduct the study was gathered through site survey, interviews, questionnaires and relevant document review.

3.6.1. Questionnaires

A combination of both open-ended and close ended questions was employed to enhance efficiency and reliability of the data. This method was used in order to confirm information that has been gathered from the theoretical documents and compare it with interviewee's response that revealed their personal experiences.

Instrument: questionnaire format

Two questionnaires were designed, one for selected building residents and the other for industry practitioners. Several types of questions were presented on the questionnaire including multiple choices with single response, multiple choices with multiple response, Likert scale, and short answer questions.

3.6.2. Interviews

The interviews with the selected building managers, owners or site engineers helped to generate data about their perceptions, opinions and understanding of the selected buildings water efficiency, energy efficiency, indoor quality, waste management and materials used. Semi-structured interviews were used.

Instrument: semi - structured interview schedule

These interviews were open ended and directed mainly to building owners and managers.

3.6.3. Site Survey

This method was applied to observe the existing situation of the area under study and was made by visiting the selected buildings to independently assess the current condition based on green building principles.

Instrument: site survey checklist

A checklist that defines green building concepts such as energy consumption, material, water efficiency, waste management and indoor ventilation and natural lighting was prepared to compare the existing building with that of green building principles. Digital camera aided with field notes was used to capture relevant data which revealed factual conditions concerning the area.

3.7. Data analysis method

Data analysis included systematically reaching and arranging the interview transcripts, filled questionnaire, field notes and other material accumulated to increase understanding of the respondent's subjective experiences.

The qualitative data was organized and presented in the form of narratives. Different soft wares such as SPSS and excel were used to analyze the data in a descriptive and statistical method including mean, frequencies and percentages. Finally, data was processed and presented.

3.8. Data Presentation

The data analyzed is described and presented in the form of tables, graphs and charts format. Selected buildings are illustrated using plans and the existing situation is presented by pictures, maps and descriptive words.

3.9. Research design

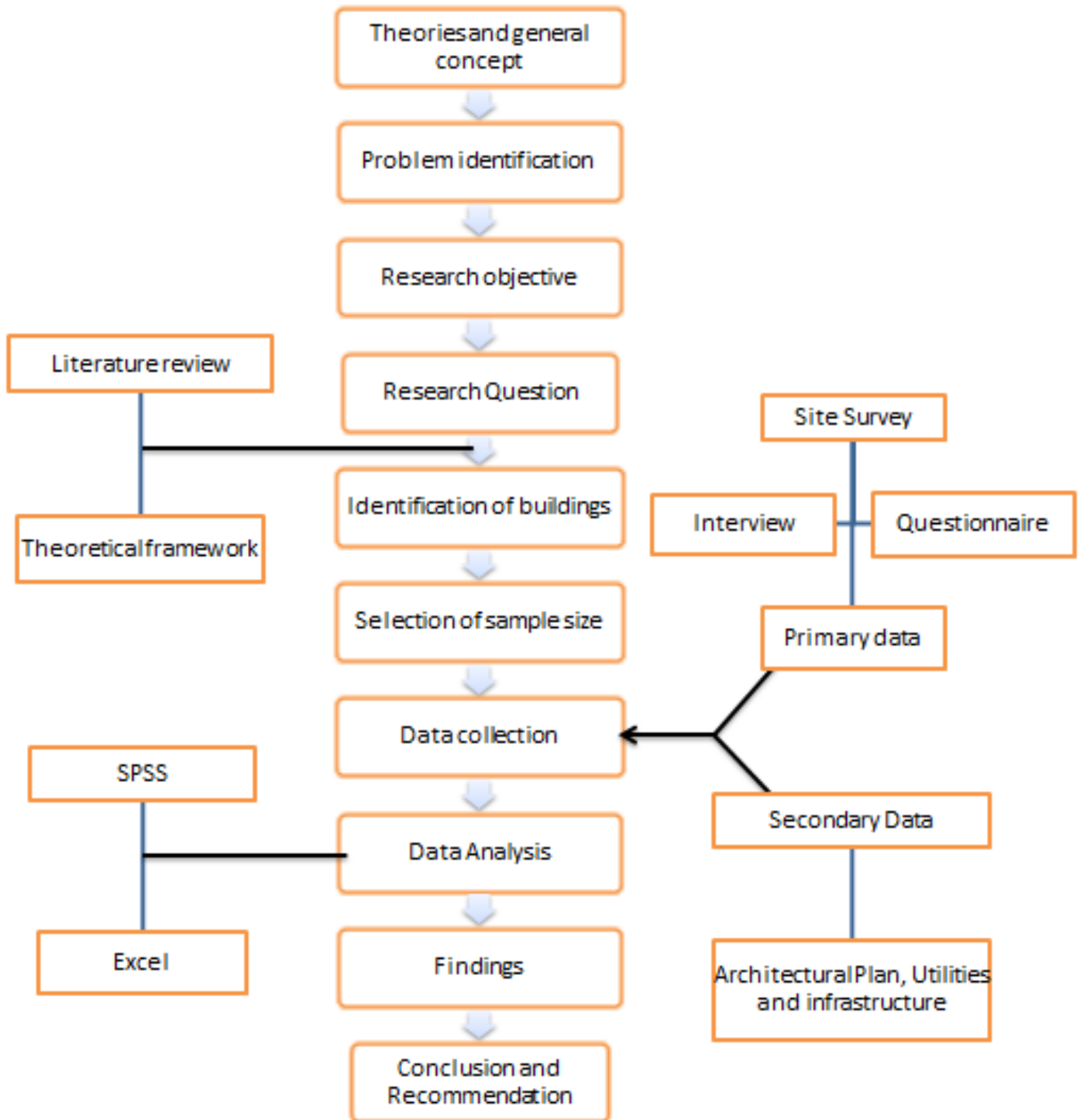


Figure 5: Research Design

Source: Computed by the researcher, 2017

3.10. Methodology Summary

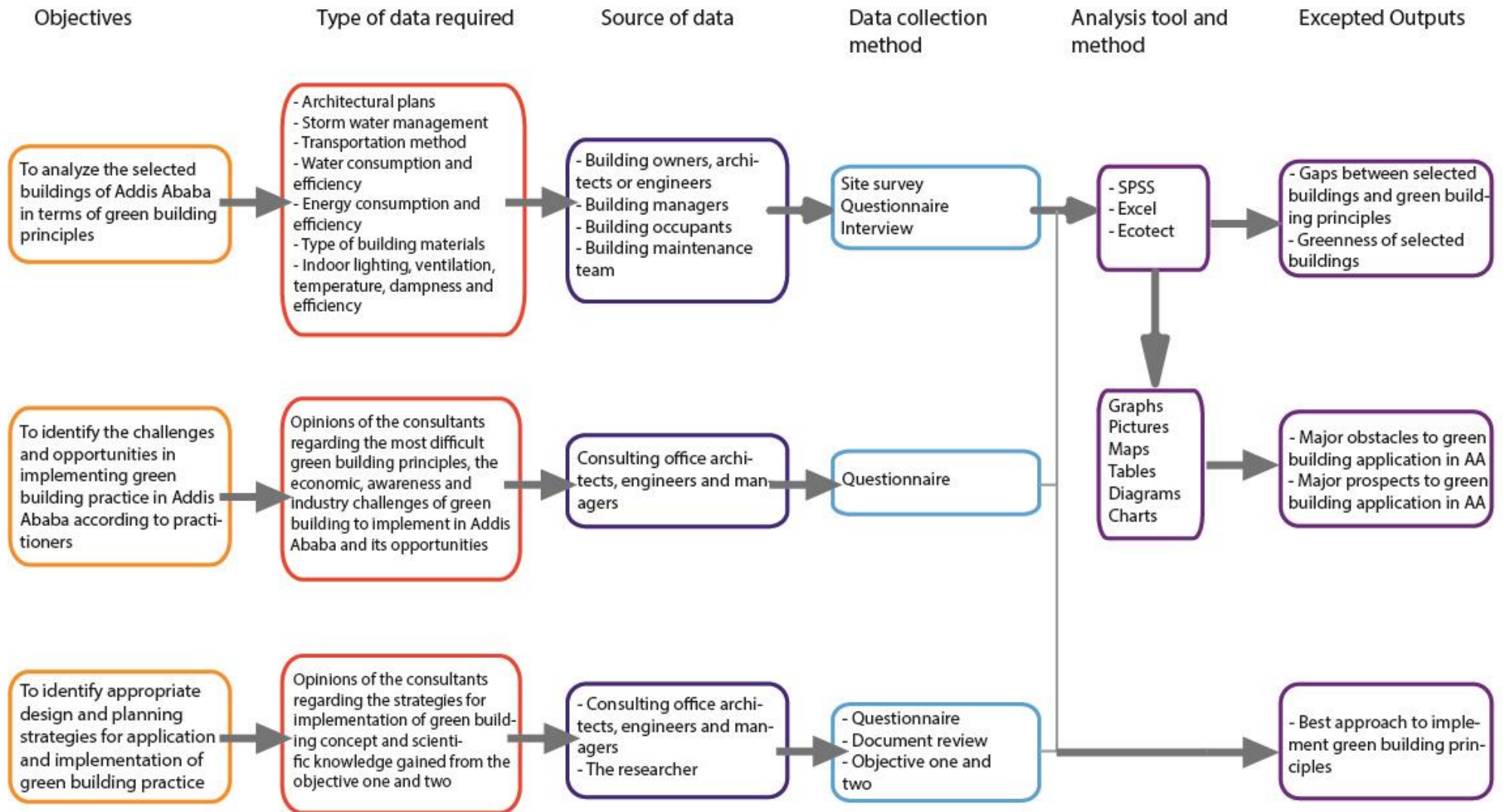


Figure 6: Methodology Summary

(Source: Computed by the researcher, 2017)

Chapter IV

4. Existing situation and Analysis of the Selected Buildings

In this chapter, the study area is briefly described and the ten selected buildings are described and analyzed based on the principles of green building.

4.1. Overview of Buildings in Addis Ababa

Addis Ababa, the capital city of Ethiopia, was founded in 1886 by Menelik II. Addis Ababa is located almost in the center of Ethiopia (8°55'–9°05'N and 38°40'–38°50'E) and its altitude is between 2200 m in the south-east to 3000 m above mean sea level in the north. The annual maximum and minimum temperatures average is 26°C and 6°C respectively. (Spaliviero and Cheru , 2017)

As stated in the (World Bank, 2015) , Addis Ababa is urbanizing at an exponential rate, and is expected to transform into a megacity of almost 10 million people by 2037. The city had a built-up land area of 647 km² and a land expansion rate of 3.2% per year in 2015.

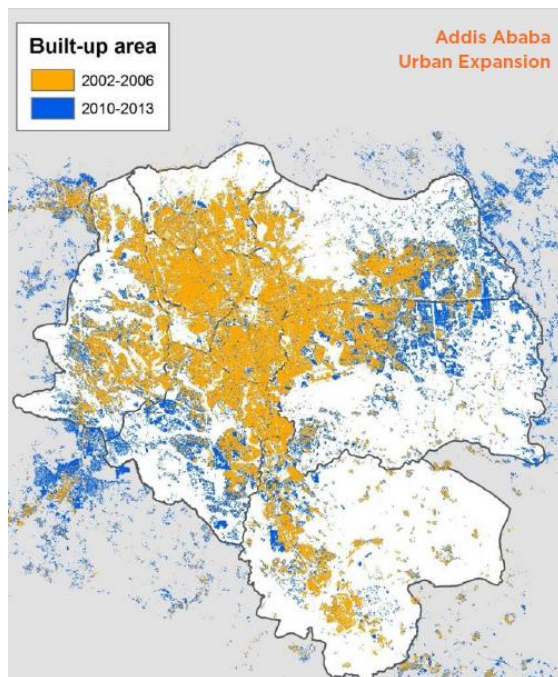


Figure 7: Addis Ababa Urban Expansion

Source: (World Bank, 2015)

The city is in the middle of a construction boom with lots of construction from Addis Ababa skyscrapers to condors and roads. The city is growing rapidly in modernity compared to other African cities. The city is undergoing a major construction boom, where the skyline suddenly has more halfway-done high-rise buildings than ever before, and new hotels are being built at a breakneck speed. Hotels, shopping centers and office complexes rise from where small shacks once stood. (www.africa-business.com)

Similar with other cities in the developed world the thriving building sector comes with it certain consequences. According to (Spaliviero and Cheru , 2017), Addis Ababa is sprawling in height and width, modifying the landscape and the land cover in and around the city. With an increasing built up area, the city is experiencing a decrease in the critical functions of its ecosystem services. This compromises the health and wellbeing of the city residents and their future livelihoods.

In order, to protect the country from the adverse effects of climate change, the nation has forwarded a Green Economy Strategy that will help Ethiopia reach its development goals while maintaining a low-carbon society. One of the pillars of the strategy is leap-frogging to modern and energy efficient technologies in the transportation, industrial, and building sectors.

Even though, the green economy strategy of the country promotes modern technologies in the building sector, the 2013 Ethiopian Building Code Standard doesn't mention green buildings. It rather sets standards in certain areas including:

1. Building orientation and ventilation

- Windows and openings to all building spaces intended for human occupancy facing intense sun radiation (facing west and south-west) shall be provided with effective radiation protection in order to prevent their covering and shifting to artificial means of lighting of the building space by users.
- All rooms used for human occupancy shall be provided with natural ventilation according to accepted standards unless conditions acceptable to the building official warrant the use of mechanical ventilation.

2. Accessibility

- When a building, or portion of a building, is required to be accessible, accessible routes within the site shall be provided from public transportation stops, accessible parking and accessible passenger loading zones

3. Planting and Landscaping

- All buildings shall have on-building and off-building planting amounting in aggregate area to at least 15% of their lot area.

4. Energy and lighting

- Every space intended for human occupancy shall be provided with natural light by means of exterior glazed openings.
- All occupancies other than dwelling occupancy shall be provided with means to generate at least 5% of their energy consumption themselves.

5. Water Supply and Sanitation

- All buildings intended for human occupancy in other than dry regions shall be provided with roof water harvesting mechanisms.
- All buildings with a Building Area Ratio (BAR) of 80 percent and less shall be provided with mechanisms that can retain their surface water on lot.
(Ministry of Urban Development and Construction, 2013)

4.2. Existing situation and analysis of the Selected Buildings

The study is confined within Addis Ababa only focusing on the selected 10 buildings. The buildings are of different time and function and are described below.

4.2.1. Gullele Botanic Garden

4.2.1.1. Building description

This building is located in the Northwestern part of Addis Ababa inside Gullele Botanic garden. It is the only Gold LEED certified buildings in Addis Ababa with total points of 63 out of 110 and currently, it functions as an office to HoA-REC&N (Horn of Africa Regional Environmental center and network). The building was built using the cradle to cradle philosophy and a design concept of *Eucalyptus globulus* (Bahr-zaf) leaves spreading to different directions. It has two conference halls, staff meeting rooms, offices, a cafeteria and a library. The building gives its longest frontal façade to the North-south direction; the morning sun warms the front side of the building while the afternoon sun gets its rear side.

4.2.1.2. Sustainable Site

In this section, the building was awarded 14 out of 27 points

I. Site location and transportation

The building is located in the northern edge of the city which has large green coverage and natural resources. Different sources claim that even though the area was once covered with forest, precautions were taken to minimize the ecological footprint of the building and protect the habitat as much as possible. It is located in a low density area relatively far from basic services and other functions with limited pedestrian access.

In addition, transportation is a problem for those using taxis as the site is located far from mass transit and there is little public transportation. But carpooling is encouraged through company service which most employees use. Although the building received points for alternative low-emitting transportation methods such as bicycles and fuel-efficient vehicles, none were seen during site visit and employees claim to never have used such transportation.

II. Site design and management

- a. ***Open space and Green areas:*** being located inside the botanical garden, the building has the advantage of having a large green coverage. Grass lawns are found in the front entrance of the building while dense trees are seen surrounding it. The majority of the

plant species are indigenous species such as junipers *procera* (Tid), *Hagenia abyssinica* (Kosso) but some introduced species such as *Eucalyptus globulus* can also be found.



Figure 8: Plant species around the building

(Source: captured by the researcher, 2017)

- b. **Pavement:** two types of pavements can be found in the site. The first is a semi-pervious surface of stone mounted with cement used for the main entrance to the building and parking area. The second is gravel which is mostly found the back of the building. Both pavements relatively allow infiltration.
- c. **Stormwater management:** According to the occupants of the building, flooding has never been an issue in the site. The stormwater from the ground is channeled by a ditch system found along the main path of the site which is then released to the surrounding green area. The rain water from the roof of the building is captured by the green roof and what remains is released through the downpipe to the gravel infiltration trench that increases percolation of the rain water to the ground.



Figure 9: gravel infiltration trench (left), ditch channeling the stormwater to the surrounding green (middle), type of pavement (right)

(Source: captured by the researcher, 2017)

- d. **Green roof:** The roof is mostly green, reducing the urban heat island effect (minimizing impacts on microclimates, human and wildlife habitats), which has earned it a point in this category. Even though in the design the roof was to be covered with a 6 cm thick soil green roof, poor management, design or other reasons has lead it to become damaged.



Figure 10: Green Roof of the building

(Source: captured by the researcher, 2017)

4.2.1.3. Water Efficiency

The building has achieved water efficiency and was awarded 10 out of 10 points in this section.

I. Water use

- a. **Water efficient fixtures:** high efficiency fixtures such as laser hand wash that automatically shuts off when not in use and dual flushing is used to reduce water consumption.
- b. **Water efficient landscaping:** the main source of water for the building is tap water which is used for toilets, cleaning and watering green areas including the green roof during dry season. In other times, the landscaping installed does not require permanent irrigation systems thus reducing water use.

II. Wastewater Technologies

- a. **Wastewater treatment:** a biological wastewater treatment area is located at the back of the building with the proper buffering but most of the occupants claim that it is not functional.



Figure 11: water efficient fixtures (left) and wastewater treatment (right)

(Source: captured by the researcher, 2017)

4.2.1.4. Energy Efficiency and Atmosphere

The building received a total of 19 out of 35 points in this category. And according to the HoA-REC&N website, it achieved over 53% in energy savings.

I. Energy Consumption

The main source of energy is electricity and the items used the most include computers, microwave, stoves and lighting bulbs. There is no utilization of air conditioners and fans. Natural daylight and ventilation is mostly used in the building but occupants are seen using artificial lighting during the day in some rooms.

II. Energy efficient equipment

The majority of the rooms in the building use LED light bulbs which conserves energy. Another energy efficient lighting used is movement sensor bulbs that turn off when no one is around and there is no movement.

III. Renewable energy

Solar energy is used for water boilers in the toilet.

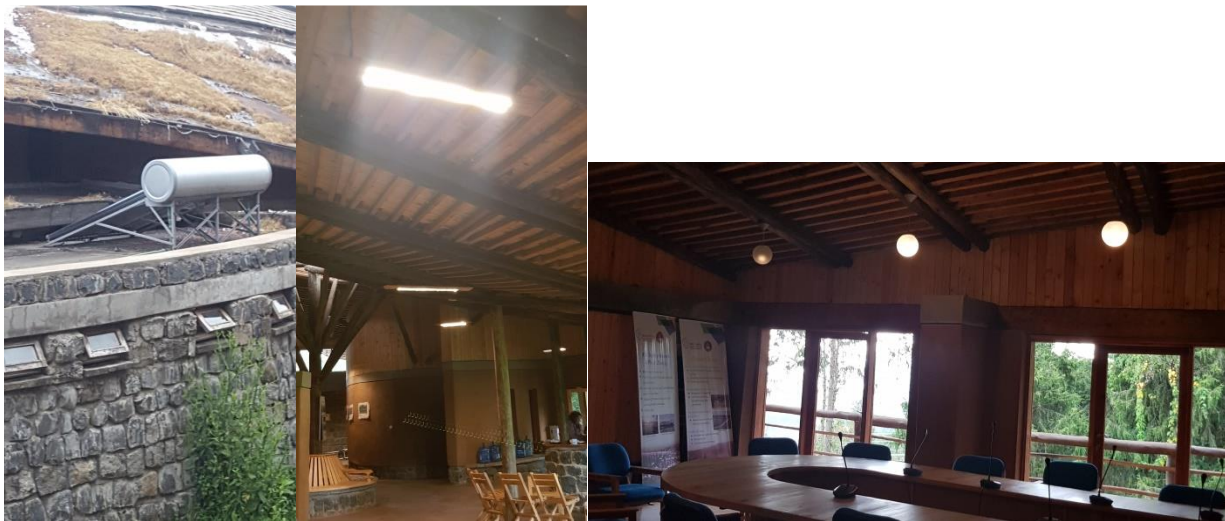


Figure 12: solar energy for boiler (left), LED lights (middle), Artificial lighting during the day (right)

(Source: captured by the researcher, 2017)

4.2.1.5. Material and Resources

In the material and resources section, the building received 5 out of 14 points. These points were earned in the construction waste management, regional materials and rapidly renewable materials categories.

I. Type of materials

Roof: certain portion of the roof was designed to be covered with vegetation even though currently the green roof is in poor condition. The part of the roof without vegetation is a copper lining with straw in the middle for insulation and a wooden plank board on the interior. Copper is said to be environmentally friendly and recyclable while the green roof provides extra insulation increasing the energy efficiency of the building and mitigating urban heat island.

Walls: adobe blocks and stones are used for the walls of the building. Adobe blocks are biodegradable, provide sufficient thermal mass and insulation as well as low sound transmission. Stone walls are colder and heat doesn't get effectively trapped in it.

Floor: for the circulation, toilets and conference halls, the floor finish used is mostly pigmented concrete while bamboo parquet is used for the library and offices. As a disadvantage the occupants said the floor finishing is slippery and cold.

II. Regional materials and rapidly renewable materials

The majority of the material used such as *Eucalyptus globulus* (Bahr-zaf), mud, straw and bamboo among others are local materials hence reducing the environmental impacts resulting from transportation. In addition, bamboo, straw and others are rapidly renewable materials thereby utilizing such materials reduces the use and depletion of finite raw and virgin materials.



Figure 13: Exterior materials (left), Interior materials (middle) and Waste disposal bin (right)

(Source: captured by the researcher, 2017)

III. Waste management

According to the occupants of the building, waste is collected from their offices every day. The waste is mainly papers and plastic bottles which is separated at the source and given to the recyclers.

4.2.1.6. Indoor environmental quality

The building was awarded 7 out of 15 in this category.

I. Lighting

Every room in the building except the mezzanine storage rooms above the conference hall have windows. The building has sufficient lighting, all four toilets have access to daylight and the circulations has large windows along its length which provides an endless supply of natural lighting. In addition, a small skylight is located in the lobby letting in daylight. Wooden shades are provided for the south west facing rooms to reduce the harsh sun of the afternoon. Nevertheless, artificial lighting is used during the day in some rooms of the building increasing energy consumption. Based on the questionnaire distributed to the offices in the building, 80% replied their office is bright while the remaining 20% said it is normal.

II. Ventilation

All the rooms in the building are naturally ventilated. Opening windows is the only method used to cool themselves and occupants claim that all windows are operable. Cafeteria and kitchen is provided but occupants use the lobby and reception area for heating their foods which causes the smell to spread. Smoking is not allowed within 25 feet (7.62 m) of the building and all of the questioned occupants replied that the air in the building is clean and fresh.

III. Dampness and microbial growth

Even though the building has a green roof no leakage was seen in it except in the toilets where dampness was observed. Occupants claim there is no microbial growth in the whole building.

IV. Thermal comfort

One of the complaint of the occupants about the indoor quality of the building is that, it is cold. During hot weather, 20% replied their room is very cold, another 20% replied it is cold while the remaining 60% replied it is normal. During cold weather, 80% of the respondents replied their room is very cold and the remaining 20% said it is cold. The location of the building, the outdoor environment as well as the orientation of the building where most of the frequently used rooms such as the offices face the west (meaning it doesn't get daylight in the morning when it is the

coldest), all contribute to the thermal comfort of the building. It also has a fireplace which is rarely used.

V. Acoustic and views

Acoustically, the building is surrounded by trees acting as a buffer to any noise pollution. Based on the information gathered, 50% replied their room is quite while the remaining half said it is normal. The building offers a view to the lavish green area outside in every direction of the building.

VI. Efficiency and health problems

According to the occupants, no serious health issues have been recorded due to the indoor quality of the building. But concerning efficiency and productivity, 60% replied their productivity decreases during the day while the remaining 40% replied it remains the same.



Figure 14: Naturally lighted and ventilated circulation (left), Wooden sun breakers (middle) and Dampness in the toilets (right)

(Source: captured by the researcher, 2017)

4.2.2. International Community School (ICS)

4.2.2.1. Building description

International community school (ICS) is located in Nifas-silk Lafto Sub-city, woreda 3 on the road from Karl Marx roundabout to Bistrate Gabriel church. The school was established in 1964 and currently the compound has an approximate area of 61,000m² serving around 1000 students. The building under review is the recently built M building which houses grade 5 to grade 8 students. According to the School's engineer that was interviewed, the building was designed with the concept of green building in mind and also applied for a LEED certification long ago but certain conditions did not pan out. It started operation in August, 2017 and has classrooms, offices, laboratories, an auditorium and basement stores. The building is orientated towards the north east direction.

4.2.2.2. Sustainable Site

I. Site location and transportation

The building is located in a mixed use neighborhood along an arterial road. It is located in close proximity to different services and functions with adequate pedestrian access. The building is constructed on the site that was previously used as the school's garbage dumping site with a small river running adjacent to it.

Private vehicle is predominantly used as a means of transportation and there is no employee service but the compound encourages bicycle. It has bicycle parking racks at the main entrance as well as shower facilities for staff and students. Transportation to and from the site is fairly accessible as there are taxis along the road and a taxi stop nearby.

II. Site design and management

- a. *Open space and Green areas:*** the whole compound has large open and green areas including playgrounds, playfields and recreational green areas. Around the reviewed building, there is a small playfield and grass lawn close to the entrance. The green areas have both indigenous and exotic species. The indigenous species include *Acacia abyssinica* (Girar), junipers *procera* (Tid), and *Dracaena steudneri* (Itsepatos) among others.

- b. Pavement:** concrete is the most used pavement for parking and paths around the building, it has higher infiltration rate and absorbs less heat than asphalt. Terrazzo tiles and porcelain tiles are also used.
- c. Stormwater management:** so far flooding has not been a problem in the site. A ditch system is used to divert the stormwater which will then flow to the river. In addition to ditches, perforated underground pipes that increase percolation are also used for channeling stormwater. Gutter and concealed downpipes are used to direct rain water from the roof to the river. While floor drains in the southern side of the building are used to guide the rain water from the balconies which is then used for irrigating the green area.



Figure 16: Green cover of the compound (left), Rain water from balcony irrigating green area (middle) and concrete pavement (right)

(Source: captured by the researcher, 2017)

- d. Green roof:** the building has an extensive vegetated green roof. The green roof is accessible to all and students come here to play in this grass cover. It is sloped a little to the east face of the building in which the infiltrated water is passed through a downpipe. The green roof is functional, maintained well and in good condition.
- e. Green Wall:** is found on the east face of the building. The method used of the green wall is a Modular Trellis Panel System type of green façade. Climbers are used for the green wall and planters are located both at the bottom and top of the vertical panel. The vertical panel has different patterns which increase the aesthetics of the building until the plants are fully developed.



Figure 17: Green wall and Green roof of the building (from left to right)

(Source: captured by the researcher, 2017)

4.2.2.3. Water Efficiency

I. Water use

- a. **Water efficient fixtures:** high efficiency fixtures such as sinks with auto-shutoff mechanism, waterless urinals and dual flushing is used to reduce water consumption.



Figure 18: waterless urinals, dual flushing, and auto-shutoff sinks (left to right)

(Source: captured by the researcher, 2017)

- a. **Alternative water source:** water source for irrigating the vast green areas including the green wall and green roof of the compound is groundwater. Groundwater is pumped from two holes to a 300m³ reservoir which is then used of irrigation, showers and toilets. There are no actions taken to reuse wastewater or rainwater in the compound.

4.2.2.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The main source of energy is electricity and the items used the most include computers, projectors, laboratory equipment and light bulbs. Air conditioner is used in the server room and the conference room of the building while fans are used in the toilets. Natural daylight and ventilation is mainly used in the building and occupants claim the building doesn't use artificial lighting during the day except in one or two offices. Security team does rounds every day after work and checks lighting. If there are rooms left lit, it is reported and warning is issued for the responsible person to prevent it from happening again.

II. Energy efficient equipment and renewable energy

Every room in the building uses LED light bulbs which conserves energy. In addition, solar energy is used for water boilers in the showers and toilets.

4.2.2.5. Material and Resources

I. Type of materials

Roof: the roof is covered partly with a green roof and for remaining part cement and porcelain tiles are used for roof finishing. For the interior gypsum board ceilings are used.

Walls: the south and north faces of the building are largely covered with fine quartz painted HCB walls while the east face has a both a green wall and stone cladding. The west has both stone cladding and HCB walls. For the interior, HCB walls are mostly used but Gypsum can also be found.

Floor: linoleum tiles and porcelain tiles are mainly used for the floor finish of the building.

II. Regional materials and rapidly renewable materials

Based on the interview, the materials used consists of both local and imported materials. The stone used for the east and west faces of the building come from Mekele and others such as the aluminum sun breakers are imported.

III. Waste management

From the interview, it was investigated that waste is mainly paper and plastic bottles which is collected from each class and trash cans along the corridors. The waste is segregated at the source and donated to recyclers. In addition to paper and plastic bottles, tables and chairs are also donated for reuse and recycling.

In the compound, there is a composting post in which the end product is used as a fertilizer for the green areas including the green roof and wall.

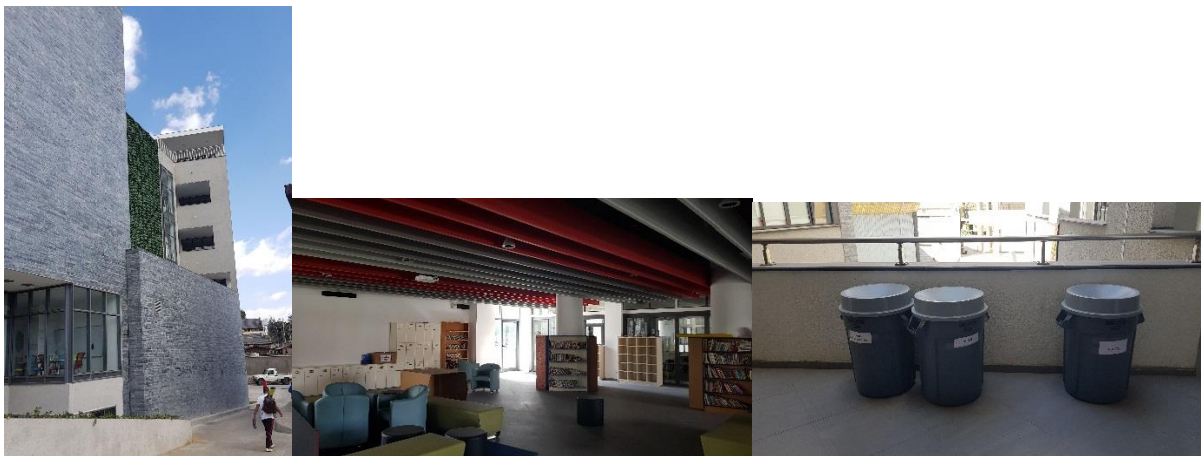


Figure 19: Exterior materials (left), Interior materials (middle) and Waste disposal bin (right)

(Source: captured by the researcher, 2017)

4.2.2.6. Indoor environmental quality

I. Lighting

Every room in this building except the handicapped toilets have windows and access to daylight. It uses operable louvre windows as well as folding doors designed to let light in whenever it is needed. The circulation is open throughout the entire building providing limitless supply of natural lighting and ventilation. In addition, in the southern direction, the circulation also acts as a buffer

protecting the adjacent classrooms from the harsh sun. Four small skylights allow natural daylight to enter the basement which is used as a workshop and store. Aluminum sun breakers operated electrically from the inside cover some parts of the south face and the staircases of the north face providing protection from the harsh sun and glares.

II. Ventilation

All the rooms in the building are naturally ventilated. But in addition to the natural ventilation, air conditioner and fans are use in the conference room and toilets respectively. The louvre windows may be out of reach for the students because it is placed 2 meters above the ground but other than that occupants have full control over ventilation. The school is fully smoking free zone and no smoking is allowed.

III. Outdoor air quality monitoring

The school has an air quality monitoring system installed in its compound. The interviewed engineer said that it is one of the two air quality monitoring equipment found in the country. It asses air pollution level in order to take pre-cautions and prevent harm to the students when it reaches a harmful level.



Figure 20: aluminum sun breakers (left), Skylight for the basement (middle) and naturally lighted and ventilated circulation (right)

(Source: captured by the researcher, 2017)

IV. Dampness and microbial growth

The engineer interviewed claims there is no dampness and microbial growth in the build but then again the building is recently built and these kind of problems are yet to surface.

V. Thermal comfort

The indoor air tends to have a chiller quality to it because the building has North East facing building orientation. Since the North orientation is accompanied by prevailing wind, most part of the building does not get to experience much warmth. In addition, the materials used such as stone cladding, green roof and wall also help to keep the temperature moderate. According to the engineer interviewed, the building has a moderate temperature and that it doesn't get too hot or too cold.

VI. Acoustic and views

The building has a setback of 35 meters from the main road but certain noise pollution coming from high vehicular movement and other activities can be noticed in the building. Inside the building, acoustic panel fins are used to prevent noise pollution between classrooms. The view in the northern face is restricted to prevent student distraction and the view of the building mainly opens to the school's compound.

VII. Efficiency and health problems

According to the engineer, no health issues have been recorded due to the indoor quality of the building. Concerning efficiency and productivity, no fluctuation of efficiency can be seen in the students but the interviewed engineer stressed on the fact that these depends more on the teaching style rather than the indoor quality of the building.



Figure 21: Acoustic panel fins (left), louvre windows and folding doors (middle) and outdoor recreational area in every floor (right)

(Source: captured by the researcher, 2017)



Figure 22: Ground floor and Typical floors from first to fourth (top to Bottom)

(Source: Site Engineer, 2017)

4.2.3. Lideta Mercato Building

4.2.3.1. Building description

The building is located in Lideta Sub-city, Woreda 09 around Lideta Condominium. It was designed by Vilalta Architecture based in Barcelona, Spain. It started construction in 2011 and was recently opened. The building is unique in the city because of the fractal pattern of the façade which is said to be derived from the patterns used in traditional African dresses. It is an eight stories shopping mall with a total surface area of 14,200 m².

4.2.3.2. Sustainable Site

I. Site location and transportation

The building is located in the inner city which was once a slum area. After the Lideta renewal project, the area has become a mixed use high density area with multi-story buildings. It is located near different services and functions with adequate pedestrian access. Regarding public transportation, there is a taxi stop as well as a train station within a walking distance from the building. There are no bicycle parking racks and according to the project manager interviewed, there are no future plans to in-cooperate it.

II. Site design and management

- a. **Open space and Green areas:** the building doesn't have any open spaces and green areas. No potted plants can also be seen in the building. The roof contains a gathering and recreational area.
- b. **Pavement:** the building is surrounded by a gravel paved street at the rear side and terrazzo tiled pedestrian walkway at the front.
- c. **Stormwater management:** the roof of the building was designed to facilitate rainwater collection. A drainage system would gather rainwater through pipes in the umbrellas and in other areas on the roof. The stormwater is then drained, stored, filtered and used for toilets and taps. But according to the project manager that was interviewed, they feared the community would not accept using recycled water or might drink it so the idea was not implemented. Rather now the rain water is released through downpipe to the nearest manhole.

- d. **Green Roof and wall:** there are no green roofs and walls in the building. Rather the roof is used as a recreational area.



Figure 23: Rainwater released to the surrounding (left), Street at the rear side of the building (middle) and Recreational area rooftop (right)

(Source: captured by the researcher, 2017)

4.2.3.3. Water Efficiency

Municipal tap water is the main source of water used for toilets, cleaning and other uses. According to the project manager, groundwater is available in the site so in the future they have plans to use it as an alternative water source. No action is taken to reuse and recycle wastewater or rainwater. Dual flushing is the only water efficient fixture used in the building.

4.2.3.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The building being a commercial building with more than 60 shops in every floor, escalators, elevator and lighting, it requires large amount of energy. Natural daylight and ventilation is mainly used in the building while air conditioners and fans are not utilized at all.

II. Energy efficient equipment and renewable energy

The building is mainly equipped with both LED lights and fluorescent light bulbs which consume less energy. But during the daytime, most lightbulbs in the circulation space as well as the shops are turned on.

In order to decrease the effect of carbon-heavy fuel generators and maintain the required energy enough for the main facilities, the building plans to use solar umbrellas on the rooftop. These provide for a well-shaded entertainment rooftop zone besides their original use as energy sources. Although nothing is installed now, the project manager said agreements are signed and it will be installed anytime soon.

4.2.3.5. Material and Resources

I. Type of materials

Roof: the roof is mostly covered with circular umbrellas for the solar panels. The material used is marble and epoxy.

Walls: the interior walls are partitioned entirely using magnesium board with aluminum and glass doors. Bricks are also used for the inside circulation of the building. The exterior is made up of Rhombus System with U-shaped steel profile framing and colored glass. The wall is constructed of perforated magnesium oxide blocks.

Floor: the floor finishing of the whole building is epoxy flooring.

II. Regional materials and rapidly renewable materials

Based on the interview, the materials used consists of mostly local materials. The exterior perforated pre-fabricated lightweight magnesium oxide blocks and the interior magnesium boards are manufactured in Addis Ababa.

III. Waste management

Waste is collected and disposed in the dumping site found at the back of the building. There are no actions taken to recycle and reuse wastes within the building.



Figure 24: exterior and interior materials of the building (left to right)

(Source: captured by the researcher, 2017)

4.2.3.6. Indoor environmental quality

I. Lighting

According to (Jayes, 2015), Vilalta (leading architect) realized Ethiopians preferred dim light opposed to bright light – he learnt this in particular while visiting vernacular Ethiopian architecture examples at Lalibela. This informed the fractal design, and allowed him to achieve a facade that protected the interior from too much light.

Natural lighting is provided through the perforated walls. The different openings in the wall create a nicely illuminated interior. An inclined atrium with a skylight allows natural daylight to enter the building. The main circulation and staircases are located along the walls and around the skylight which is provided with continuous natural lighting. The partitions and arrangement of the shops require additional artificial lighting during the day. The majority of the shops are seen using light bulbs during the day and even the terraces around the skylight use artificial lighting. No sun breakers or shades are needed as the wall itself protects the interior from harsh sun.

The questioned building occupants gave different response to the lighting in the building, the majority of 40% responded it is bright, while 25% replied it is dark. 10% of the respondents answered the building is very dark while another 10% said it is normal and the remaining 15% replied it is very bright.

II. Ventilation

Similar with lighting, natural ventilation is provided through the perforated walls. The perforated wall in opposite side allow for air to pass from one side to other and encourage passive cross ventilation throughout. In addition, air can freely move from the entrances to the inclined atrium naturally ventilating the whole building. The toilets don't have natural ventilation but are placed

close to the openings of the wall. Green buildings offer occupants control over the lighting and ventilation through operable windows and such earning two points in LEED certification. Since the openings can't be closed or opened whenever, this building limits occupants' ability to adjustments ventilation and lighting to meet their individual needs and preferences. So far smoking is not allowed in the building. In regards to the air quality, 30% of the respondents answered it is normal while 35% said it is normal and another 35% said the air is clean and fresh.

III. Dampness and microbial growth

The building is relatively new but water leakage has caused dampness in the building and if not controlled according it could lead to microbial growth.



Figure 25: the inclined atrium (artificial lighting during the day) and natural lighting through the perforated wall (left to right)

(Source: captured by the researcher, 2017)

IV. Thermal comfort

In accords to thermal comfort, the project manager said this type of building is usually recommended for areas with very hot weather but this building has limited access to sunlight. Therefore, it gets very cold. In addition to limited sunlight, the continuous movement of air from top to bottom, from entrance to entrance and from wall to wall with limited ways of controlling it creates a colder temperature as stated by the project manager. When asked if there have been any complaints about the indoor quality, the answer was no because the building is very new but I am sure in the future there will be complaint about the coldness of the building. During hot weather, 30% of the questioned occupants replied the indoor temperature gets very cold, while 40% said it is cold and the remaining 30% answered it is normal. When asked about the indoor temperature during cold weather, the majority of 50% replied it is very cold followed by 30% whose response was the building gets cold while the remaining 20% said it is normal.

V. Acoustic and views

According to the project manager, noise pollution is not an issue in the building because the materials used can restrict it to some level. The rooftop terrace which is used as a recreational area offers a view of the city's built landscape. However, inside the building even though the openings are of different size, the building envelop somewhat restricts the view to the outside environment.

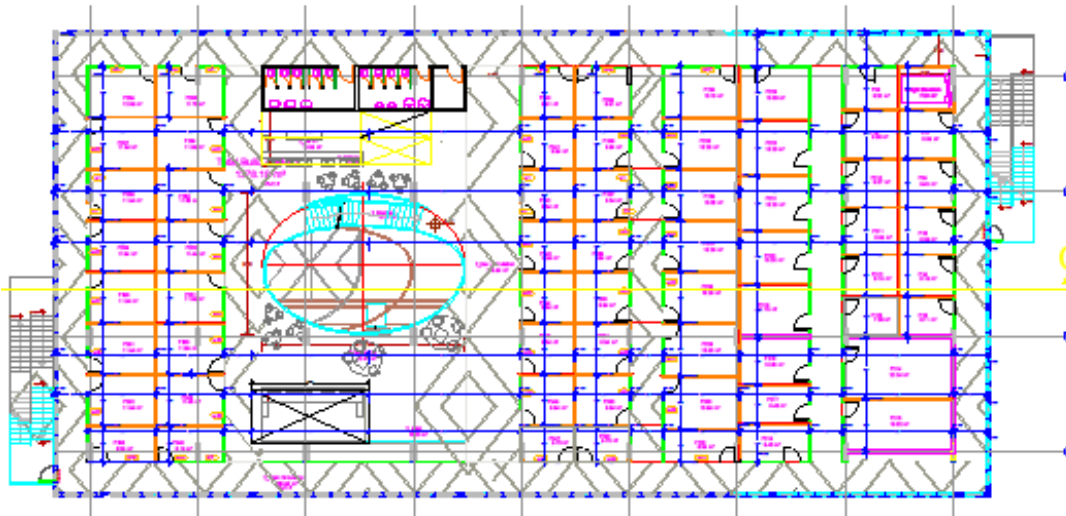
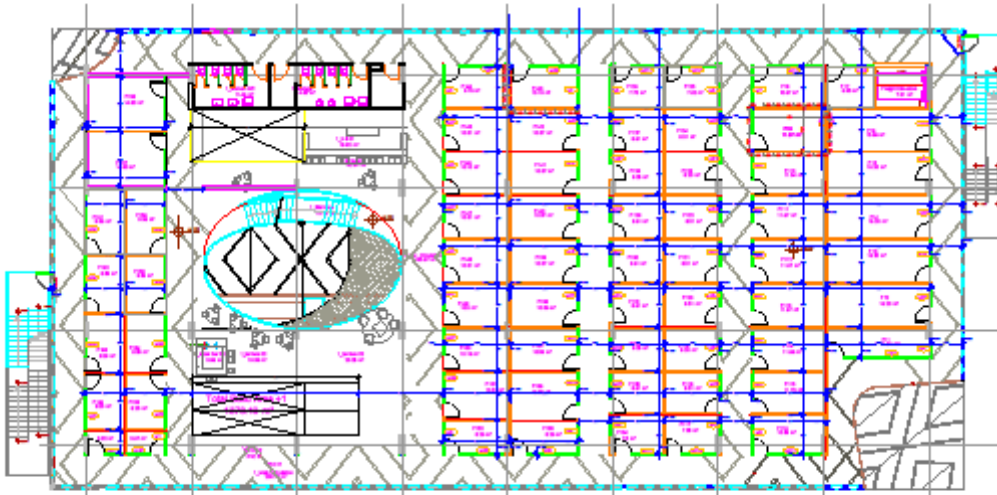
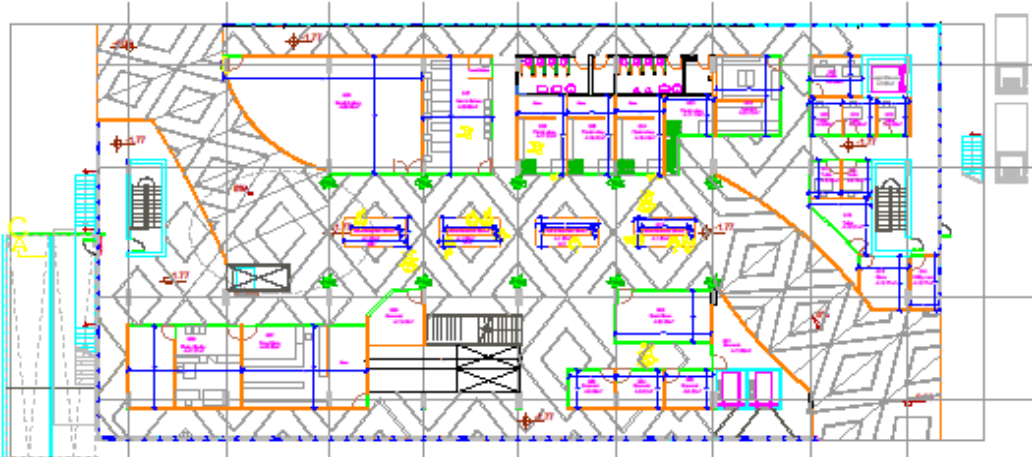
VI. Efficiency and health problems

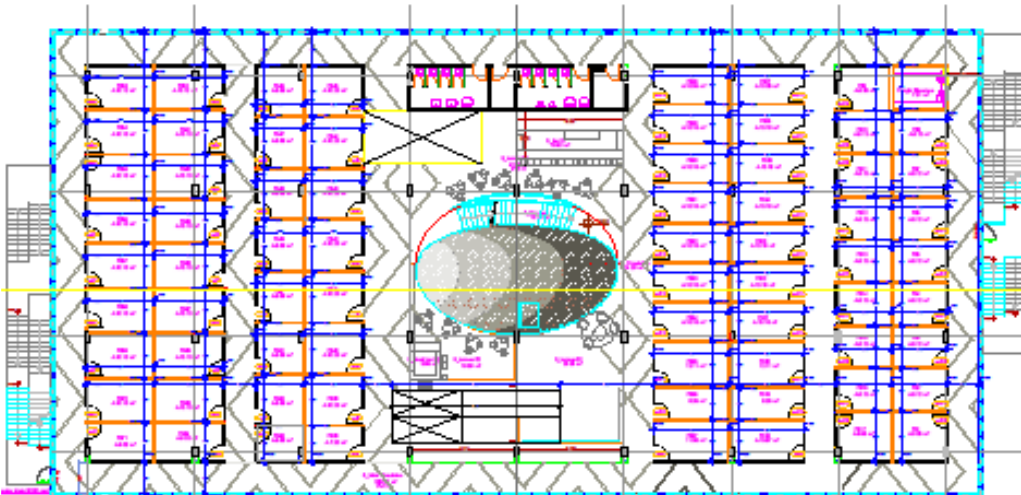
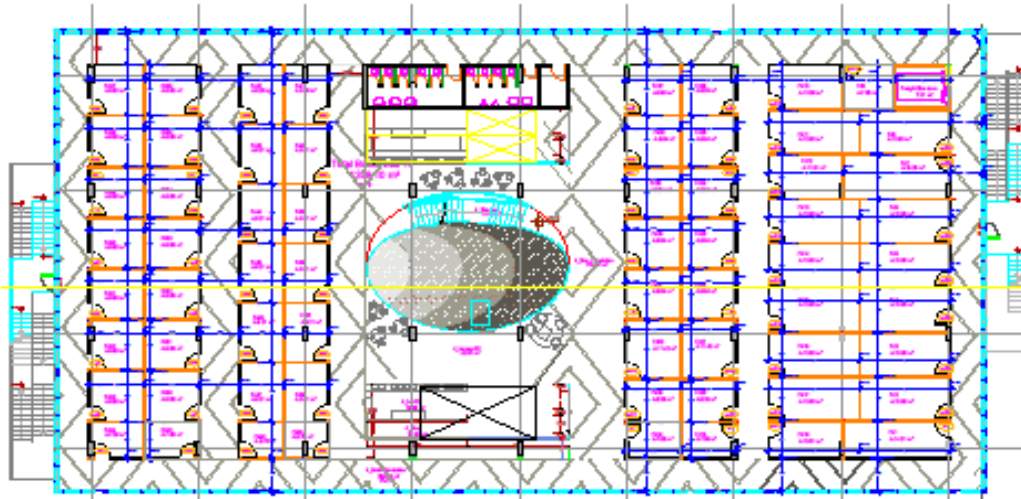
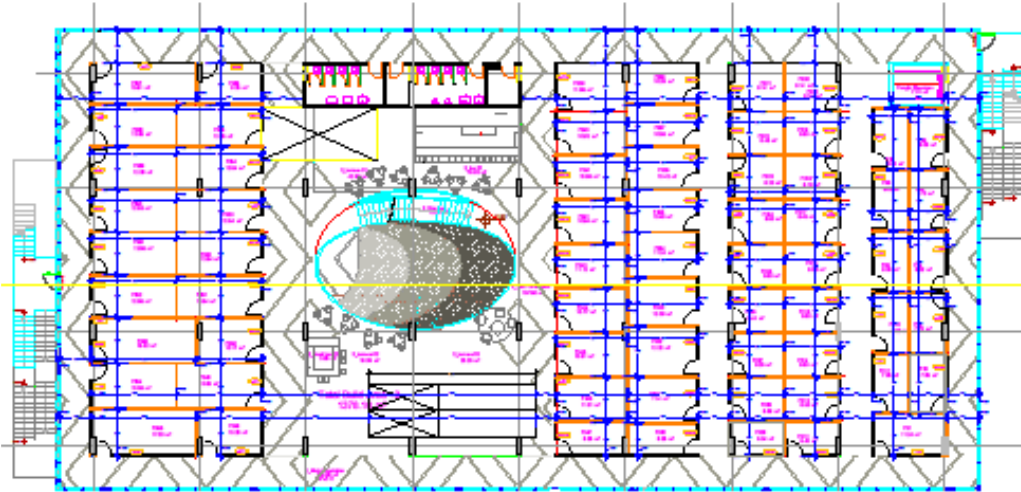
Concerning health problems due to the indoor quality, 75% said they haven't had any problems while 25% replied they have suffered from minor illness such as colds and flus due to the coldness in the building. As for productivity and efficiency, 55% answered there is no change in their productivity because of the indoor quality while 45% responded their efficiency decreases during the day.



Figure 26: Dampness problem (left), open down to the main entrance (middle) and shops inside the building (right)

(Source: captured by the researcher, 2017)





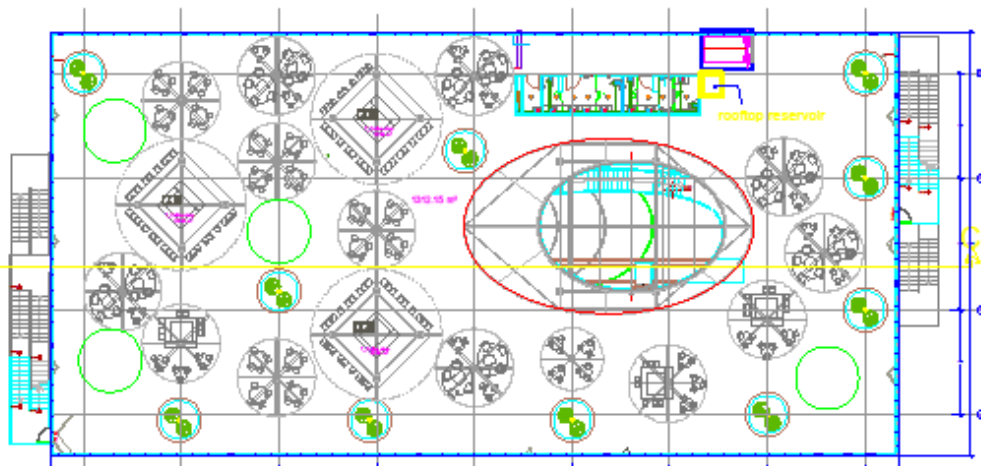
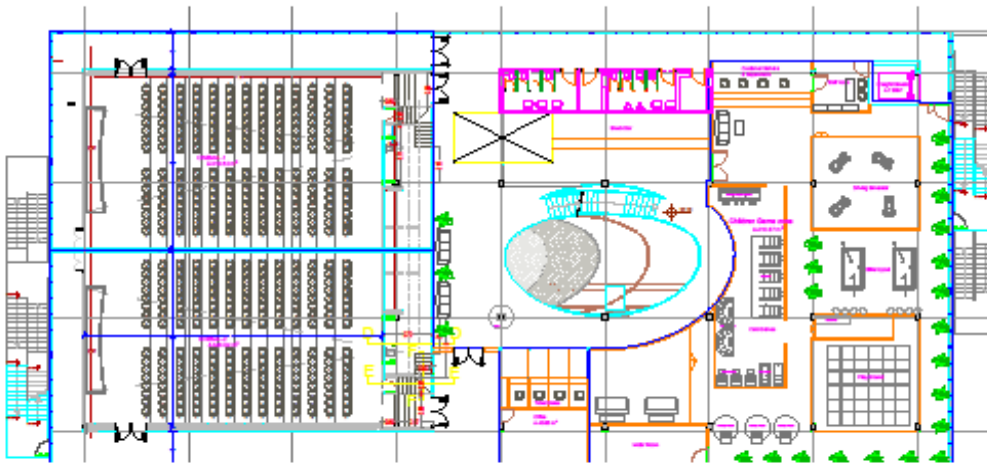
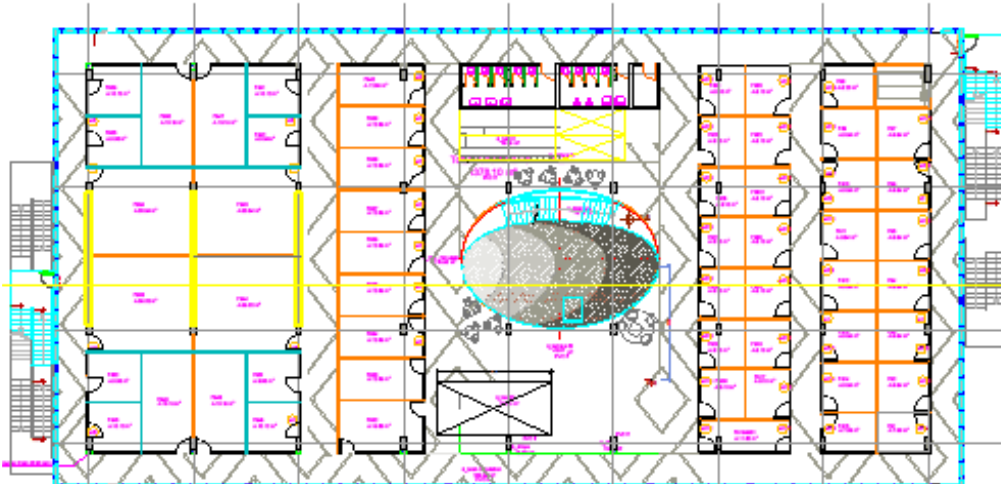


Figure 27: Lideta Mercato floor plan from ground floor to terrace

(Source: Flintstone Engineering, 2017)

4.2.4. Hope University Library

4.2.4.1. Building description

The Henk De Pagter library is found within the Hope University compound. Hope University is located in Nifas-silk Lafto Sub-city, woreda 01 around Jemo area. The university was established in 1971 on 50,000 m² plot of land. The library is located on the left side of the main entrance. The design was done by GelukTreurniet Architecten BV of the Netherlands, in collaboration with ABBA architects from Ethiopia. The construction of the whole campus started in 2007 and by 2010 the library was 90% complete. The building under review has a basement which is used as a store, ground floor and a mezzanine floor which completely functions as a library. The building gives it longest face to the North South direction.

4.2.4.2. Sustainable Site

I. Site location and transportation

The building is located in Jemo area which is rapidly growing into an active neighborhood. The mixed-use neighborhood has different functions surrounding it. There is fair access to and from the compound as there is a taxi and Bajaj route along the road and a taxi stop nearby. Taxi and private car is mostly used as a means of transportation in the university. Nothing that encourage other methods of transportation such as bicycle can be seen in the campus.

II. Site design and management

- a. **Open space and Green areas:** the campus as a whole is green with lawn surrounding most buildings. The library is no exception as a large grass lawn with scattered trees extends in front of it. Indigenous species such as *Acacia abyssinica* (Girar), *Dracaena steudneri* (Itsepatos), *Cordia Africana* (Wanza) and *Borassus aethiopum* (zembaba) are predominantly planted. Introduced species such as *Grevillea robusta* is also very common.
- b. **Pavement:** tiles are mostly used around the library for circulation while on the west side of the building, there is an asphalt paved parking area. The first allows infiltration to some extent while the later doesn't.
- c. **Stormwater management:** according to the librarian that was interviewed, flooding has occurred many times in the building. Before the flooding, little site work was done on the back side of the building. The stormwater was channeled by a ditch to the back and during

heavy rain it would overflow to the basement through its windows. The flooded water once reached knee height and ruined many books that were stored in the basement. Currently, concrete blocks the stormwater from entering it. The entire roof is covered by vegetation so rain water from the roof is absorbed by it and what remains flows to the surrounding green.



Figure 28: Pavement around the building (left), the effect of the recurring flooding in the basement (middle) and prevention method for the flooding (right)

(Source: captured by the researcher, 2017)

- d. **Green roof:** the building has an intensive vegetated green roof. The roof is sloped at some angle and is covered entirely with grass. It gives a feeling of continuity because the green roof extends to the ground level green area. According to the librarian, due to faulty waterproofing works water leakage was very common but recently intense maintenance was conducted and the problem is now fixed to some extent. Although no one was seen on the green roof during site visit, the librarian claims students can access it. According to (USGBC,2011), green roof system installed on 50% or more of the roof surface virtually guarantees 2 LEED points and can contribute an additional 7 points toward LEED certification which makes up 20% of the total points needed to get certified.



Figure 29: Green roof of the library and the surrounding green area (left to right)

(Source: captured by the researcher, 2017)

4.2.4.3. Water Efficiency

Tap water is the main source of water for toilets, cleaning and other uses in the building. During dry season the green roof and the surrounding water is irrigated using hoses connected to the main line. The only water efficient fixture used is dual flushing while nothing is done to recycle wastewater. But the green roof contributes to creating a water efficient landscape.

4.2.4.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The main source of energy is electricity and the items used the most include computers and light bulbs. Air conditioners and fans are not utilized at all. Natural daylight and ventilation which reduces the total energy consumption are mainly used in the building. The librarian claims, artificial light is not used during the day and none were seen during site visit.

II. Energy efficient equipment and renewable energy

Fluorescent light bulbs are entirely used in the inside while LED lights are seen on certain parts of the outside. Renewable energy is not utilized at all.

4.2.4.5. Material and Resources

I. Type of materials

Roof: as mentioned before the roof is completely covered with grass.

Walls: the east face exterior wall of the building is completely covered with glass while the rest is a combination of both the HCB wall and glass windows. Stones are used around the entrance and brick is used for the basement. Relatively there is little interior partition wall in the building and it is mainly HCB walls.

Floor: plastic tiles are the floor finishing used in the whole building.

II. Regional materials and rapidly renewable materials

Bamboo, which is a rapidly renewable material is used in the east face of the building as a shade. In addition, the green roof reduces the demand for virgin materials and reduces waste, in doing so, decreasing impacts associated with the extraction and processing of virgin resources.

III. Waste management

Similar for both the building under review and the whole campus, waste is collected on a daily routine and burned at the back of the campus. The waste is mainly papers and no recycling or reusing scheme is used.



Figure 30: Exterior materials and Interior materials (left to right)

(Source: captured by the researcher, 2017)

4.2.4.6. Indoor environmental quality

I. Lighting

The library is mostly enclosed with large window extending the length of the walls providing it with unlimited natural lighting. Bamboo sun breakers are used to protect the East face while the afternoon harsh sun is avoided with the slopping green roof. The building also has two open downs on each side with a green area at the bottom and louvre windows on the side. This allows the flow of natural lighting and ventilation throughout the building. Additionally, the greenery at the bottom of the open down can be accessed by a small door but it is usually closed. The rooms with the sloppiest roof are used for computer rooms, toilets and offices. These rooms have several small opening in the roof such as skylights which is used for lighting and ventilation. Based on the questioned library users concerning lighting in the library, 18.75% replied the library is very bright while the remaining 81.25% said it is bright.

II. Ventilation

The whole building is naturally ventilated and it doesn't utilize any form of mechanical ventilation. The occupants' control of ventilation is limited in this buildings as the operable windows are small in number and size. The school is fully smoking free zone. Library users reply concerning air quality in the building is as follows, 43.75% replied the indoor air in clean and fresh, 25% said it

is normal while another 25% said it varies in a good way and the remaining 6.25% answered it is variable in a bad way.

III. Dampness and microbial growth

As mentioned above, water leakage from the green roof was a problem in the building until maintenance work was done. Currently no dampness can be seen in the building especially inside but there is some dampness in the entrance to the building.

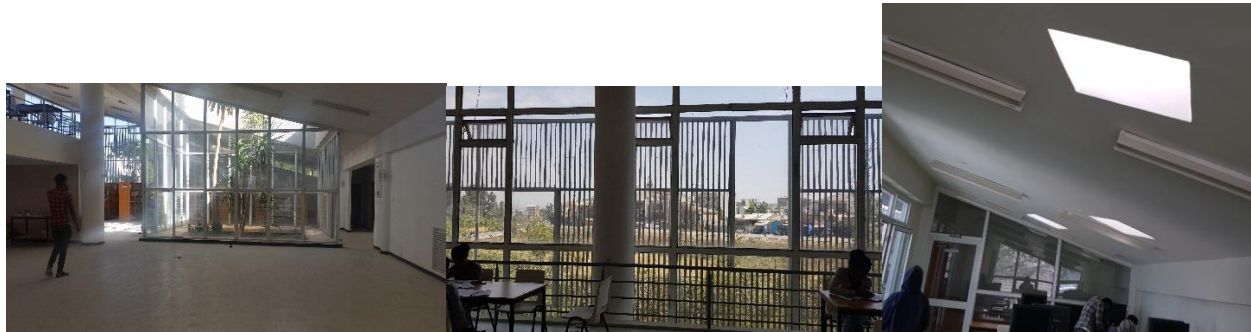


Figure 31: Open down with a greenery (left), Bamboo sun breakers (middle) and Skylight for ventilation and lighting (right)

(Source: captured by the researcher, 2017)

IV. Thermal comfort

The temperature within the building tends to have a chiller quality because North orientation is accompanied by prevailing wind and most rooms do not get to experience much warmth. In addition, the green roof also helps to regulate the indoor temperature. In regards to temperature, library users were asked the indoor temperature during hot and cold weathers, they replied as follows: during hot weather, the majority 81.25% replied the indoor temperature is normal, 12.5% replied it gets hot while 6.25% said it is cold. During cold weather, 25% answered the library gets very cold, 56.25% said it is cold while the remaining 18.75% said it is normal.

V. Acoustic and views

The compound is located a few meters from the main road and residences is the immediate function surrounding it so noise is not a major problem in the building. But the newly built cobble stone collector street causes slight disruption as the library is located close to it. The sloped green

roof restricts view on the west face of the building but on other sides because of the large windows it offers views to the outside environment.

VI. Efficiency and health problems

According to the librarian, no health issues have occurred due to the indoor quality of the building. Similar with the librarian's reply all users answered, they never had health problems because of the indoor environmental quality in the building. And in regards to the efficiency and productivity, the questioned users were split into half where 50% replied their productivity decreased due to the temperature and air quality in the building while the other half said there is no change in productivity.



Figure 32: Opening for ventilation and lighting (left), Limited operable windows (middle) and water leakage from the green roof (right)

(Source: captured by the researcher, 2017)

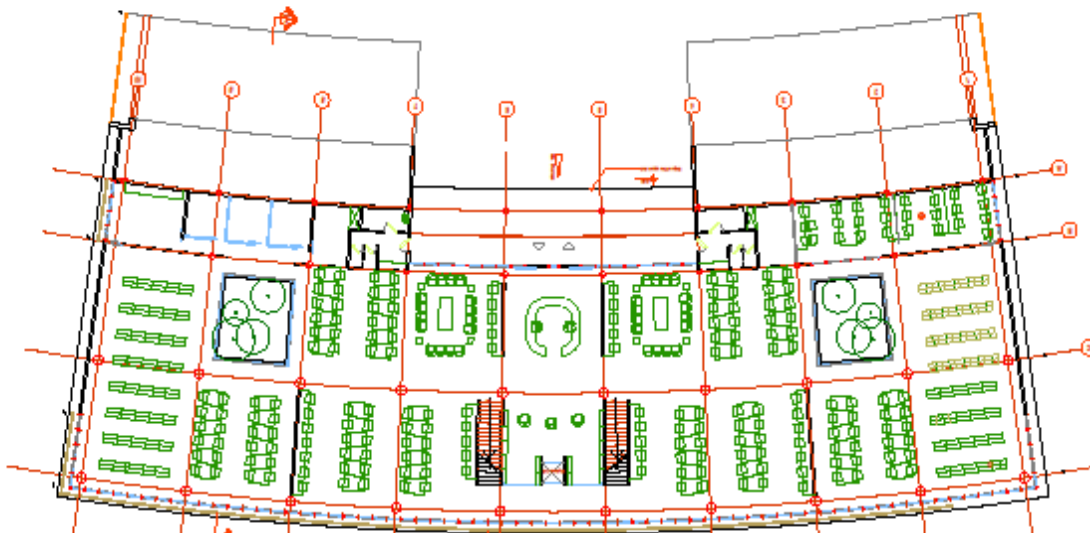




Figure 33: ground and first floor plan of Hope University Library

(Source: Hope University, 2017)

4.2.5. Varnero Apartments

4.2.5.1. Building description

Varnero real estate compound is located in Nifas-silk Lafto Sub-city, woreda 01 around Lebu area. The compound has both villas and five story apartments and was built by Varnero construction. There are a total of eight apartment building in the compound. The building under review is chosen randomly and is located on the left side of the back entrance. It is entirely used for residence with two and three bedroom apartments. The building has a square shape facing the North direction.

4.2.5.2. Sustainable Site

I. Site location and transportation

Lebu area is a mixed use neighborhood with commercial activities along the main road leading to Jemo. The area is rapidly flourishing into a nodal area with diverse functions and services all within a walking distance from the varnero compound. Private vehicle is predominantly used as a means of transportation with large parking area for both residents and guests while bicycle parking rack is nowhere to be seen in the compound. For those using taxi, there is a taxi route

along the road connecting it to city centers such as Mexico and others. A taxi stop is also located a few meters from the compound.

II. Site design and management

- a. **Open space and Green areas:** the whole compound has large open and green areas including playgrounds and recreational green areas. Around the building being studied large green lawn areas are found in front of and adjacent to it. Indigenous species such as *Acacia abyssinica* (Girar), *Borassus aethiopum* (Zembaba), *Vernonia amygdalina* (Grawa) are seen to dominate while introduced species including *Jacaranda mimosifolia* (Yetebmenja zaf) and *Spathodea campanulata* (African tulip tree) can also be found.
- b. **Pavement:** Asphalt is used for the main circulation and parking areas. For pedestrian circulation terrazzo tiles are mainly used, in some areas the tiles do not have cement lining in between to increase infiltration.
- c. **Stormwater management:** A ditch system connected to the main drainage line diverts stormwater in the compound. The rain water from the roof is released through floor drains to the adjacent green area which then passes through different layers and areas of green spaces until it reaches the drainage line. This allows the utilization of rain water to irrigate some of the greeneries and increase infiltration to the ground.



Figure 34: Surrounding green area and tile pavement (left) and Rainwater released to different layers of green areas (right)

(Source: captured by the researcher, 2017)

- d. **Green roof:** the apartment building does not have a green roof. However, the roof of the parking is covered with well-maintained and accessible grass lawn with some ornamental

plants. The roof of the parking is constructed with the proper waterproofing but leakage can be seen in some areas especially around openings.

- e. **Green Wall:** potted plants are seen on the balconies of most buildings but only the building that is being studied has a green wall. Climbers have grown on the wall of the building without any wires or mesh by simply clinging to it.



Figure 35: Green wall and the green area on the roof of the parking (left to right)

(Source: captured by the researcher, 2017)

4.2.5.3. Water Efficiency

As an alternative water source groundwater from two boreholes is used to irrigate the green areas of the whole compound. As for drinking and other functions tap water is used. Nothing is done to reuse or recycle the wastewater. In addition, the only water efficient fixture used to reduce water consumption is dual flushing.

4.2.5.4. Energy Efficiency and Atmosphere

I. Energy Consumption

Electricity is the many source of energy. Some apartments use air conditioners and fans while the majority of the units claim they don't use artificial lighting in the daytime unless it is cloudy. The items utilized the most include kitchen equipment, laptops, television, water boilers and lighting.

II. Energy efficient equipment and renewable energy

Most apartment units claim they do not use energy efficient light bulbs while some units use both types of light bulbs. The entire compound including the building under study do not use renewable energy.

4.2.5.5. Material and Resources

I. Type of materials

Roof: stone coated steel roofing system is used for the roof.

Walls: HCB walls make up both the exterior and interior walls of the building. However, stone coated light weight steel is used for the exterior wall of the last floor.

Floor: ceramic tiles and wood parquets are the most common floor finishing in the building.

II. Waste management

Residents dump their waste at the disposal site found in the compound without sorting it or any plans to reuse or recycle the waste.

4.2.5.6. Indoor environmental quality

I. Lighting

Every room except certain toilets have windows and access to natural lighting. Balconies are provided for the living and dining rooms of each apartment unit. According to the residents that were questioned, 61.5% answered their apartment has normal lighting while 38.5% responded that it is bright.

II. Ventilation

All the rooms in each apartment unit are naturally ventilated except for certain toilets. But in addition to the natural ventilation, air conditioner and fans are used in some apartment units. There is no restriction or designated area for smoking and most apartments allow it in their balconies. Residents have full control over ventilation as all the windows in the building are operable. Concerning air quality in the building, 53.8% said the air quality is normal while 23.1% replied it varies in a good way and another 23.1% answered the air is clean and fresh.

III. Dampness and microbial growth

All the questioned residents claim there is no microbial growth in the entire building. Water leakage is observed in the parking garage with the green roof.

IV. Thermal comfort

The apartments at the rear side experience higher temperature than those on the front. The bedrooms face the east and west side while the living room and kitchen face the north and south face. According to the resident the building has moderate temperature and during hot weather the 69.3% said the indoor temperature is normal while the remaining 30.7% answered it is cold. During cold weather, 61.5% responded the temperature gets cold whereas 38.5% answered it is normal.

V. Acoustic and views

The building under study is located at the back side so noise disruption from the street is not an issue. As for interior noise pollution, the walls have noise reduction materials embedded in-between the HCB blocks to prevent noise transfer through the walls. When asked about the acoustic in the building, the majority 61.5% said it is quite whereas the rest 38.5% answered it is normal. In regards to views, the building offers views to the outside environment through its windows which can be found in every room.

VI. Health problems

All of the questioned residents of the building answered that they have not had any health issues because of the indoor quality of the building.



Figure 36: The front side of the building studied (left), Water leakage in the parking garage with green roof (middle) and Part of the compound (right)

(Source: captured by the researcher, 2017)

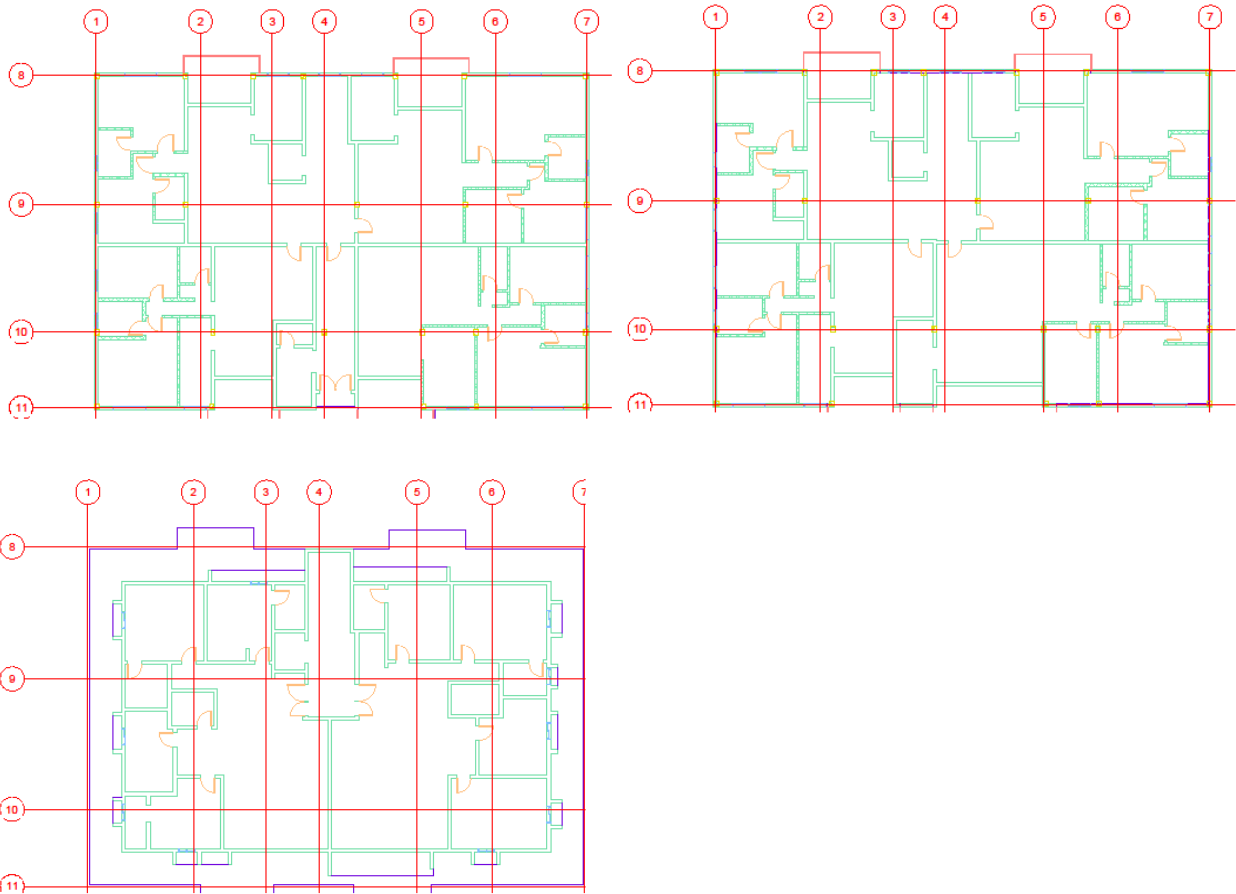


Figure 37: Varnero apartment floor plan: ground, first to fourth typical and fifth floor (top to bottom)

(Source: Varnero Construction, 2017)

4.2.6. CMC Apartments

4.2.6.1. Building description

CMC compound is located in Bole Sub-city, Woreda 10 on the road from Megenagna roundabout to Ayat. The building was built during the Derg regime to be used as a residence for different embassies in Ethiopia. It is named after the Italian company that built it during that time. Currently, the building is owned by the Addis Ababa rental housing Agency. The compound consists of a fitness center, retail store, play grounds and recreational areas. There are different typologies of apartment in the compound as well as town houses of varying size. The building that is being studied is a G+3 apartment building with four units per floor and a total of 16 apartment units. The

building stands alone with a surrounding green area and has an orientation towards the North direction.

4.2.6.2. Sustainable Site

I. Site location and transportation

During the Derg regime when the building was built, the compound was in the peripheral area of the city. Now with the city continuously growing, the neighborhood has blossomed into mixed use neighborhood where different function and services can be found close by. Transportation wise, the road is one of the busiest road in the city with traffic congestion during peak hours. Public transportation is available with taxi stops and train station in close proximity but since the supply doesn't meet the demand for transportation, many of the occupants complain about the lack of transportation. In the building under study, most occupants use private cars and taxis. There are no bicycle users and nothing positive to encourage bicycle transportation can be seen.

II. Site design and management

- a. **Open space and Green areas:** the whole compound has large open and green areas including playgrounds and recreational green areas and the same can be said around the reviewed building. The green areas have both indigenous species such as *Dracaena steudneri* (Itsepatos), *Phoenix reclinata* (zembaba), *Acacia abyssinica* (Girar) and others. Exotic species including *Grevillea robusta* can also be found.
- b. **Pavement:** concrete squares with grass in between is used for the circulation into and around the building while asphalt is used for parking in front of the building.
- c. **Stormwater management:** Ditches are used to divert stormwater from the building to the main line. The rain water from the roof of the building is channeled through down pipes and released to the green area before joining the main drainage line.
- d. **Green roof and wall:** there are no green roofs or walls in the building. The roof is a slopped corrugated iron sheet making it difficult to construct a green roof. There are two open downs in the building each with a greenery at the ground floor and on the balconies of most apartment units potted plants can be seen.



Figure 38: green area at the back of the building (left), rain water released to the surrounding green (middle) and concrete pavement and front green spaces (right)

(Source: captured by the researcher, 2017)

4.2.6.3. Water Efficiency

The main source of water for the building is tap water which is used for everything including watering plants, washing cars and for toilets. There is no scheme for reusing and recycling wastewater as well as utilizing any water efficient fixtures in the entire apartment.

4.2.6.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The main source of energy is electricity. The items used the most are television, boilers, cooking equipment, refrigerators and others. Natural daylight and ventilation is mainly used in the building and occupants claim the building doesn't use artificial lighting during the day at all.

II. Energy efficient equipment and renewable energy

None of the apartment units in the building use renewable energy. Based on the questionnaire gathered, 50% of the occupants replied they use both normal bulbs and energy efficient bulbs (mostly used in kitchens and toilets), while 25% said all their rooms have energy efficient bulbs and the remaining 25% answered they don't use any energy efficient blubs.

4.2.6.5. Material and Resources

I. Type of materials

Roof: the material used for the roof is corrugated iron sheet.

Walls: the exterior HCB walls of the building have artistic façade made of terrazzo tiles cladding. The interiors partition walls are also HCB.

Floor: the entire interior floor finishing is terrazzo tiles but in most apartments carpets are also very common.

II. Waste management

The occupants said their waste mainly consists of organic materials but that they don't reuse and recycle their wastes. Rather they collect their waste and dispose it in the primary waste collection point found a few meters from the apartment.



Figure 39: Exterior material of the building and waste dumping site (left to right)

(Source: captured by the researcher, 2017)

4.2.6.6. Indoor environmental quality

I. Lighting

The building has four apartment units in each floor and it is typical throughout. Every room in the building have windows and access to daylight. There are two open downs with the staircase in the middle, this allows the kitchens, stairs and toilets to have opening. The circulation also has square openings throughout. According to the resident's response about the lighting in their room, 75% replied their apartment is bright while the remaining 25% said it is normal. In addition, all said they don't use artificial lighting during the day.

II. Ventilation

All the rooms in the building are naturally ventilated and there is no utilization of air conditioners. There are four roof vents connected to the kitchen of each unit for ventilation but most residents doubt its functionality. Almost all residents allow smoking in their balconies. Residents have

control of lighting and ventilation because all windows are operable. Concerning the air quality of the building, out of the total questioned, 75% replied it is normal while the remaining 25% said it is clean and fresh.

III. Dampness and microbial growth

One of the major complaints of the residents in this CMC apartment is that, there is an enormous problem of dampness and microbial growth in the building. Especially during the cold seasons, the situation gets worse.

IV. Thermal comfort

The two open downs in the building create a chiller environment as one enters the building. In the building, the side that faces harsh sun rays experiences a relatively hotter indoor temperature. One resident claimed that during hot days even the walls are difficult to touch because it gets very hot. Considering the thermal comfort during hot weather, 66.6% replied their apartment is normal while 25% said it is hot and the other 8.4% replied it gets very hot. During cold weather, 50% of the questioned residents replied the temperature in their apartment is normal, 25% said it gets cold and the remaining 25% said very cold.

V. Acoustic and views

The noise from the main road is the major source of noise pollution in the building and as for interior acoustic issues the residents claim there are none. The building offers unrestricted views to the surrounding area as well as the entire CMC compound.

VI. Health problems

According to the residents, they have faced health problems such as flus and allergies due to the dampness and microbial growth within the building.



Figure 40: Open down, naturally ventilated and lighted staircase, Dampness and microbial growth and green area in the ground floor of the open down (from left to right)

(Source: captured by the researcher, 2017)

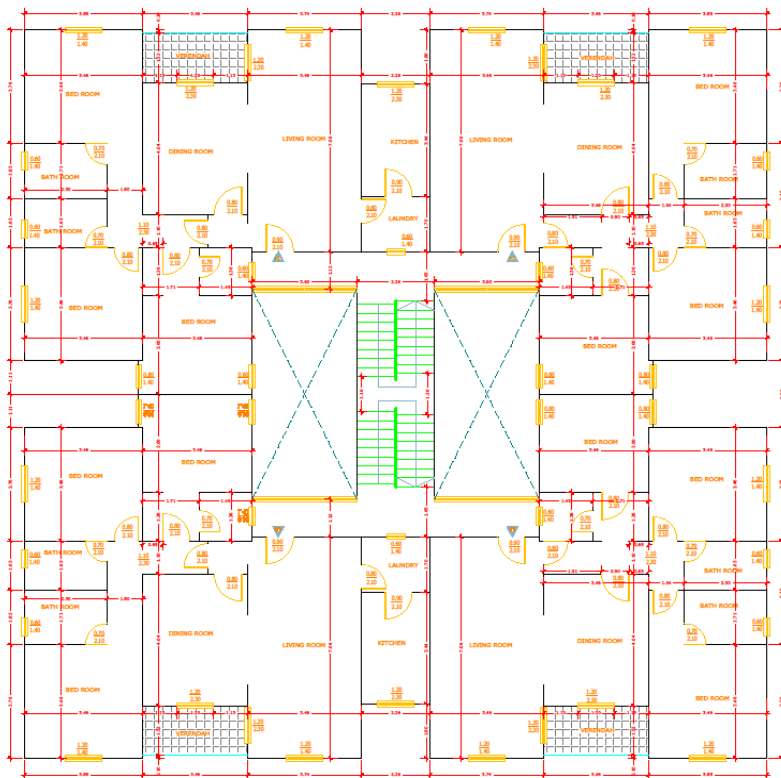


Figure 41: typical ground floor of CMC

(Source: Addis Ababa Housing Agency, 2017)

4.2.7. Yeka Sub-City Administration Building

4.2.7.1. Building description

The building is located in Yeka Sub-city, Woreda 05 around Megegnagna. This building is one of the 10 typical buildings built for each of the 10 sub-cities. Designed by MGM consult and constructed by Zamra construction, it was completed in 2015. It is a 12 stories building housing all the sub-city's offices. The building is mostly used for offices but it also has a conference hall, gymnasium, restaurants and a bank at the ground floor. The building gives its longest side to the North East direction.

4.2.7.2. Sustainable Site

I. Site location and transportation

The building is located around one of the city's center, Megegnagna. Different services and diverse functions are available within a walking distance from the building. In regards to transportation, Megegnagna taxi and bus station is located very close by. Furthermore, there is a taxi stop right in the entrance of the building as well as a train station near to it. There is a vehicle parking in the left and back side of the building, but no bicycle racks or any other devices that encourage alternative transportation. Most of the occupants use the public service buses provided by the government.

II. Site design and management

- a. **Open space and Green areas:** the building has small green lawn in the front entrance, at the back and around the outside boundary of the compound. The green areas are mostly covered with grass and ornamental plants. Introduced species such as Cypress, Araucaria and *Grevillea robusta* are predominantly planted.
- b. **Pavement:** Asphalt is the main paving material used in the compound followed by concrete which is used mostly around the building.
- c. **Stormwater management:** according to the building administrator interviewed, flooding has occurred a few times in the building overflowing in to the basement floor. The main method used to manage stormwater is a ditch system around the building. In addition, water pumps are installed on opposite sides of the building to divert stormwater away from the building. Rain water is released to the ditch through the downpipes from the roof.

- d. **Green Roof and wall:** there are no green roofs and walls in the building. Potted plants are seen in the second floor terrace and around the inside circulation.



Figure 42: Taxi and bus stop at the entrance (left), Front side green area (middle), Rain water released to the ditch and green area at the back of the building (right)

(Source: captured by the researcher, 2017)

4.2.7.3. Water Efficiency

Municipal tap water is the main source of water used for toilets, cleaning, irrigation and other uses. No action is taken to reuse and recycle wastewater or rainwater. Dual flushing is the only water efficient fixture used in the building.

4.2.7.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The main source of energy for the building is electricity and the items used the most include computers, lighting, elevators and others. Natural daylight and ventilation is mainly used in the building. According to the building administrator, the building doesn't utilize air conditioners. Electric breakers are found on the corridor outside each office to turn off lights left lit after working hours, this is checked by security every night when they do their rounds.

II. Energy efficient equipment and renewable energy

The building is uses LED lights in the circulation areas while fluorescent light bulbs are used for the offices. Both consume less energy than regular light bulbs. No renewable energy is used in this building.

4.2.7.5. Material and Resources

I. Type of materials

Roof: corrugated iron sheet and marble with the aluminum framed skylight in the middle make up the roof of the building.

Walls: the interior wall partitions are mostly aluminum. The exterior wall materials range from black and white marble cladded walls to grey and white clinker wall finishing.

Floor: Marble floor finishing is used for the circulation around the elevators while porcelain tiles are used for the offices. Carpet and parquet is used for the conference hall and gymnasium respectively.

II. Waste management

The office is cleaned twice a day and waste is collected and disposed in the dumping site found at the back of the building. There are no actions taken to recycle and reuse wastes within the building. In addition, no trash cans can be seen inside the building.



Figure 43: Exterior materials (left), Interior materials (middle) and Artificial lighting used during the day even when not necessary (right)

(Source: captured by the researcher, 2017)

4.2.7.6. Indoor environmental quality

I. Lighting

The building is supplied with sufficient lighting through the windows which cover most of the walls in all sides of the building. Additionally, an open down with a skylight in the middle of building showers the interior with ample day light. The main circulation and staircases also have windows illuminating it. To some extent the deep volume of the balconies protects the rooms from direct

sunlight but there are no sun breakers or shades protecting the building from the harsh sun so most offices are seen using newspaper to cover their windows. According to the surveyed building occupants concerning lighting, 45.8% answered it is normal, 41.7% said the building has bright lighting while the remaining 12.5% replied it is very bright.

II. Ventilation

Natural ventilation is mainly used in the building. According to the building administrator, opening windows is the only method used to cool themselves and most windows are operable. Smoking area with a balcony is provided adjacent to the toilet but it is usually closed and not functional. In regards to the air quality, the minority of 8.3% said it is variable in a bad way, the majority of 41.7% answered it is normal, 33.4% replied it varies in a good way while the remaining 16.6% said the indoor air is clean and fresh.

III. Dampness and microbial growth

The building administrator interviewed claims there are no microbial growth in the entire building. But water leakage resulting in dampness can be seen in the building and damp conditions inside a building might cause microbial growth if not taken care of early.



Figure 44: Open down all the way to the ground floor with skylight (left), Dampness in the building (middle) and well-lighted circulation (right)

(Source: captured by the researcher, 2017)

IV. Thermal comfort

The building administrator claims, the temperature in the building is moderate and that it doesn't get hot. He also added being located near the mountainous area of Megenagna, adds to the chiller air quality of the building. In order to study the indoor temperature building occupants were asked about the temperature during hot and cold weathers, their reply is as follows. During hot weather, 25% said it is cold, 37.5% answered it is normal while the remaining 37.5% said the indoor temperature is hot. During cold weather, 12.5% said it is very cold, 25% said it is cold and the majority of 54.2% answered it is normal whereas the remaining 8.3% replied the indoor temperature is hot.

V. Acoustic and views

In the interview the building manger stated that, the only noise disturbance is from the busy street outside and that the interior acoustic isn't a problem. The building offers a view to all four sides without restrictions. Concerning acoustics, 4.17% said it is very noisy, 20.8% answered noisy, 33.3% replied the building has normal noise level while 25% and 16.6% answered quiet and very quiet respectively.

VI. Efficiency and health problems

There are no recorded health issues arising from the indoor air quality of the building. Concerning their productivity and efficiency, 62.5% of the building occupants responded that it remains the same while 37.5% answered it decreases throughout the day.

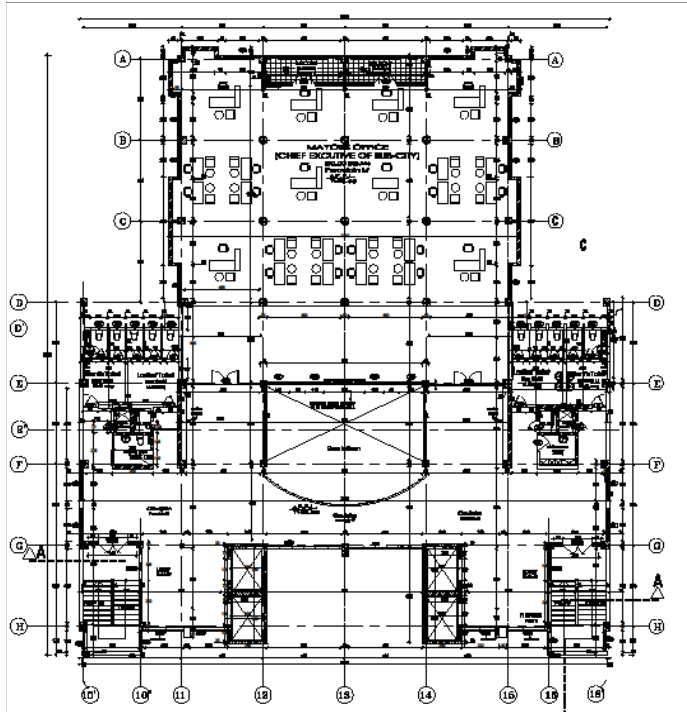


Figure 45: ground floor plan, first floor to seventh floor typical and eighth to eleventh floor typical (top to bottom)

(Source: MGM consult, 2017)

4.2.8. Ye Enat Building

4.2.8.1. Building description

Ye Enat building is located in Arada Sub-city, Woreda 01 around Enrico Pastry in Piassa. Construction began mid-2004 and by 2010 the completed building started operation. The building stands on 800 m² plot and has four stories with a mezzanine at the top and two level basements. The entire building is used for offices of different companies including Ethiopian Revenue Customs Authority, Arada Sub-city branch and Al-Sam Company which occupies two floors each. The building has a slightly slanted North South orientation.

4.2.8.2. Sustainable Site

I. Site location and transportation

The building is located in one of the historic neighborhoods of the city, Piassa. Planned as one of the main business district in the city by the Italians, the neighborhood still functions as the city's

center. The area is gradually changing from low story buildings to high rise buildings especially along Churchill Street. Diverse and numerous functions can be found in this city center within a very close proximity from Ye Enat building. Although there are no taxi routes passing through the road adjacent to the building, taxi stations are available within a walking distance. Taxis and private cars are mostly used as a means of transportation by occupants of the building. Nothing that encourages other methods of transportation such as bicycle can be seen.

II. Site design and management

- a. **Open space and Green areas:** similar to most buildings in the inner city, Ye Enat building also contributed its entire plot to the building. Therefore, there are no open and green spaces surrounding the building.
- b. **Pavement:** as mentioned above the buildings footprint lies on the whole plot so the only pavements seen are the cobble stoned pedestrian walkways.
- c. **Stormwater management:** rainwater from the roof passes through the downpipes to the main drainage line without being harvested or reused.
- d. **Green roof:** the building doesn't have a green roof and the roof is also not suitable to accommodate one. There are potted plants in all the balconies and around the entrance.



Figure 46: Rainwater through downpipe to main drainage line(left), Ground level greenery and cobble stone paved walkway (middle) and Balconies with potted plants(right)

(Source: captured by the researcher, 2017)

4.2.8.3. Water Efficiency

Tap water is the main source of water for toilets, cleaning and other uses in the building. No water efficient fixtures are used and nothing is done to recycle or reuse rainwater and waste water.

4.2.8.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The main source of energy is electricity and the items used the most include computers and light bulbs. Air conditioners and fans are not utilized at all. Artificial lighting is used in almost every room of the building during the day. While some rooms require artificial lighting other rooms with sufficient daylight also use light bulbs perhaps due to negligence.

II. Energy efficient equipment and renewable energy

Fluorescent and LED lights make up the majority of the light bulbs used in the building. Renewable energy is not utilized at all.

4.2.8.5. Material and Resources

I. Type of materials

Roof: corrugated iron sheet is the main material used for the roof.

Walls: the interior partition walls differ from office to office, it includes aluminum, wood and glass. The exterior walls are made of HCB walls with stone finishing. Copper is used for the door and windows.

Floor: for the circulation granite is used while for the offices different materials such as ceramic and plastic tiles are the most common.

II. Waste management

Waste is collected from each office on a daily basis and dumped at the back of the building. Recycling and reusing waste is a new notion in the building and nothing is done to apply this concept.



Figure 47: Exterior and Interior materials in the building (Left to right)

(Source: captured by the researcher, 2017)

4.2.8.6. Indoor environmental quality

I. Lighting

As one enters, it is hard not to notice large windows that extend the length of two floors. This windows would have let in ample daylight but because of the afternoon sun, most of the occupants use curtains which are closed all day long somewhat restricting natural lighting. In addition, the partitions are done in a way that reduces access to natural lighting. Glass block windows are used for the staircases and a dormer window is used on the pitched roof of the building to allow natural lighting. The surveyed occupants in regards to lighting answered as follows, 28% said their room is dark while 44% answered it is normal and the remaining 28% replied it is bright.

II. Ventilation

The building doesn't use any air conditioners or fans and is naturally ventilated. The only method used by the occupants to cool themselves is opening windows. There is very high movement in the first and second floors which is occupied by the Ethiopian Revenue Customs Authority, Arada Sub-city branch and with that the air quality is a little suffocating as compared to the upper floors. On the subject of air quality, 20% said it is fresh and clean, 32% replied the air quality is normal while the remaining 48% of the occupants were split three ways equally answering the air quality is stuffy, variable in a good way and variable in a bad way.

III. Dampness and microbial growth

The interviewed building manager and all occupants claim there is no dampness and microbial growth and none were seen during site visit as well.

IV. Thermal comfort

The combination of directly entering harsh sun, high movement of people, turned on lightbulbs and closed window creates a warmer temperature in the first and second floors. On the topic of temperature during hot weather, 16% replied it is very cold, 32% said it gets cold while another 32% answered it is normal and the remaining 20% said it is hot. When asked during cold weather 28% said it is very cold, 32% responded it is cold while the remaining 40% were spilt equally saying it is normal and hot.

V. Acoustic and views

According to the building manager, noise is not a problem especially in the upper floors however in the first and second floor where there is high activity, noise pollution exists. The building offers view to the outside surrounding through its large window without restriction.

VI. Efficiency and health problems

All of the questioned occupants replied that they have never encountered health problems due to the indoor quality. As regards to productivity and efficiency, 34% said their productivity decreases due to the indoor quality while the majority of 64% responded it remains the same.



Figure 48: Dormer windows on the roof (left), large windows on the front face (middle) and high indoor activity (right)

(Source: captured by the researcher, 2017)

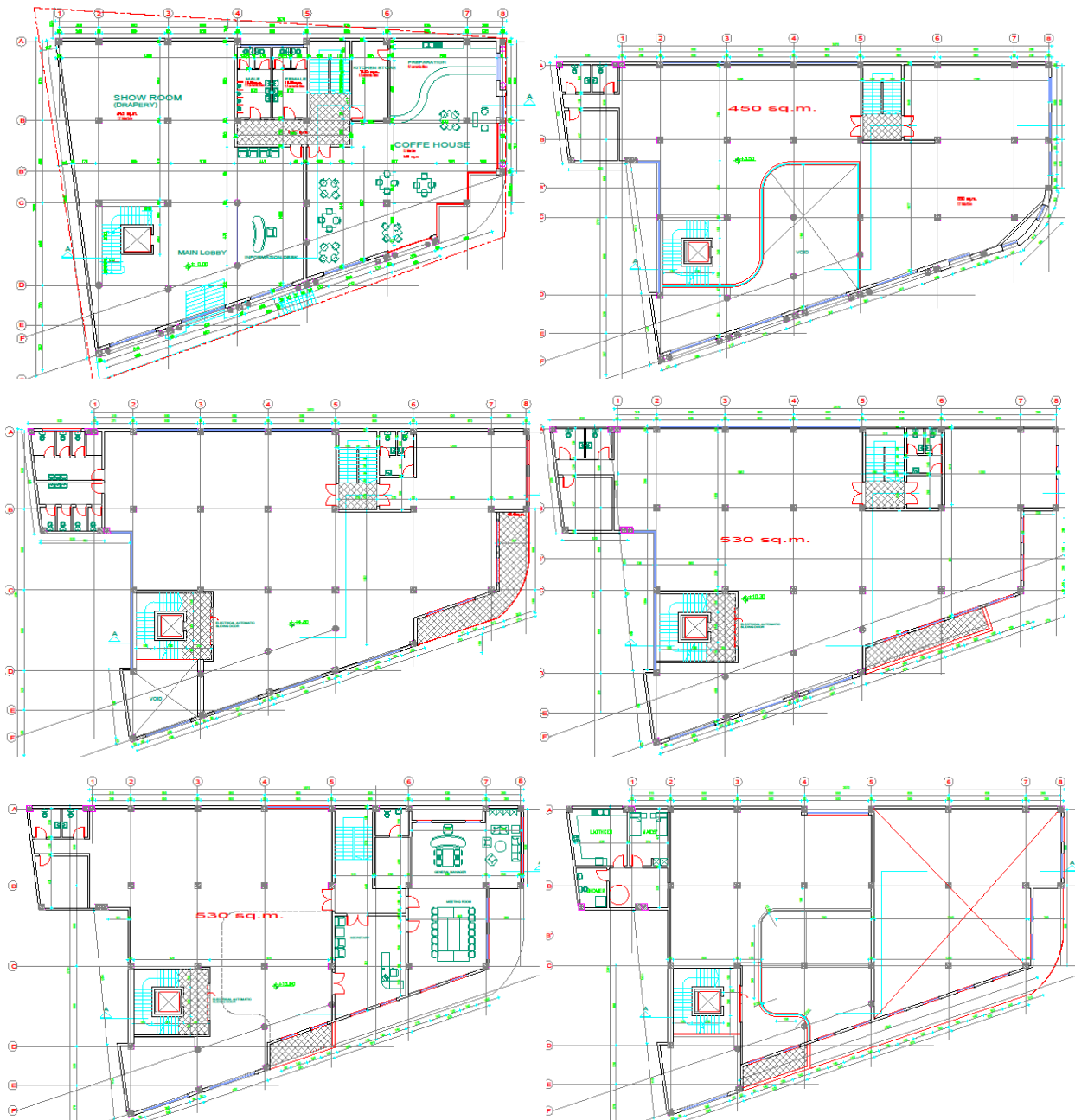


Figure 49: floor plan from ground to fourth mezzanine (top to bottom)

(Source: Building's Architect, 2017)

4.2.9. K Kare Building

4.2.9.1. Building description

K Kare building is located in Kirkos Sub-city, Woreda 06 on the road from Mexico to Kera. It is a ten story building bounded by streets on the front and left side. It is a highly active building with shops, offices, cafes, banks, game zone, language and catering schools as well as other uses. The building is orientated towards the North South direction.

4.2.9.2. Sustainable Site

I. Site location and transportation

The building's location, Mexico is one of main centers in the city. As the city's center different services and functions can be found in it. Therefore, almost anything can be accessed in a close proximity from K kare building. There are different taxi and train routes connecting the site from different locations making transportation to and from the building relatively easy. Taxi stations and train stations are located within a walking distance from the building. There is vehicle parking on the right side of the building, but no bicycle racks.

II. Site design and management

- a. **Open space and Green areas:** the building does not have a green area. The small open space on the right side of the building is used for parking.
- b. **Pavement:** concrete is used as a paving material for the parking while asphalt with tiled pedestrian walkways bound the front and left side of the building.
- c. **Stormwater management:** rainwater from the roof is released through downpipes straight to the surrounding area.
- d. **Green Roof and wall:** there are no green roofs and walls in the building but the roof can accommodate a vegetated roof if needed. Not even a single potted plant can be seen in or around the building.

4.2.9.3. Water Efficiency

Municipal tap water is the main source of water used for toilets, cleaning and other uses. None of the toilets use any of the water efficient fixtures and no action is taken to reuse and recycle wastewater or rainwater.

4.2.9.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The main source of energy for the building is electricity. The items used the utmost include computers, lighting, elevators and others. Fans are utilized in some shops when the indoor temperature rises. Artificial lighting is used during the day as most shops and circulations get very dark even in the day time.

II. Energy efficient equipment and renewable energy

Regular light bulbs and fluorescent make up the majority of the lighting while LED is used in some rooms. In addition, most shops use advertising light inside the building. No renewable energy is used in this building.



Figure 50: Parking area (left), Advertising lighting used inside the building (middle) and Artificial lighting during daytime and fans (right)

(Source: captured by the researcher, 2017)

4.2.9.5. Material and Resources

I. Type of materials

Roof: the roof is covered with corrugated iron sheet.

Walls: curtain walls make up the exterior walls of the building while the interior partitions range from gypsum, wood, asbestos, glass and aluminum.

Floor: Marble and ceramic tiles are the main floor finishing used in the entire building.

II. Waste management

The office is cleaned twice a day and waste is collected and disposed in the dumping site found at the back of the building. There are no actions taken to recycle and reuse wastes within the building. In addition, no trash cans can be seen inside the building.



Figure 51: Exterior and interior materials used in the building (left to right)

(Source: captured by the researcher, 2017)

4.2.9.6. Indoor environmental quality

I. Lighting

The majority of the rooms in the building do not have access to natural daylighting. The shops are partitioned in a way that limits natural lighting forcing them to depend on artificial lighting during the day. The front curtain wall faces the harsh sunlight without any sun breakers or shades causing glare problems. Both staircases have windows along its length while most circulations are relatively dim. Regarding lighting, the majority of 31.4% of the respondents answered the building has normal lighting followed by 28.6% who replied it is very dark, while 14.3% said it is dark. The remaining 20% and 5.7% said it is bright and very bright respectively.

II. Ventilation

Opening windows is mostly used as a method of ventilation but for those in the middle section of the building fans are utilized. Most windows are operable but the majority of the occupants' do not have access to it. Ventilation is an issue in the building because the toilets and cafes lack proper ventilation and opening causing the smell to spread throughout the entire building. The air quality seems to get better after the sixth floor because the toilets have windows and is less crowded. The majority of 37.1% of the questioned occupants said the air quality is very stuffy while 31.4% answered it is normal. 20% replied it varies in a bad way and the rest 11.4% responded the air is clean and fresh.

III. Dampness and microbial growth

According to the building administrator interviewed, there are no microbial growth in the whole building. But water leakage resulting in dampness can be seen in limited parts of the building especially around windows and toilets.

IV. Thermal comfort

The front curtain wall side of the building faces the harsh afternoon sun and has a relatively higher temperature. Stickers, curtains and newspapers are used to protect this side of the building. Artificial lighting in addition to limited openings in the building also cause a higher indoor temperature. During hot weather, 5.7% of the questioned occupants answered the indoor temperature gets very hot, 48.5% answered it is hot, 40% said it is normal while the rest 5.7% answered it is cold. During cold weather, the majority 34.3% of the respondents said it is normal followed by 25.7% who responded it gets hot. 22.8% and 17.1% replied the indoor temperature gets very cold and cold respectively.

V. Acoustic and views

There is diverse functions and high activity in the building, moreover it is located along a busy street so some noise disturbance is inevitable. In regards to noise in the building, 22.8% said it very loud while 20% answered the building is quite. The remaining 57.2% of the respondents were spilt equally, the first half saying it is loud while the other half answering it is normal. The majority of the rooms don't have access to the outside view but along the edges the building has view to the surrounding environment.

VI. Efficiency and health problems

According to the respondents, 22.8% have had health problems such as colds and flus due to the low air quality and the strong winds from the windows opened for ventilation while 77.2% said they have never faced any health problems. When questioned about productivity, 37.1% said their productivity decreases due to the indoor quality while the majority 62.9% answered it doesn't fluctuate throughout the day.

4.2.10. Lion House Building

4.2.10.1. Building description

Lion House building is located in Kirkos Sub-city, Woreda 09 in front of Meskel Square. The building was built in 1967 during the era of Emperor Haile Selassie. From the lay out, it is clear to see the building was designed for apartment residence. Currently, the building is owned by Ethiopian Insurance cooperation. It is an eleven stories mixed use building housing different functions such as banks, offices and residence. The building gives it longest side to the Northwest-Southeast direction.

4.2.10.2. Sustainable Site

I. Site location and transportation

The building is located in front of the iconic Meskel square which is used for religious ceremonies, concerts, parades, car races, and various government and public events as well as sport activities. Hotels, offices, cafes, shops, church and others are the functions found within a walking proximity from the building. Many taxi routes from different locations passes through Meskel square with a taxi and train station very close by. In the Lion House building, most occupants use private cars, train and taxis. There are no bicycle users and nothing positive to encourage sustainable transportation can be seen.

II. Site design and management

- a. ***Open space and Green areas:*** there is an open space at the back of the building which is used for parking however there are no green areas within the building's plot while a riverine greenery is found behind the building.

- b. **Pavement:** Asphalt is used for paving the parking area at the back while tiled pedestrian walkways and asphalted parking areas make up the boundaries of the front side of the building.
- c. **Stormwater management:** rainwater is released to the surrounding area through downpipes from the roof and floor drain from the balconies with no intention of reusing or recycling it.
- d. **Green roof and wall:** there are no green roofs or walls in the building. The roof is suitable for a vegetated roof but is currently used for placing of water tanks and advertising posts. Potted plants are found on the balconies and corridors of some units in the building.

4.2.10.3. Water Efficiency

The main source of water for the building is tap water which is used for everything including watering plants, washing cars and for toilets. There is no scheme for reusing and recycling wastewater or rainwater. Almost all toilets still have the same fixtures installed when the building was constructed in 1967 so none of the water efficient fixtures used nowadays are found here.

4.2.10.4. Energy Efficiency and Atmosphere

I. Energy Consumption

The items used most by building occupants include computers, printers, stoves and others with electricity being the main source. Artificial lighting is used in most offices during the day but none is used for public spaces including circulation. The occupants don't use air conditioners or fans and mainly rely on natural ventilation.

II. Energy efficient equipment and renewable energy

None of the units in the building use renewable energy. With the majority being fluorescent light bulbs, both LED and regular light bulbs can also be found in the building.

4.2.10.5. Material and Resources

I. Type of materials

Roof: concrete is used for the roof.

Walls: the exterior HCB walls of the building are lined with white ceramic clinkers. The interior partitions differ from unit to unit ranging from HCB walls, wood and aluminum.

Floor: ceramic tile, marbles, carpets and plastic tiles are the most common floor finishing used in the building.

II. Waste management

Occupants don't recycle or reuse their wastes which is mostly paper and plastic bottles. They dispose it in the building's waste collection bin found outside.



Figure 52: Front facade of the building (left), Asphalted parking, waste disposal area and river at the back (middle) and Indoor potted plant (right)

(Source: captured by the researcher, 2017)

4.2.10.6. Indoor environmental quality

I. Lighting

The indoor lighting differs from unit to unit because of the type of partition wall used. The circulation and corridors have ambient lighting due to the glassed wall adjacent to it. Every room in the building have windows and access to daylight. Most of the rooms in the front have their curtains drawn even in the morning for protection from the harsh sun. According to the occupant's response, 60.9% answered their unit is bright, 21.7% said it is very bright and the remaining 17.4% replied it is dark.

II. Ventilation

All the rooms in the building are naturally ventilated and there is no utilization of air conditioners. Occupants have control of lighting and ventilation because most windows are operable. The kitchen and toilets have natural ventilation preventing the smell to spread. Smoking is not allowed in the offices while the residential units allow it in the balconies. Concerning the air quality of the

building, out of the total questioned, 43% replied the air quality is normal, 8.7 said it is stuffy, 13% answered it varies in a bad way while the remaining 34.8% were spilt equally, the first half answering it is fresh and the second answering it is variable in a good way.

III. Dampness and microbial growth

Water leakage especially in the rainy seasons is common in the building. In the building units that had maintenance work recently dampness is not observed however in other units dampness is a huge problem and if not treated right will result in microbial growth.



Figure 53: Different partitions affecting the lighting in the building unit and utilization of artificial lighting during the day

(Source: captured by the researcher, 2017)

IV. Thermal comfort

On the west side, where the sun hits it with full intensity large windows and recessed balconies are used. The first lets in the harsh sun so most windows are plastered with reflectors or newspapers while the latter reduces it to some extent. However, these rooms have relatively higher indoor temperature. When asked about the indoor temperature during hot weather, 26.1% said their unit is cold, 30.4% replied it gets hot while the majority of 43.5% answered it is normal. During cold weather, 47.8% said the indoor temperature is normal, 26.1% said it is very cold while another 26.1% said it gets cold.

V. Acoustic and views

The building is located along a major intersection so noise pollution from the street is inevitable especially when the windows are open. The interior acoustic depends on the partition material and whether it is a private or pool office. Therefore, 52.2% of the questioned occupants concerning acoustic answered it is normal, 21.7% said it is quite while 13% responded it is too noisy and another 13% replied their unit is noisy. In regards to views, the building has an unrestricted view to the outside surrounding especially in the upper floors whereas on the lower floors, the recently built railway overpass has disrupted it to some extent.

VI. Health problems

According to the occupants, no one has ever faced health problems due to the indoor quality. Concerning productivity and efficiency the majority of 78.3% of the questioned occupants said it remains the same while 21.7% answered their productivity decreases due to the indoor quality of the building.



Figure 54: Naturally lighted circulation, Dampness in the toilets, closed curtain on the front side due to harsh sun (left to right)

(Source: captured by the researcher, 2017)

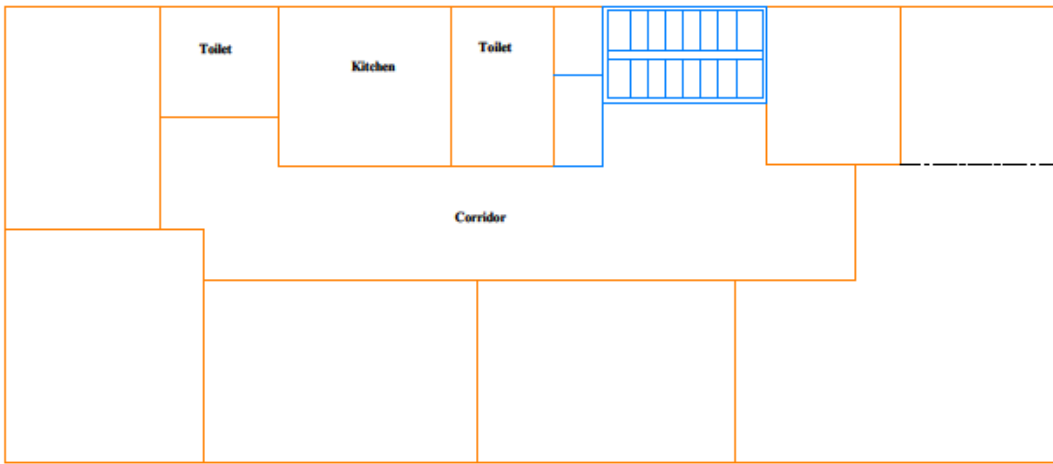
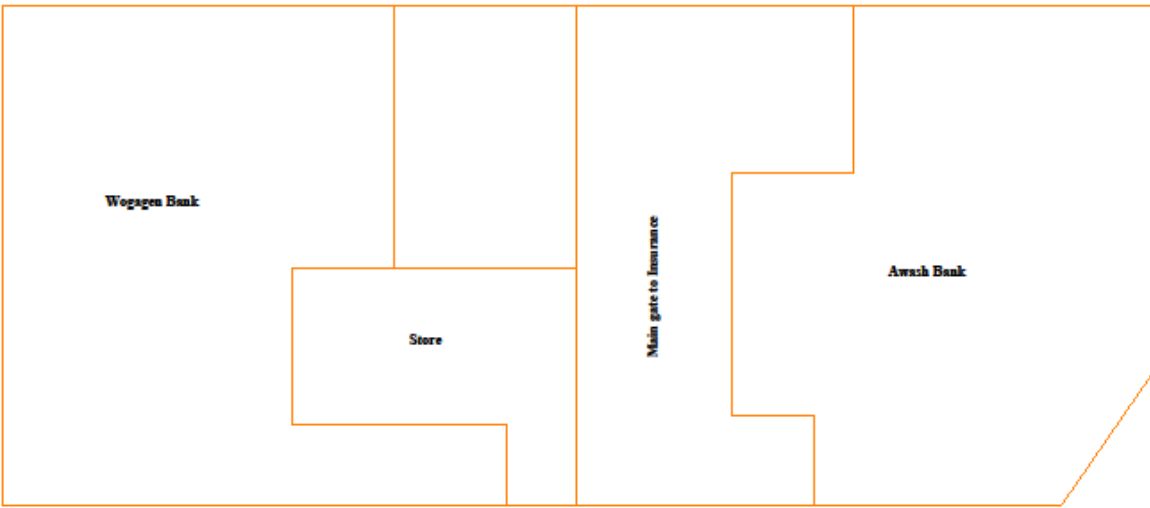


Figure 55: Sketch floor plan of the ground and typical first to tenth floor (top to bottom)
 (Source: Ethiopian Insurance cooperation, 2017)

Chapter V

5. Data Analysis and Presentation

In this chapter, the data collected is analyzed in descriptive and statistical method using different software. Finally, the data is processed and presented as follows.

5.1. Analysis of the selected buildings

As described above a total of 10 buildings in Addis Ababa were surveyed. The buildings were selected according to the selection criteria set and their function and ownership is summarized in the graph below.

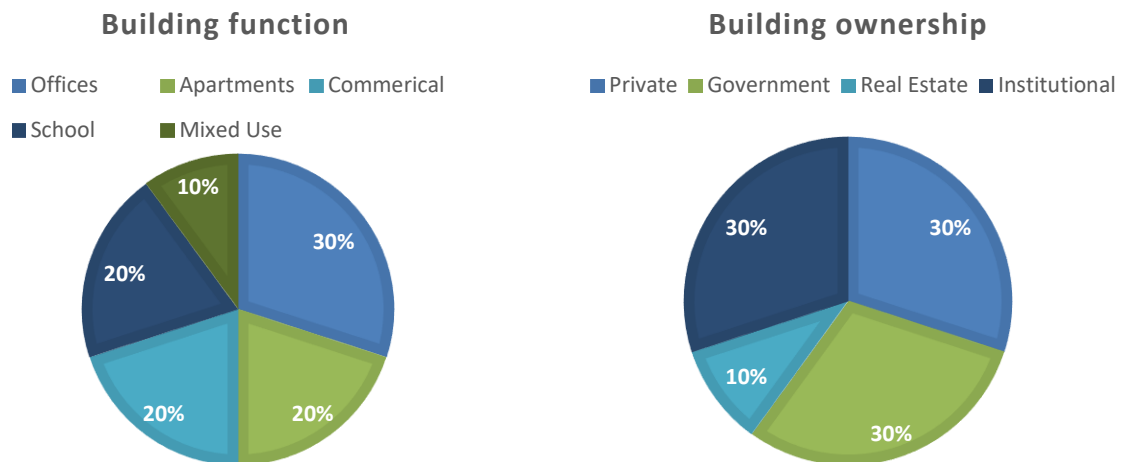


Figure 56: Building function and ownership

(Source: computed by the researcher, 2017)

Therefore, out of the total 10 buildings, only one building (lion House) has mixed residence and commercial use while CMC and Varnero are pure residence. 30% of the surveyed buildings are used for offices, these are Yeka, Ye enat and GBG. Lideta Mercato and K kare with 20% function as commercial including shops and offices while the remaining 20% is ICS and Hope which are under the school category. The building ownership is split three ways each with 30%, these are privately owned (Ye enat, Lideta Mercato, K kare), Institutional (GBG, ICS and Hope) and Governmental (CMC, Lion and Yeka Sub city) while the remaining one building (varnero) is a real estate (plc).

5.1.1. Sustainable sites

I. Site location and transport

Out of the total surveyed buildings, 50% have good access to service and transport as they are found in the city's center with taxi and train stations located within a walking distance these are Lion House, Lideta Mercato, K kare, Ye enat and Yeka. 40% have fair access because of their location, difficulty of transportation and are accessed only by taxi routes. While GBG is located in the city's fringe with limited access to transportation and different functions as well as services.

In regards to alternative transport bicycle is encouraged in ICS by placing parking racks and other methods, while company service is used in Yeka and GBG which promotes carpooling whereas the remaining buildings haven't considered it at all.

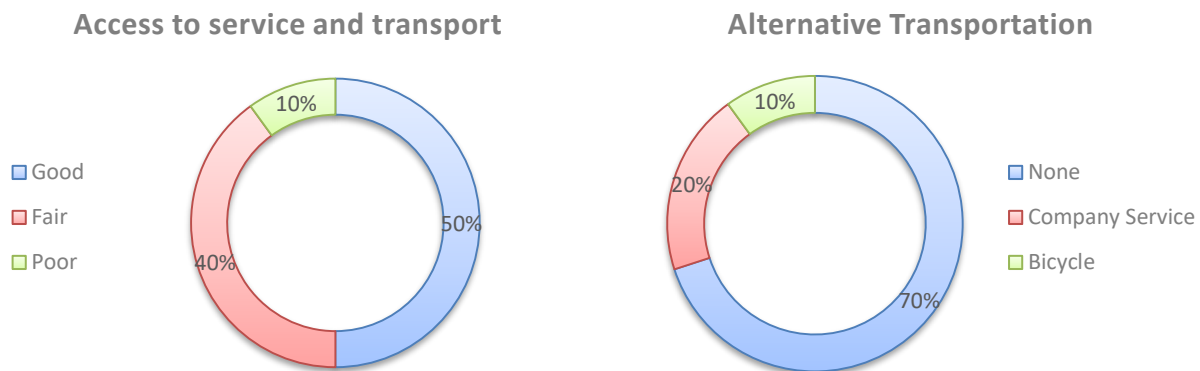


Figure 57: Access to service and transport and Alternative Transportation

(Source: computed by the researcher, 2017)

II. Stormwater management

The stormwater from the ground of all 10 buildings is channeled through ditches before joining the main drainage line. Flooding has occurred in two of the buildings (Yeka and Hope) due to lack of proper management of stormwater. As for the rain water from the roof, 50% of the total buildings use downpipes connected to ditches while the other 50%(including GBG, ICS, CMC, Hope and Varnero) have some of its downpipes and floor drains release rainwater to the surrounding green areas. These allows infiltration of rain water to the ground as well as irrigation of the greenery.

III. Open and green areas, Green Roof and Green Wall

As figure 58 shows, 40% of the total building (including Lideta Mercato, K kare, Ye enat and Lion House) do not have green areas. The remaining 60% have green areas ranging from large dense tree covers to small lawn green spaces. Three buildings have green roofs ranging from full green cover in Hope University to partial vegetated roof of ICS and deteriorating partial green roof of GBG. Only two buildings have green walls, the one in ICS is designed properly whereas the second found in Varnero apartments has grown spontaneously.

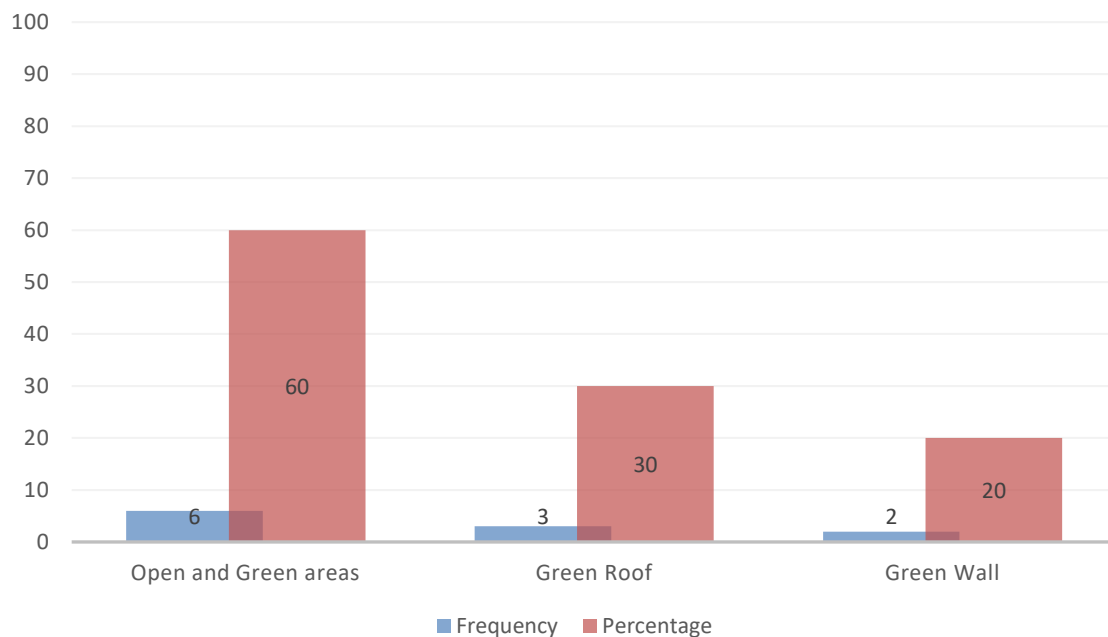


Figure 58: availability of open and green areas, green roof and green wall

(Source: computed by the researcher, 2017)

5.1.2. Water efficiency

I. Water efficient fixtures

As figure 59 shows, four buildings (Ye enat, Lion House, CMC and K Kare) do not use any water efficient fixtures while the most common high efficiency fixture is dual flashing. Automatic shutoff water faucets and waterless urinals are only used in GBG and ICS.

Use of water efficient fixtures

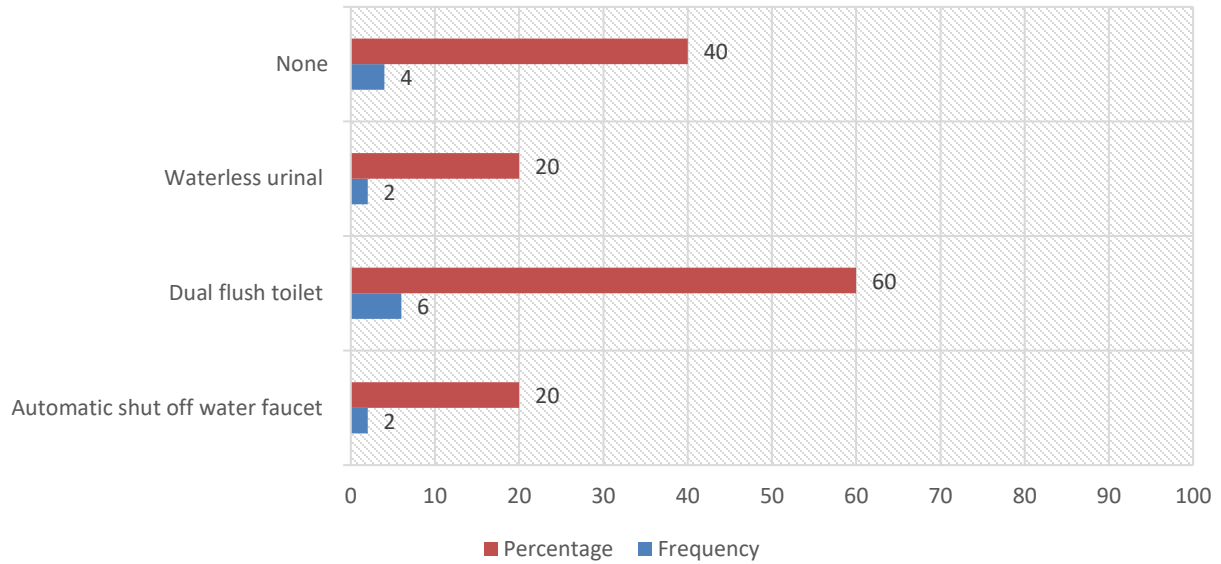


Figure 59: Use of water efficient fixtures
 (Source: computed by the researcher, 2017)

II. Water usage

Water Usage

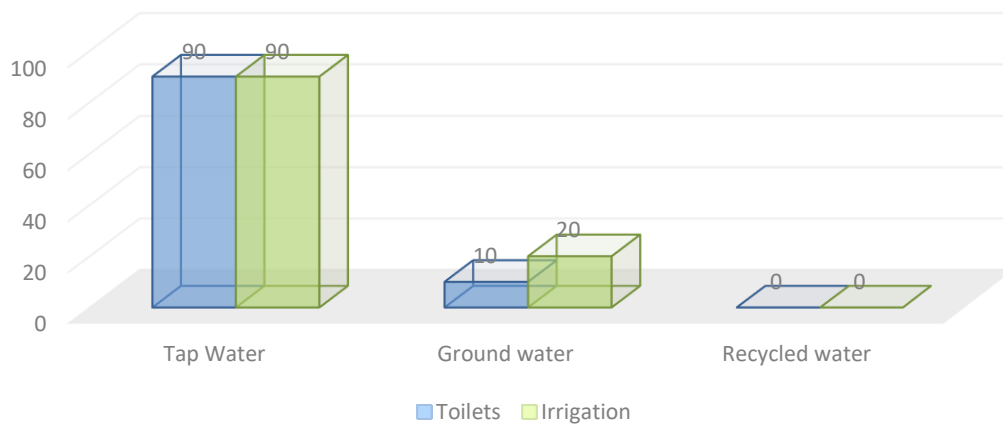


Figure 60: Water Usage
 (Source: computed by the researcher, 2017)

As seen in figure 60, the main source of water for toilets and irrigation is municipal tap water with the exception of ICS which uses groundwater for both functions. In addition, Varnero apartments uses both tap water and groundwater for irrigation of the green areas. But the use of recycled water for any function is elusive to all buildings. A wastewater treatment is found in GBG but it is not functional.

5.1.3. Energy Efficiency and Atmosphere

I. Energy usage

Due to the ideal weather condition of the city, most of the buildings do not use air conditioners and fans. Those, that do use AC such as ICS, is only used for meeting halls and server rooms where controlled indoor temperature is required. Fans are used in some shops of K kare while few apartment units in Varnero also use fans and AC. The use of fans is very much associated with the use of artificial lighting during the day especially in the case of K Kare building.

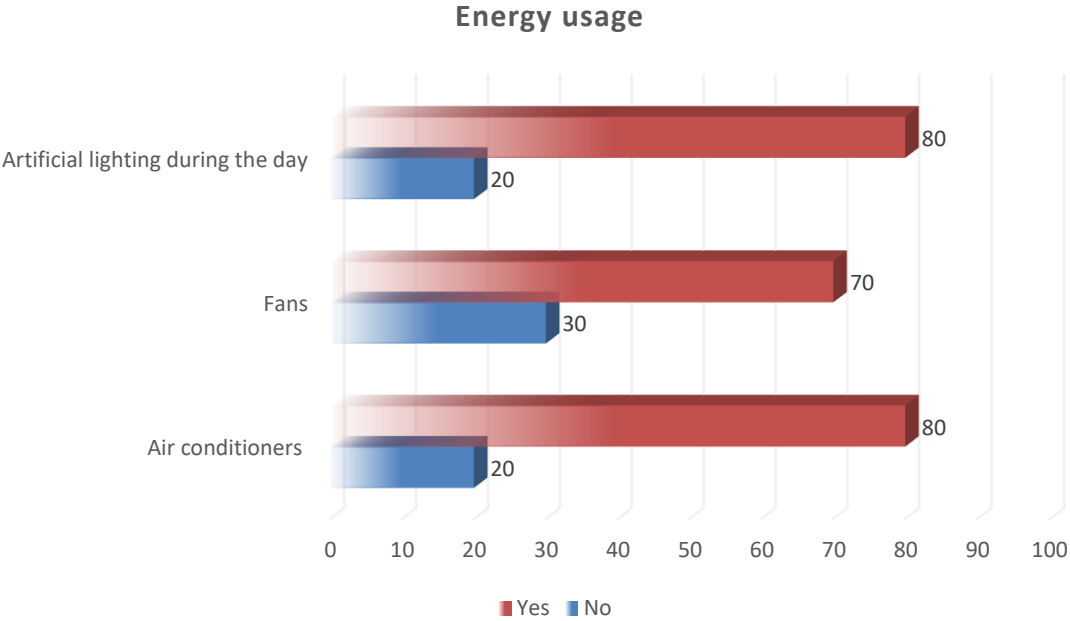


Figure 61: Energy usage
(Source: computed by the researcher, 2017)

As figure 61 shows, only two buildings including Hope University and CMC don't use artificial lighting during the day while the others do. However, the extent and reason varies, for example

in ICS, Yeka and varnero only a few rooms have lights turned on while K kare and ye enat use artificial lighting in many areas. The reason also differs from negligence to actually requiring lighting because the rooms are dark, for example, in Yeka which is due to carelessness while in k kare, lideta Mercato and others, artificial lighting is required in most rooms.

II. Energy efficient lighting and Renewable energy

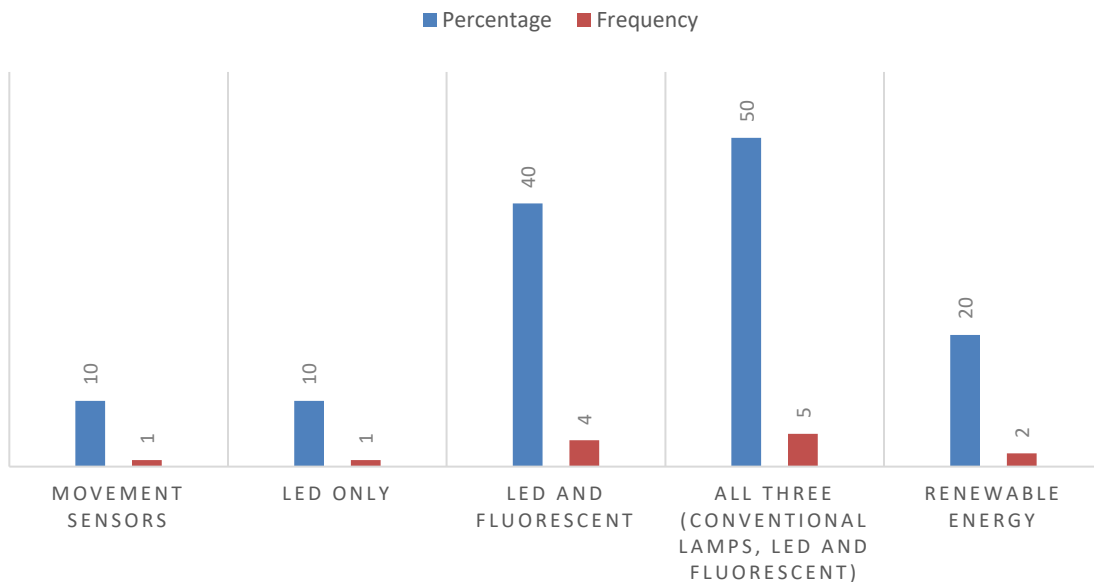


Figure 62: Energy efficient lighting and Renewable energy

(Source: computed by the researcher, 2017)

As figure 62 indicates above, movement sensors are only used in GBG while the entire building of ICS uses LED lights. Buildings such as Lideta Mercato, Yeka, Hope and Ye enat making up 40% of the total use both LED and fluorescent while the remaining 50% use all three types of light bulbs.

Solar energy is used for boilers in GBG and ICS while no other building utilizes any type of renewable energy. However, Lideta Mercato has finalized agreements to install solar panels on the roof of the building which according to sources will be installed very soon.

5.1.4. Material and Resources

I. Types of materials

As it can be seen in figure 63 below, the most common wall material is HCB with plastering or painting followed by stone and stone cladding used in buildings such as Ye enat, GBG, ICS and some parts of Hope. Adobe bricks is the most environmentally friendly of all but is only used in GBG. Glass is used for K kare and Hope University while magnesium oxide makes up the walls of Lideta Mercato. In regards to roof type, the most used is corrugated iron followed by concrete and green roof used in three buildings each. Tiles whether it is ceramic, marble, plastic and porcelain are used in seven buildings while bamboo and wood parquets are used in GBG and Varnero apartments.

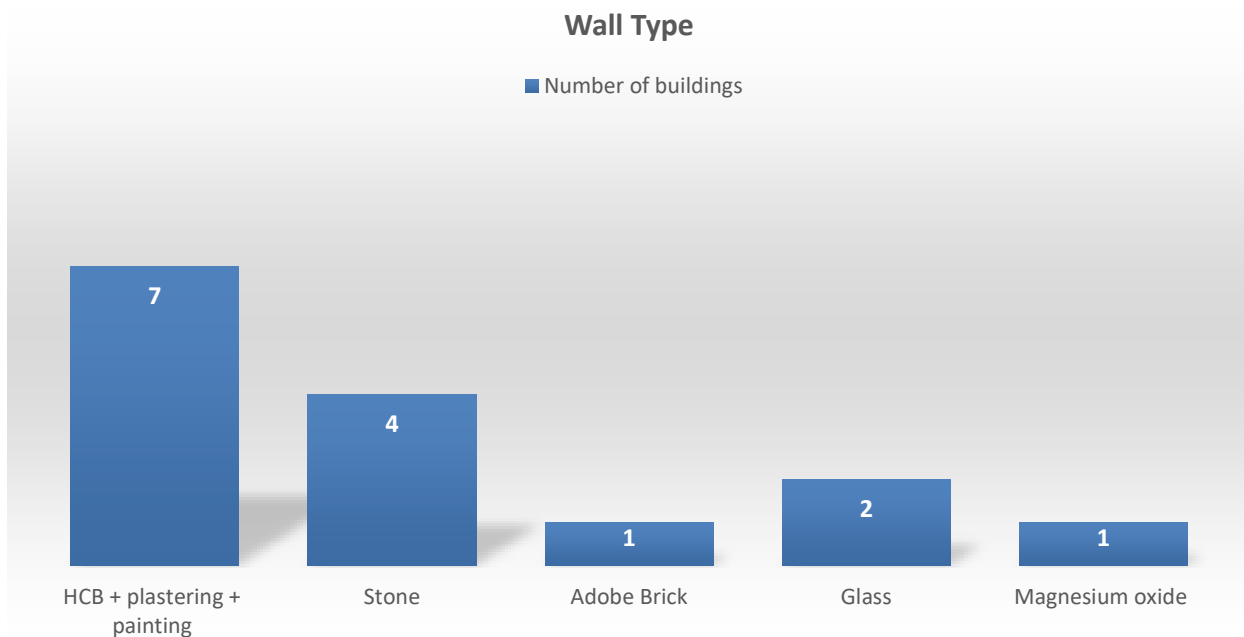


Figure 63: Type of wall used in the selected buildings

(Source: computed by the researcher, 2017)

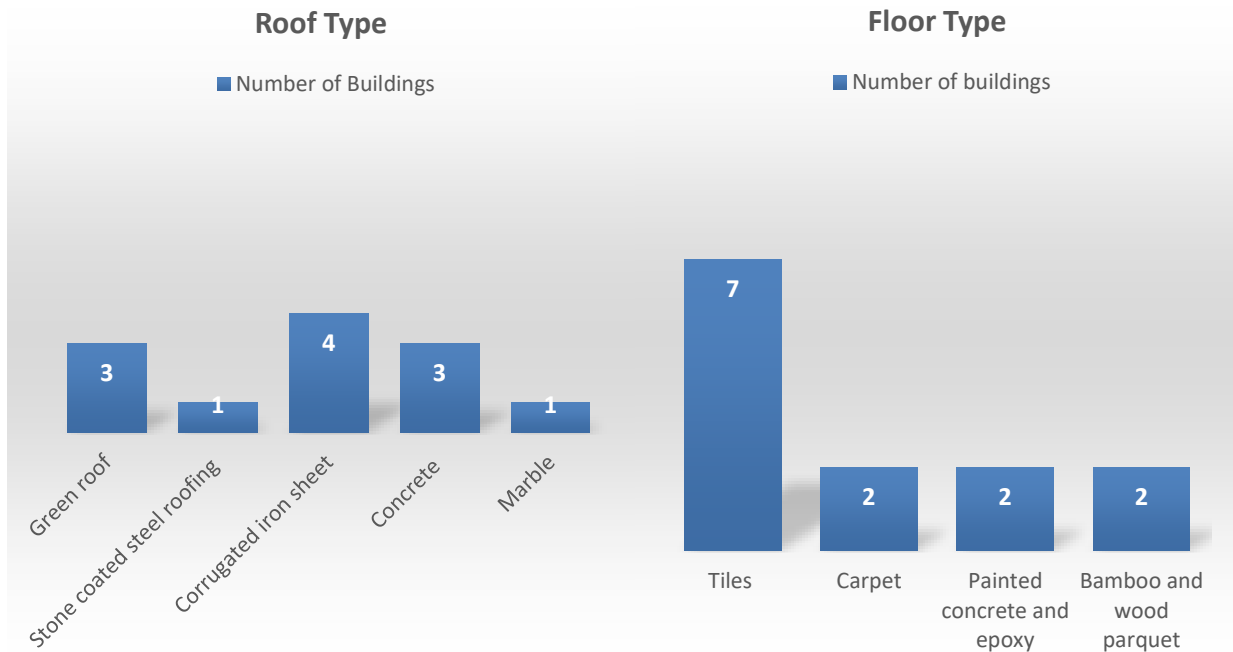


Figure 64: Roof and Floor materials

(Source: computed by the researcher, 2017)

II. Thermal properties of materials used in the surveyed buildings

The building envelope is the major interface between indoors and outdoors, and affects the comfort sense for occupants and heating/cooling loads of the building.

Building materials are evaluated for thermal performance based on conductivity measurements known as R- and U- values. The R-value indicates the ability of a wall to insulate effectively-the higher the resistance to the conductive transfer of heat, the higher the R-value and the better the insulator. The R-value is calculated by dividing the thickness of the wall by the wall's thermal conductivity, which is the amount of heat per square foot per hour flowing from the hotter to the cooler side of the wall. The U-value, or conductance is represented by the reciprocal of the R-value and reflects the rate at which heat is conducted through a material.

Building with HCB walls: these building have relatively low thermal resistance causing the indoor temperature to greatly fluctuate during the day sometimes requiring additional energy to regulate temperature.

Building with Stone cladding and masonry: Although the mineral composition and constitution of natural stones differ, generally stones do not let heat escape or let in heat easily. Buildings with this material have chiller indoor temperature during the day and releases heat during the night time creating a warmer environment. In addition, stones have low carbon footprint compared to other materials and are durable.

Building with Adobe brick: has relatively high thermal conductivity meaning it is able to absorb heat during the day keeping the building cool and then release this stored heat at night, warming the interior. Additionally, it helps in reducing large fluctuations of indoor temperatures during the summer and winter. Adobe bricks are also sound resistant and environmentally friendly.

Buildings with Glass: this type of materials also allow easy transfer of heat from hot to cold areas affecting the indoor temperature of the building. If not installed with the proper shadings different problems including glare and discomfort of building occupants due to higher temperature is common.

Building with Magnesium oxide: has limited thermal insulation value.

III. Regional, Renewable and Recycled Materials

Most buildings used both local and imported materials even though the exact amount couldn't be identified. LEED requires at least 20% usage of local materials to obtain the full two points. However, buildings such as Lideta Mercato used wall material pre-fabricated in Addis Ababa, ICS used stone cladding from Mekelle and GBG was built from eucalyptus wood, mud and bamboo locally produced. As for rapidly renewable material, only two buildings GBG and Hope used bamboo which can be rapidly harvested while GBG used adobe brick which has low impact, is environmentally friendly and rapidly renewable. Based on the interview with the building engineers and architects of the recently built buildings, none used recycled materials or materials on their second life during their design or construction.

IV. Waste management

The waste produced in each building differs on its function, for example paper is a very common waste in commercial and school buildings while in apartments organic wastes such as food is the highest. One thing that all building have in common is a communal waste dumping site found

within the compound and is collected by the municipality in certain intervals. Sorting at source and recycling is a very new concept to most building occupants and only two buildings, GBG and ICS, sort their waste and give it to the recyclers. As for composting, 90% of the total surveyed buildings didn't even consider it as an option while only one building, ICS uses it for its vast greenery.



Figure 65: Waste Management

(Source: computed by the researcher, 2017)

5.1.5. Indoor environmental quality

I. Lighting

As seen in figure 66 below, most building have sufficient light and the mean score ranges between normal or moderate lighting to bright lighting. Hope University is the brightest building with a mean of 4.18 while K kare is the darkest with 2.6 mean. K kare building even though has a curtain wall which lets in sufficient lighting due to the continuous partitioning to accommodate different shops which is common in most commercial shops in Addis Ababa has resulted in rooms with limited or no natural lighting. Buildings that have windows in most rooms and have used different methods

to allow natural lighting such as large windows, skylights, open downs, dormer windows and others, including GBG, Yeka and CMC have sufficient lighting with mean score mildly leaning towards bright lighting.

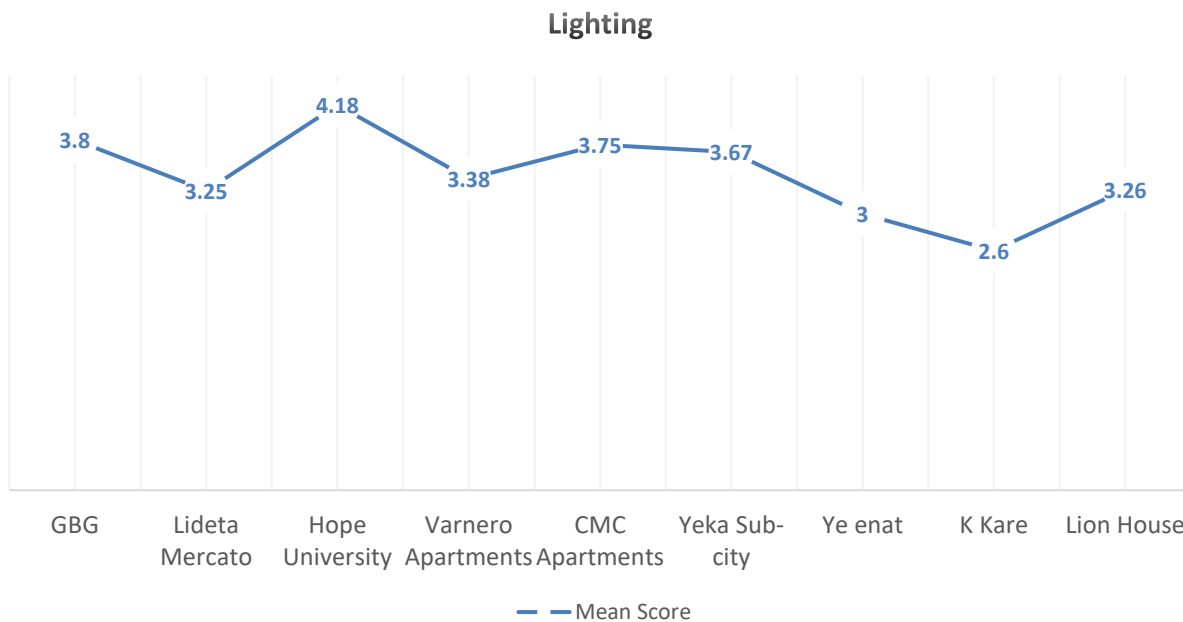


Figure 66: lighting mean score

(Source: computed by the researcher, 2017)

II. Ventilation

As figure 67 indicates, almost all of surveyed buildings have good natural ventilation with mean score between moderately ventilated to clean and fresh indoor air. GBG has the highest score in which the surrounding green and the different opening of the building which contributes to the clean air quality. With the second rank is Lideta Mercato, in which passive cross ventilation is stimulated through its many openings in the perforated walls and the inclined atrium. Hope university library because of the green roof, surrounding green area and a large open area with vegetated and operable open downs is ranked third. In opposite, K kare building has the lowest mean score suggesting the air quality is variable in a bad way due to the unventilated toilets, cafes and restaurants without proper exhaust fans, limited access to opening windows and other reasons. However, other important issues such as air quality monitoring is done only in ICS, the equipment is installed in the compound and monitors the amount of pollutants. Occupants control

is also necessary and it ranges from Lideta Mercato in which occupants have limited control over ventilation to buildings such as GBG, CMC and others where the majority of windows can be opened.

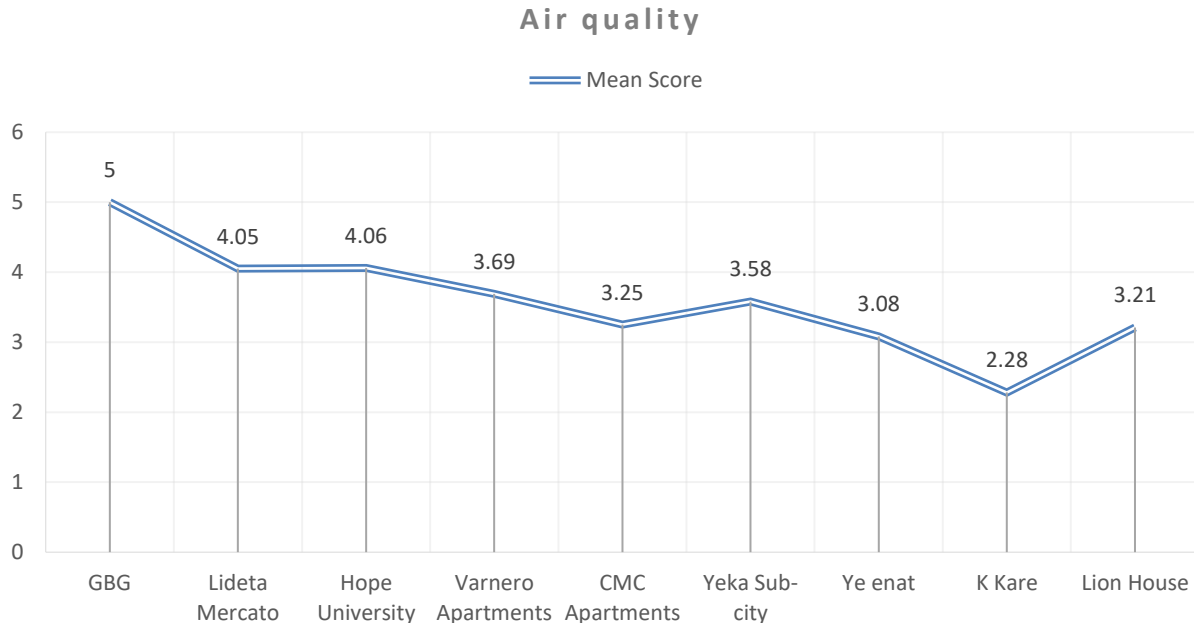


Figure 67: Air quality mean score

(Source: computed by the researcher, 2017)

III. Thermal Comfort

Thermal comfort of the buildings depends on many issues such as building orientation, outside temperature, appropriate shading and material used among other things. The chart below shows that during hot weather, the means score of most buildings range from 2 - 3.54 which is between cold and considerably moderate temperature. Lideta Mercato is ranked as coldest even in hot weather because of the constant air movement through the perforated walls, limited occupants control and the fact that the sun only gets its rear side for a short period during the day. Another building which is ranked as slightly cold during hot weather is GBG because of the outside temperature and orientation even though the material used has good thermal resistance. The hottest of all the surveyed building with a mean of 3.54 is K kare due to the curtain wall exterior, artificial lighting during the day and lack of proper shading and orientation.

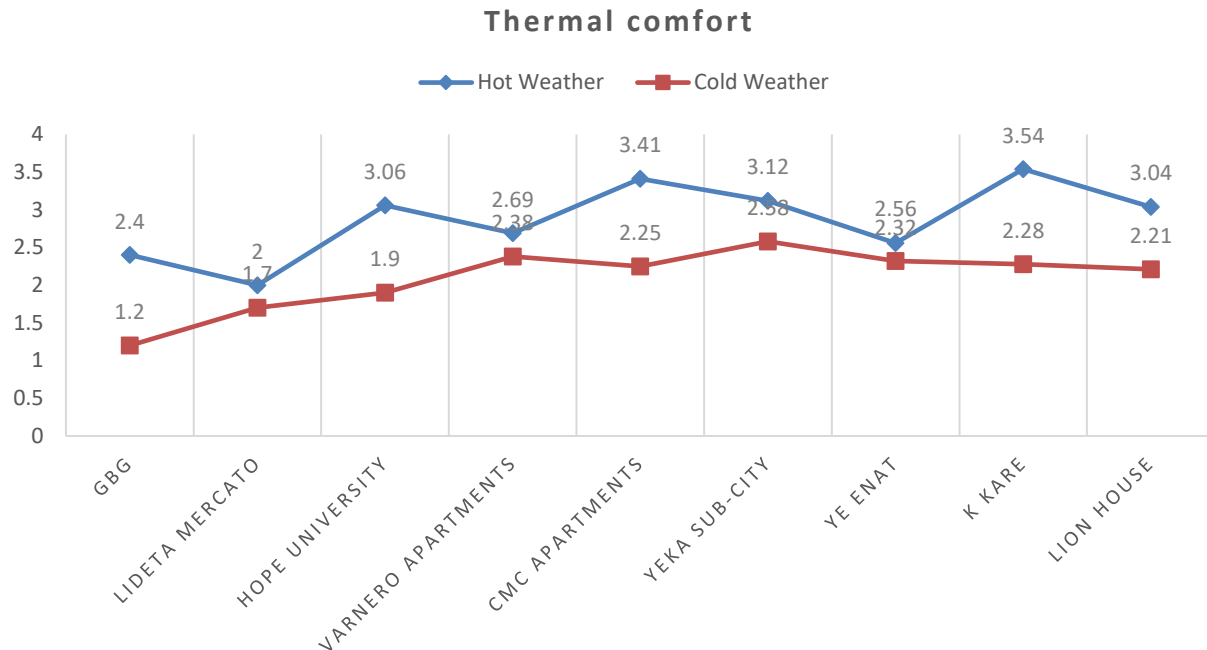


Figure 68: Thermal Comfort

(Source: computed by the researcher, 2017)

Whereas during cold weather, most building range from very cold to cold with mean score range of 1.2 – 2.58, the coldest being GBG and Lideta Mercato due to reasons explained above. Ye enat building constructed of stone cladding have the least fluctuation during hot and cold weather whereas HCB and glass show great difference during different seasons. Therefore, in order to maintain regular and moderate indoor temperature with optimum indoor environmental quality factors mentioned above should be considered to the fullest.

IV. Acoustic and views

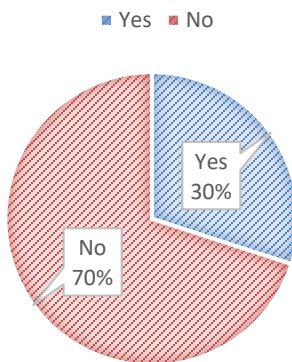
Noise from the outside roads and surrounding activities is the cause of acoustic problems in most building. While the partition material and level of activity also contribute to higher noisy areas. This is observed in building including Ye enat and K kare. In regards to views, some building such as GBG, ICS, CMC and Yeka sub-city offer views to the outside while there is certain restriction in some sides including Hope university library, Lideta Mercato and K kare.

V. Dampness and microbial growth

Out of the ten surveyed, 8 buildings have water leakage problems such as seepage between ill constructed details of windows, doors, roofs, plumbing system and groundwater entry causing dampness. Whereas, out of the 8 buildings, none except CMC claim there is microbial growth. When buildings are damp for a sufficient time period, mold and bacteria will often colonize it. The molds and bacteria can produce microscopic airborne particles, some containing allergens or chemicals with the potential to induce inflammation in the respiratory system. Therefore, to prevent this problem attention to detail during construction and rapid maintenance is necessary.

VI. Efficiency and health problems

Health problems



Efficiency and productivity

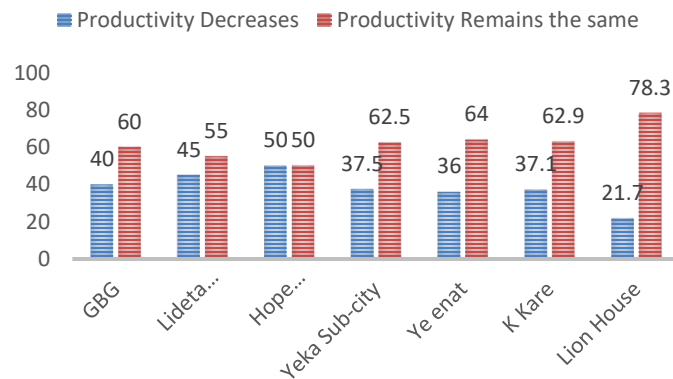


Figure 69: Efficiency and health problems due to IEQ

(Source: computed by the researcher, 2017)

As shown in the pie chart above, health problems such as flus, colds and allergy is common in buildings including CMC, K kare and Lideta Mercato. This is caused by foul smell coming from damp rooms with microbial growth, stuffiness and poorly ventilated rooms as well as wind drafts from openings in the building.

In an optimum and suitable indoor environment, building occupant become efficient and productive in their work which is one of the attributes of green building. However, as the bar chart above shows the productivity of building occupants in almost all buildings fluctuates due to the indoor quality. Therefore, if the principles of green buildings are implemented and the indoor

quality of the building is improved then the efficiency of the occupants can be raised, profiting that particular company and perhaps eventually the country.

5.2. Challenges and Opportunities in implementing Green building principles

5.2.1. Respondents profession and Professional experience

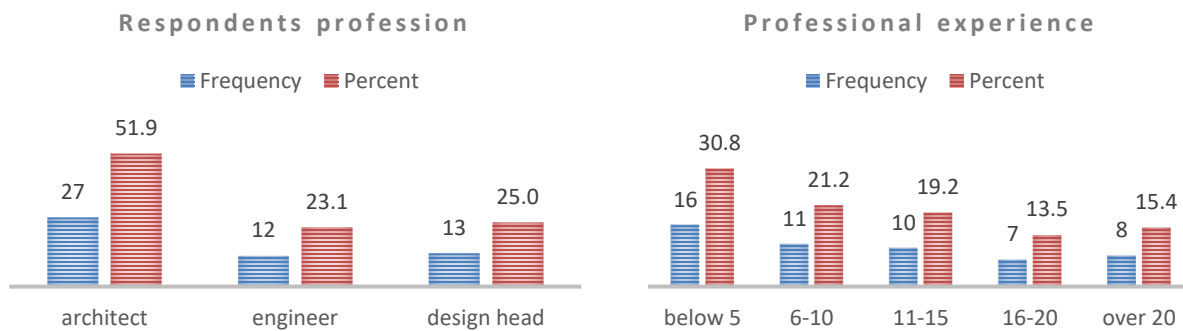


Figure 70: Respondents profession and Professional experience

(Source: computed by the researcher, 2017)

Based on the figure above about 51.9% of the respondents are architects, followed by managers or design heads making up 25% and lastly 23.1% are engineers. When dealing with professional experience, out of the 52 practitioners, 30.8% have less than 5 years of experience, 21.2% have 6 - 10 years of experience while 19.2% have 11 - 15 years of experience and 13.5% have 16 - 20 years of experience and the remaining 15.4% have practiced their profession for more than 20 years.

5.2.2. Familiarity with green building concept

This question was asked to understand the extent of knowledge of the consultants about the concept of green building and their response is as follows. As shown in the figure below, 8% of the total respondents are totally unfamiliar with the concept and another 8% said they are familiar with the concept. On the other hand, the majority of 42% answered fairly familiar with the concept of green buildings. The remaining 34% and 8% answered neutral and completely familiar respectively. Therefore, the majority of the respondents are familiar with the concept but it should be noted that most of their knowledge about green building is theoretical and not on the construction of it.

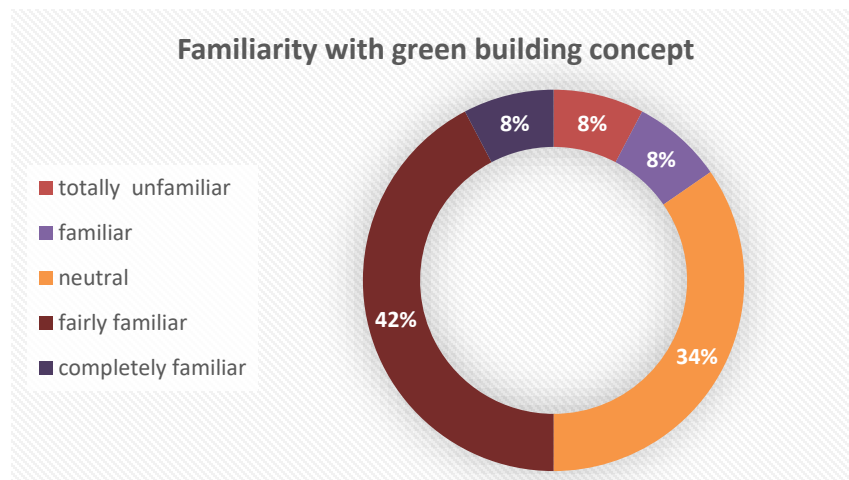


Figure 71: Familiarity with green building concept

(Source: computed by the researcher, 2017)

5.2.3. Application and difficulty of green building principles

To further investigate the gap and challenges that exists in the adoption of green building concept, it is important to find out which principles the consultants have applied and which principles they found easy or difficult to implement in their design.

Accordingly, out of the total 21 consultants surveyed only one (Abba Architects) have been involved in a certified green building project which is Gulele Botanic Garden. However, some consultants claim they have integrated some concepts of green building in their design. Based on the figure below, in regards to sustainable site only 28.8% of the respondents replied, they have applied certain ideas of it in their design, the remaining 71.2% answered no or not sure. Concerning water efficiency 28.8% of the practitioners have in-cooperated this idea into their design while some ideas of energy efficiency was integrated by 36.5% of the respondents. On the other hand, the ideas of sustainable material and indoor environmental quality was applied by 23.1% and 36.5% of the respondents respectively.

Hence, the ideas of energy efficiency and indoor environmental quality are applied the most because certain concepts such as using natural lighting, natural ventilation and energy efficient fixture including LEDs are relatively simple and are also seen in the surveyed buildings as well. But the other principles requiring more investment, knowledge and technology lack application so further work should be done dealing with sustainable site, material and water efficiency.

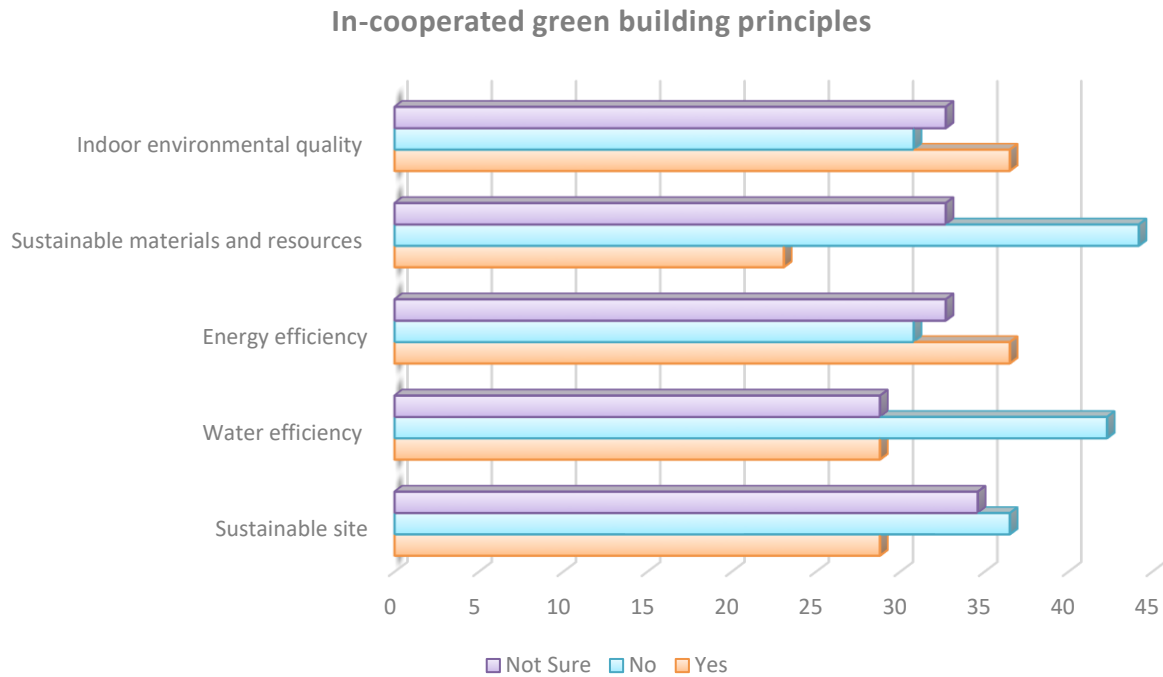


Figure 72: In-cooperated green building principles

(Source: computed by the researcher, 2017)

According to the respondents who aired their views on which aspects of green building are difficult to apply in Addis Ababa, waste management and recycling was ranked the highest with 50% of the respondents saying, there are many challenges to applying it in Addis Ababa. The second most difficult with 44.2% is reusing and recycling of waste water while the third and fourth with 40.4% and 34.6% respectively is using of material that can be used after the building life and using of materials with low environmental impact. On the other hand, the least difficult, according to the 52 practitioners are use of daylighting (1.9%), natural ventilation (9.6%), use of artificial lighting control such movement sensors and dimmers (9.6%) and site landscaping (11.5%). The figure below shows the answer of the respondents to the question discussed above.

Difficulty of green building concept

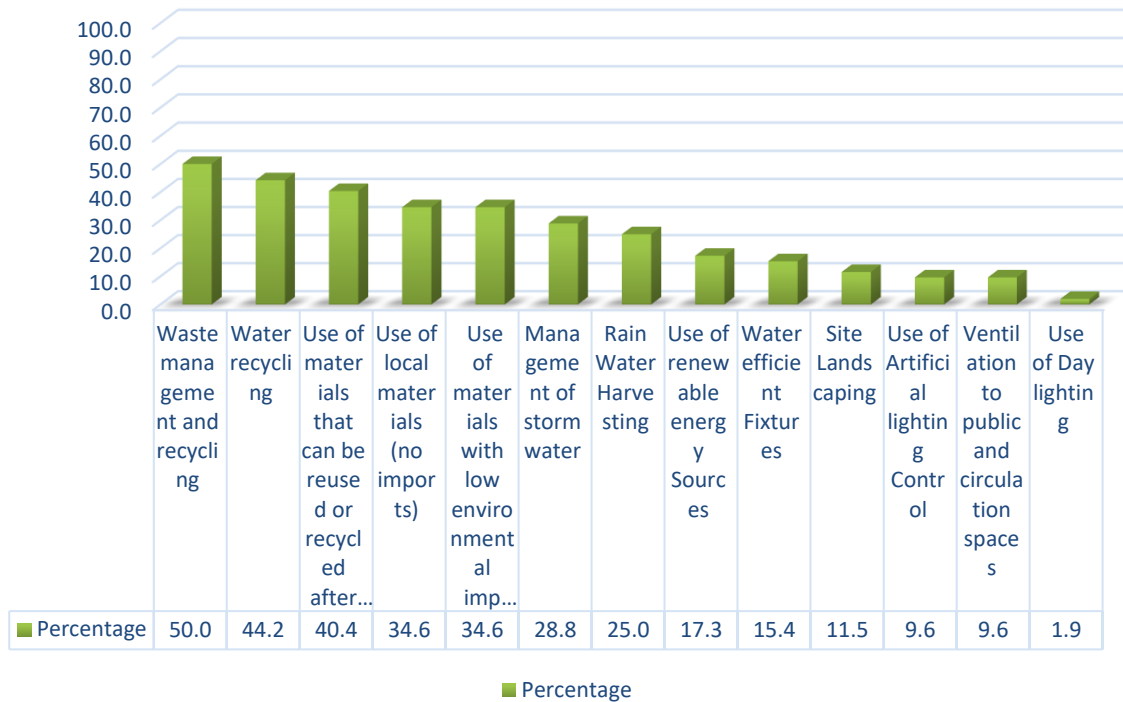


Figure 73: Difficulty of green building concept

(Source: computed by the researcher, 2017)

The aspects of green building stated as the most difficult are challenging not just because of lack of awareness and technology but also due to lack of integration between the designer, client, contractor, building material producers and building operators or managers at the start of any architectural project. Therefore, there should be constant communication among the design, construction and operation team so as to avoid the mistakes seen in the Gold certified Gulele Botanic Garden where the wastewater treatment is not functional and the green roof is damaged.

5.2.4. Economic Challenges

Concerning economic challenges in applying green building principles in Addis Ababa, consultants were given three questions and asked to rank them in Likert scale (from strongly disagree to strongly agree), their response is shown in the figure and table below.

Economic Challenges

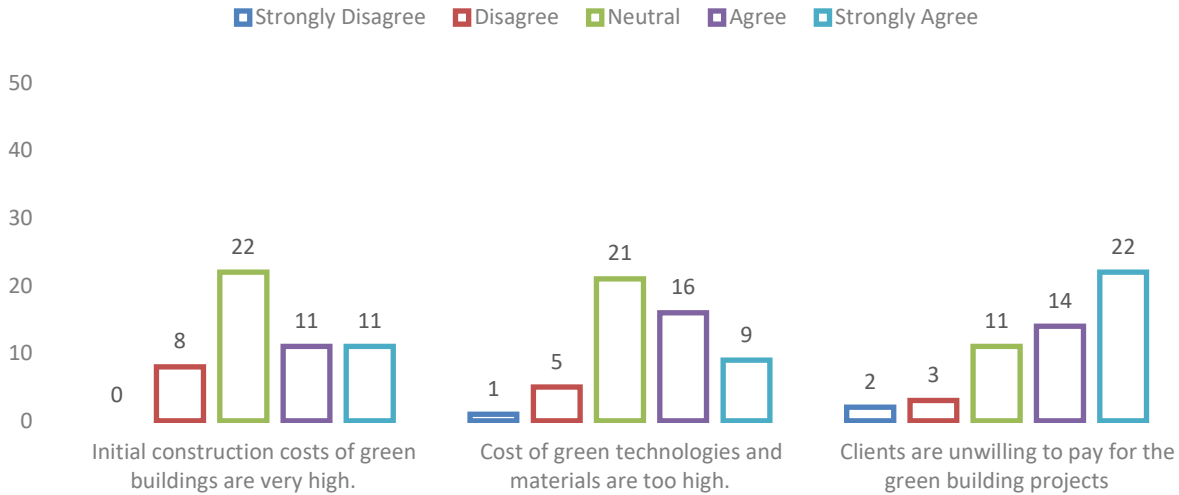


Figure 74: Economic Challenges

Table 1: Mean Scores for economic challenges

	Mean	Std. Deviation	Rank
Initial construction costs of green buildings are very high.	3.48	1.000	3
Cost of green technologies and materials are too high.	3.52	.960	2
Clients are unwilling to pay for the green building projects	3.98	1.111	1

(Source: computed by the researcher, 2017)

The overall result shows that most of the respondents agreed on clients' unwillingness to pay for green buildings with a mean value of 3.98. Concerning high price of green materials and technologies the majority, 40.4% answered neutral probably because most consultants find it difficult to use recycled and low environmental materials as mentioned in the above section. However, this question was ranked the second with a mild agreement of mean 3.52. Lastly, the majority of 42.3% respondents answered neutral to the higher initial cost of green building mostly because most consultants haven't participated in the construction of green building. Therefore, as indicated above it is very essential to inform clients about the benefits and gains of going green and raise awareness among them as well as create an economic atmosphere where investing in green building is rewarded.

5.2.5. Awareness and education challenges

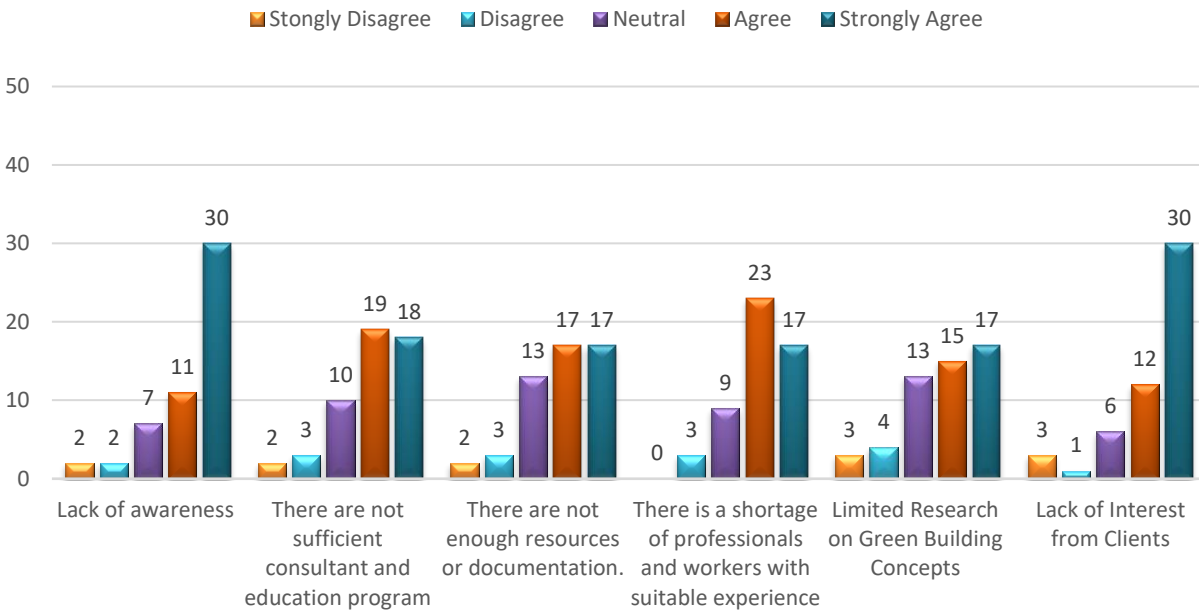


Figure 75: Awareness and education challenges

Table 2: Mean score for education and awareness challenges

	Mean	Std. Deviation	Rank
Lack of awareness about green building	4.25	1.082	1
There are not sufficient consultant and education program about green building concept.	3.92	1.064	3
Because green building knowledge (technologies, materials) is new, there are not enough resources or documentation.	3.85	1.073	4
There is a shortage of professionals and workers with suitable experience.	4.04	.862	2
Limited Research on Green Building Concepts	3.75	1.169	5
Lack of Interest from Clients	4.25	1.118	1

(Source: computed by the researcher, 2017)

The overall result show that awareness and education is more of a challenge than economic issues. 57.7% of the total respondents said they strongly agree that lack of awareness and lack of interest from clients in a major challenge. The highest and equal mean of 4.25 of this two issues

suggests that, it is the most agreed point by most respondents. The second most agreed issue is the shortage of professional specializing on green building with a mean score of 4.04 in which 44.2% agreed and 32.7% strongly agreed. This is followed by insufficient education programs, resource or documentation and research on the topic. Therefore, working on education and awareness and changing the mindset of all involved in the industry is key to the development of green buildings.

5.2.6. Industry and organizational challenges

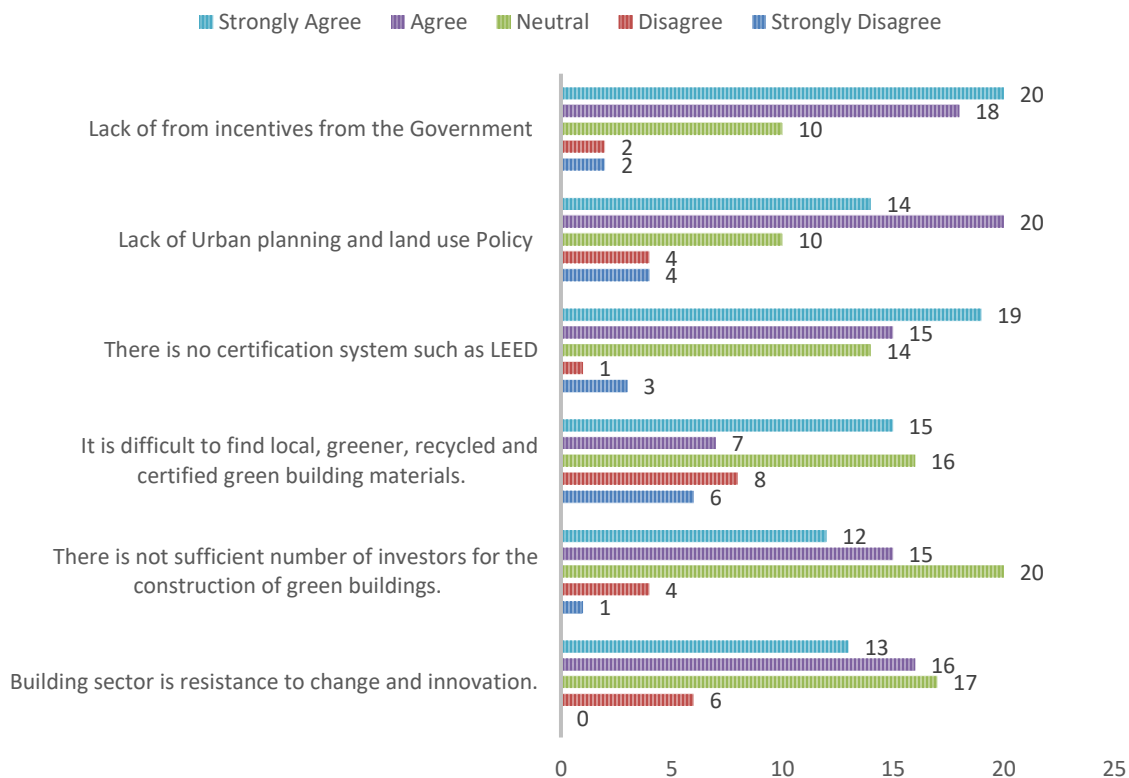


Figure 76: Industry and organizational challenges

Table 3: Mean score for Industry and organizational challenges

	Mean	Std. Deviation	Rank
Building sector is resistance to change and innovation.	3.69	.981	3
There is not sufficient number of investors for the construction of green buildings.	3.63	.991	4

It is difficult to find local, greener, recycled and certified green building materials.	3.33	1.354	5
There is no certification system such as LEED	3.88	1.114	2
Lack of Urban planning and land use Policy	3.69	1.181	3
Lack of from incentives from the Government	4.00	1.048	1

(Source: computed by the researcher, 2017)

In this section the most agreed upon issue by the consultants' is lack of government incentive with a mean value of 4.0 followed by the absence of certification system such as LEED in the city with a mean value of 3.88. The 52 respondents are relatively in mild agreement in regards to the issues of building sector being resistant to change and lack of urban planning or land use policy with an equal mean value of 3.69. Therefore, it is clear from the overall result that the participation of government in the green building movement is as important as other stakeholders and work should be done to motivate the government to take charge and lead in expanding the development of green buildings.

In addition to the above stated challenges, some of the respondents also mentioned the following issues as a challenge to implementation of green building practice in Addis Ababa

- There is absence of laboratories for experimenting on green materials and other aspects of green building.
- The plot area of buildings in small and mostly used for the whole building making some concepts of green building hard to apply.
- The current land value of the city is very high and allocating space to green areas to achieve sustainable site in unacceptable to most clients.
- Lack of local inspirations and examples to be follow.
- The city's economic status hasn't reached the stage of green building

5.2.7. Opportunities in implementing green building practice

Regarding the opportunities that encourage the uptake of green building principles, most of the respondents stated the moderate weather of Addis Ababa as an opportunity saying by using only natural lighting and ventilation, energy consumption can be reduced and IEQ can be achieved. Secondly, the construction boom and different renewal and revitalization projects that are being

undertaken by the city currently create chances for new and innovative ideas in the building industry. Thirdly, the central location of Addis Ababa allows access to local materials from different areas of the country. Lastly, a few consultants stated existing and future collaboration with architectural firms from other countries with sufficient experience in green building is a great prospect.

Table 4: Major opportunities according to practitioners

Major Opportunities	Rank
Weather condition of the city	1
Current construction boom	2
Central location of Addis Ababa	3
Existing and future collaboration with architectural firms from other countries	4

(Source: computed by the researcher, 2017)

5.3. Strategies for application of green building practice

With the intent to find out the most appropriate strategy to accelerate the green building movement in the Addis Ababa, the consultants were surveyed and their response is described in the figure and table below.

As the overall results show in the figure and table below, all of the 7 promotion strategies are considered to be significantly important, implying that these strategies have an enabling role in promoting green building. However, the most agreed upon issue as the best strategy to implement green building principles in Addis Ababa is Public Awareness Campaigns with a mean score 4.62. This strategy is strongly agreed by 72.1% of the total respondents. The second is Education and training focusing on green buildings with a 4.58 mean followed by financial incentives and development of a green building rating system with 4.37 and 4.35 mean score respectively. The above mentioned issues were identified as the top four important promotion strategies.

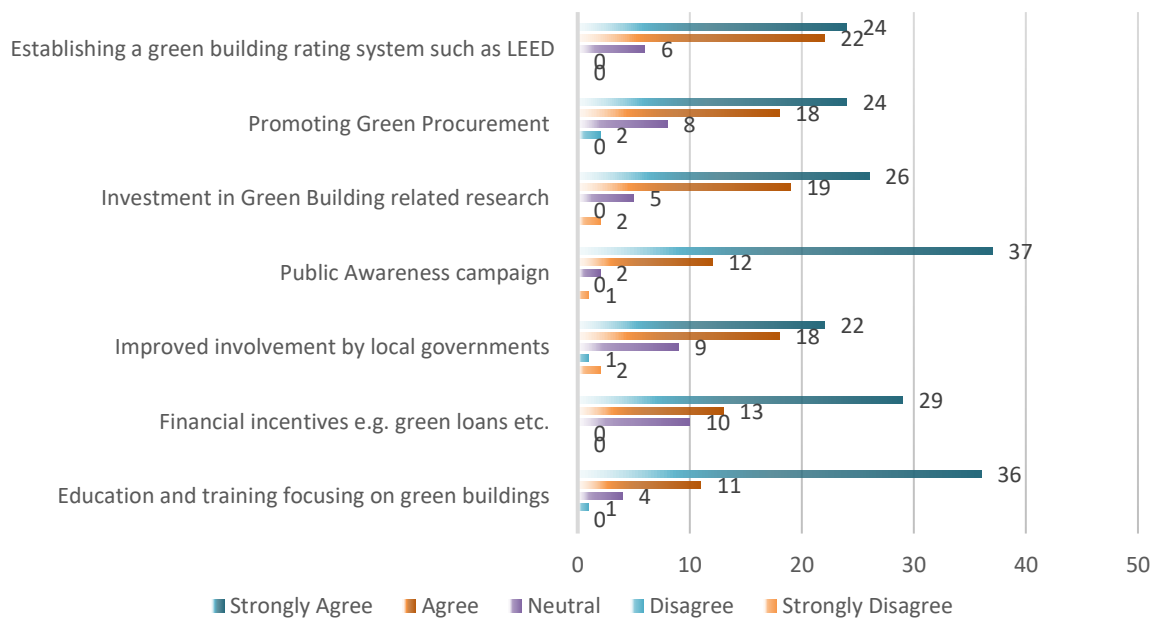


Figure 77: Strategies for application of green building practice

Table 5: Mean score for strategies for application of green building practice

	Mean	Std. Deviation	Rank
Education and training focusing on green buildings	4.58	.723	2
Financial incentives e.g. green loans etc.	4.37	.793	3
Improved involvement by local governments	4.10	1.015	7
Public Awareness campaign	4.62	.745	1
Investment in Green Building related research including cost-benefit	4.29	.936	5
Promoting Green Procurement	4.23	.854	6
Establishing a green building rating system such as LEED	4.35	.683	4

(Source: computed by the researcher, 2017)

Chapter VI

6. Summary of Findings and Discussion

In this chapter, the data analyzed is summarized and discussed in accordance to the three objectives set and the research questions asked at the beginning of the research and compared to other studies and literatures.

The four research questions formulated for this study are as follows:

1. What are the building practices in Addis Ababa? How does it relate to green building principles?
2. What are the opportunities that boost the green building practice?
3. What are the challenges restricting the application of green building principles in Addis Ababa?
4. What needs to be done in order to reduce the constraints and exploit the opportunities?

6.1. Building practice in Addis Ababa and efforts of application of green building principles

The first research question was formulated with the intention to analyze the gaps between the 10 surveyed buildings and green building concept in order to identify which principles need the utmost attention to bring about sustainability of buildings in the city. The issues are discussed below.

6.1.1. Gaps between green buildings and surveyed buildings concerning Sustainable site

- Application of alternative sustainable transportations such as bicycle, low emitting and fuel efficient vehicles is very limited.
- Little is done to reduce the overall footprint of the building
- Providing space for open and green spaces is very rare especially for buildings located in the inner city

- Sustainable stormwater techniques such as rain gardens, bio swales, bio retention and others are completely lacking
- Habit of planting exotic plants rather than native and succulent species to reduce water usage and urban heat island effect
- The design, construction and maintenance for green roofs and walls require further work

As Adebayo (2002), argues in many urban areas of Africa, the construction of buildings occupy the entire site with total disregard to the natural environment. This is consistent with the findings of this study, that the majority of surveyed buildings especially in the inner city lack spaces in which most green building principles such as open spaces and site landscaping, impervious surfaces and sustainable stormwater can be implemented.

As an alternative to open spaces on the ground, green roofs and walls, can provide many benefits but the study has identified that design, construction and maintenance of these green roofs and walls is a problem (as evident in the leaking roof of Hope and the damaged green roof of GBG) due to main reasons including: lack of awareness and technology among others. This finding is supported by (Labuschagne and Zulch, 2016) proving that lack of knowledge amongst professional regarding the construction of green rooftop systems and lack of knowledge regarding the advantages of green rooftop systems are the major obstacles in most African countries.

6.1.2. Gaps between green buildings and surveyed buildings concerning water efficiency

- Complete dependence on municipal water supply
- No effort done to recycle rainwater or wastewater
- Using landscape that require constant irrigation and using tap water for watering it
- The irrigation technique of all buildings is spraying water by hoses instead of supplying water directly to the plants which may result in evaporation of the water into the air
- Installing of high efficient fixture is lacking especially water faucets and shower heads
- Lack of awareness about the technology, design and maintenance of wastewater treatment

The study's findings show that, water efficiency is one of the least applied green building concept with none of the surveyed building recycling waste water (GBG has a waste water treatment but it is not functional). As explained in (El Yamany et al, 2016), the use of non-sewage and grey water for on-site use such as site-irrigation will minimize demand on the local aquifer. A sustainable building should reduce, control, and/or treat site runoff, use water efficiently, and reuse or recycle water for on-site use. However, due to possible reason such as lack of space and knowledge, fear of occupants' attitude about recycling (lideta Mercato) has restricted its application. In addition to this, (Taeka, 2015), have also identified the major gap in water efficiency in Addis Ababa buildings is lack of water recycling leading to higher water bills.

According to the findings of this study (practitioners response) and (Biggs, 2017), reducing water use from fixtures and equipment is perhaps the easiest method to reduce total potable water use. It does not require extensive design solutions, just specifying certain products. However, only the recently built buildings utilize it, especially dual flushing while the older ones have not integrated this technology at all even now.

6.1.3. Gaps between green buildings and surveyed buildings concerning energy efficiency

- Lack of emphasizing on the proper orientation and building envelop to reduce use of ACs and fans
- Experimenting and utilizing different types of renewable energy is very limited
- Lack of consideration to natural lighting when wall partitions are constructed resulting in use of artificial lighting which leads to utilizing mechanical ventilation techniques
- Energy demand, consumption and conservation is not considered in early stages of the design process
- Negligence of building occupants and responsible bodies to turn off appliance and lighting when not in use
- Awareness on high efficiency appliances such as energy star equipment and lighting is low

In green building literature, buildings do not use HVAC&R or select those that minimize or eliminate the emission of compounds that contribute to ozone depletion and climate change. (USGBC, 2011). The majority of surveyed buildings do not use any HVAC suggesting with little

modifications and carefulness in selecting orientation and material and by promoting passive design, a balance can be achieved between energy efficiency and quality indoor environment due to the weather of the city.

Renewable energy, energy efficient appliances as well as planning for energy efficiency and energy modeling during the design stage (such as calculating energy demand and consumption in different scenarios) is one part of energy efficiency that is very much lacking in the surveyed buildings. This is consistent with a research conducted in another African country, (Slabbert, 2013), which states few buildings had solar panels installed at their commercial building because most owners felt that it was too expensive to set up the panels, irrespective of the fact that they would probably save money in the long term. Therefore, perhaps expensiveness among other reasons such as lack of technology and awareness can be reasons to its low applicability in the in Addis Ababa as well.

Commercial and offices buildings leave lighting and appliances on when not in use more when compared to other functions due to negligence and small partitioned spaces. These buildings also use generators during blackouts increasing energy consumption.

6.1.4. Gaps between green buildings and surveyed buildings concerning material and resources

- Use of materials not appropriate for the weather condition
- Use of materials with low thermal resistance resulting in higher temperature which might increase energy consumption through the use of HVAC
- Lack of reusing and recycling of waste
- Limited technology and awareness about low impact and environmental friendly materials
- Shortage of using rapidly renewable materials and recycled materials
- Dependence on imported materials

A study conducted in Kenya, (Were, 2015) reveals that the use of materials with low environmental impact was the most incorporated concept under sustainable materials followed by use of local materials and components. This could be attributed to the fact that there has been introduction of various environmental laws under authorities. However, in opposite to this, the

findings of this research shows that sustainable and local materials are applied the slightest, perhaps lack of regulations in relation to this issue has some contribution to it.

Concerning use of recycled materials, the study conducted by Were (2015) concurs the findings of this study, both showing that the use of recycled materials are not incorporated in most buildings. Another study (Rode, 2011) discloses that recycling of building materials is a relatively new concept and has only been assessed in a few studies suggesting more work is needed in the application this concept.

In regards to waste management, paper and plastic bottles are the main waste types in commercial, school and office buildings while organic wastes make up the largest waste category in residential buildings. In addition, recycling and reusing of waste is a very new concept applied in only two buildings. This finding is supported by the study of Taeka (2015), which states that almost all of the buildings studied do not sort, reuse and recycle garbage.

6.1.5. Gaps between green buildings and surveyed buildings concerning Indoor Environmental quality

In the literature concerning IEQ, green buildings balance the impacts of ventilation rates on energy use and indoor air quality to optimize energy efficiency and occupant comfort. It also provides building occupants connection between indoor spaces and the outdoors through the introduction of daylight and views among other issues. However, the following gaps are identified in this category:

- Indoor temperature fluctuation during the day
- Unbalanced ventilation affecting the indoor temperature
- Lack of ideal orientation with proper shading or sun breakers from harsh sun
- Leakage causing dampness and microbial growth
- Poor indoor quality causing decrease in efficiency and sickness
- Room lay outs that don't take advantage of the natural ventilation and lighting
- Lack of concern and limited access to low emitting materials
- Use of materials and facades that does not exploit the comfortable weather condition of the city affecting the IEQ
- Shortage of regulations in regards to smoking in buildings

- Thermal comfort of occupants fluctuates during the day and season especially during cold weather which shows that the majority of the surveyed buildings are below the average mean score.

In general, when compared to other concepts of green building, indoor environmental quality is relatively applied more with the exception of the gaps described above. Other studies such as (Matthiessen and Morris, 2004) have also supported this finding by stating that, of all the categories, the LEED points in IEQ tend to be the most often sought because so many of these points are already incorporated into normal designs, due to building codes and availability of materials.

Therefore, through small modifications, attention to detail in the design, construction and maintenance of buildings and proper material selection and orientation, this concept can be achieved.

6.2. Challenges and opportunities in implementing green building principles

The second research question analyzed the difficulties and prospects in applying green building concept in Addis Ababa in order to give justifications of the gaps identified in the above question.

According to the data collected about the green building concept, the practitioners applied the least in their projects are those requiring more investment, knowledge and technology such as sustainable site, material and resources and water efficiency. In addition, waste management and recycling, water recycling, use of materials that can be reused or recycled after the building's life, use of local materials (no imports), use of materials with low environmental impact, management of stormwater and rain water harvesting are ranked as the top six most difficult green building concepts to implement in Addis Ababa.

This result complements the findings of the first research question as the least applied green building principles in the surveyed buildings are those mentioned above. In addition, (Matthiessen and Morris, 2004), supports this finding by stating, most certified projects achieve 5 or 6 of the total 14 sustainable site points, with higher LEED levels achieving 9 or more showing the difficulty of this concept. Furthermore, this studies also revealed few projects incorporate the building reuse points as it can be difficult for remodeling projects without a significant increase in cost plus most

projects are unable to meet both the rapidly renewable materials and reused materials because of cost and the difficulty in achieving the percentage of building material.

The greatest obstacles to the implementation of green building principles are lack of awareness and lack of client's interest, both having the highest rank. This finding is in line with certain studies such as (Hankinson and Breytenbach, 2012) revealing, that professionals within the built environment are not yet fully trained in green construction principles and thus lack education and experience to properly carry out such practices. This is because it was not studied or comprehensively covered at tertiary institutions, since it is a specialized field of study. Jacobs (2011) also identifies lack of knowledge about green practices, lack of knowledge about the effects of non-green practices on the environment, lack of training and education as the main barriers to the implementation of green building.

As the result shows, lack of interest from clients has both awareness and economic aspects to it. This is further attested by (Rydin et al., 2006) which argues that not only are professionals supposed to be knowledgeable, professionals need to form an integrated team from conception to inception comprising of the developer/owner, project manager, contractor, architect, services engineer, structural engineer, civil engineer, environmental engineer, landscape consultant, cost planner and building surveyor.

On the other hand, there are some studies such as (Bernstein and Mandyck, 2013) with findings indicating that higher first costs for green building as the most significant obstacle, this issue however, is ranked as one of the least challenges to implement green building principles in this study.

The study further revealed that, lack of incentive from government as one of the main challenges to green building implementation. This is consistent with the findings of (Gundogan, 2012) placing lack of government support as the first economic barrier to the widespread adoption of sustainable design strategies. But, the provision of incentives will undoubtedly reduce the presumed high up front cost for green building projects.

In addition, lack of LEED certification and proper land use and urban planning are identified as hindrances to its implementation. As Tessema, et al. (2010) puts it, building site is often overlooked as one of the significant elements of sustainable buildings and construction, even

though, this has significant impacts on several sustainability aspects. In many urban areas of Africa, a large proportion of existing green area has been destroyed and all trees have been removed instead of integrating them to the built environment. In some cases, the buildings have been constructed so densely that air movement is prevented even after the construction has been completed. Therefore, policies and planning regulation are very important in guiding the building industry to a more sustainable path and providing attention to this issue is vital to bring about green building concept in Addis Ababa.

With all the challenges above in mind, the urban environments also has some opportunities for implementing green building concept. The climatic and weather condition of Addis Ababa was identified as a major prospect in applying these principles. This undoubtedly is suggested by many studies including (Zegeye and Helawi, 2012) uttering that Ethiopia has an ideal climatic condition and that the design of buildings should take advantage of it. The influence of climate in green building design is reflected by (Agboola,2011) which states design of pleasant buildings that ensures physiological comfort of users is only achieved through an understanding of the climate it continues saying that climate and weather are the major environmental factors which directly affect building forms and designs.

The second identified potential is the current construction boom taking place in the country. This finding concurs the findings of a study conducted in Africa by (Umar and Khamidi, 2012) which reveals the region's growing urbanization and high population densities are the natural potential for the building of the highly-economical energy systems. The central location of the city makes transportation and access to different materials easy while collaboration with different organizations allows the transfer of knowledge and education which is a major challenge in implementing green building concept in the city.

6.3. Appropriate strategies for application and implementation of green building practice

6.3.1. Public Awareness and Education

Literature distinguishes the strategies to implement green building practice into three categories: the prescriptive or regulatory approach, the incentive-based approach, and the promotional/educational approach. The findings from this study reveals that the best strategy

according to the practitioners is raising awareness through public awareness campaigns as well as education and trainings focusing on green buildings which falls under promotional and educational approach.

This finding is consistent with Umar and Khamidi (2012) which reveals that the rate of success towards sustainability in construction would depend mainly on enhancing awareness, knowledge and understanding of the influences of stakeholders' action.

Nevertheless, other studies such as Were (2015) and Chan, Darko, and Ameyaw (2017) disclosed that strict enforceable urban land and planning policy and financial and market-based incentives to be the best strategy respectively. This contradicts with this research's finding showing that green building concept is still at its preliminary stage in Addis Ababa and has not reached the level of other cities. Therefore, informing and educating the public and all stakeholders is the best option to implement green building concept.

The following are important strategies under this category:

- Television, newspaper and radio coverage can spread the message about green buildings to different people. Interviews with experts and shows such as 'ke bet eske ketema' and 'bet lombosa' can boost public awareness.
- Conferences, workshops, seminars and educational opportunities on practices & benefits of green buildings design and technologies
- Different expos and exhibition hosted by the building industry such as 'Addis Built', "China construction expo" and others present a good opportunity to diffuse information about green buildings.
- Dissemination of magazines, brochures, flyers and newspapers
- Outdoor advertising on transit shelters, billboards, area maps, benches and buses
- Creating a website and using interactive social medias and technologies (such as Facebook, twitter, YouTube, etc.) to create engagement with potential audiences
- Trainings with continuing education credits in universities, colleges and TVET
- Guidelines and codes to help communities understand green building design
- Public recognition of efforts and awards for green building projects
- Set up educational programs and better curricula on green building agenda
- Lead with good practices "on the ground"/walking the walk

6.3.1.1. Planning for Public Awareness Campaigns

Chan et al. (2017) pointed out that education and awareness campaigns are always the welcome means for continuous promotion of a green building market, and the task could be shared between industry associations and governmental and non-governmental organizations.

While providing education to these three groups of stakeholders is valuable for encouraging the adoption of green building technology in the industry, to further foster green buildings adoption, educating the entire public should also be an important approach to enhance the attractiveness of green buildings in society. Society's attitude toward it could be translated into market demand, which impacts corporate behavior, and this can originate from public education. (Ofori and Ho cited in Chan et al., 2017).

a. Concept of public awareness

The primary meaning of "awareness" in the communication industry is to make a target audience "aware of" a product, service or issue. Public awareness campaigns are designed with the main objectives of: drawing the public's attention to certain public issues or problem areas and bringing about behavior and social change. (Umar and Khamidi, 2012)

b. Procedures for public awareness campaigns

I. Identify partners/stakeholders and form a core team

The team should be comprised of different associations, government and non-governmental organizations, NGOs, consultants, academicians or any concerned individuals. The intention is to establish strong line of communication, bring unique perspectives from diverse population groups and share the cost and burdens of the campaign.

II. Establish goals and objectives

The campaign goal is aimed at increasing knowledge, influencing attitudes and changing the practice of the building industry. Thus, the goal of this particular public awareness campaign can be the following depending on the resources available and timeframe.

- Improve overall awareness about green buildings
- Increase public awareness of the benefits of green building practices for new and existing buildings.
- Increase public awareness and understanding of green building principles
- Increase public awareness and understanding of green building ratings systems

III. Identify target Audience

Awareness campaigns are successful when the target group is identified and strategies can be tailored to that particular group(s). In these case, the target group can be:

- | | |
|--------------------------------------|---|
| • Designers | • Contractors |
| • Engineers | • Builders |
| • Developers | • Academicians |
| • Home owners | • Financial institutions |
| • Real estates | • Other affiliated with the building industry |
| • Building material suppliers | |
| • Local government and policy makers | |

IV. Develop Key campaign message

According to GTZ (2006), the effectiveness of a strategy largely depends on the ability of its messages to catch the attention and understanding of the target audience. For the message to be successful, it should follow the KISS AIDA principle that is often used in social marketing: Keep it short and simple in order to catch the audience's Attention, raise its Interest and instigate Desire that will lead to Action in relation with a desirable sustainable practice.

As stated in (Pardo, 2006), there are three basic channels through which people can be addressed. These are informative, persuasive and specific activities. This categorization comes from the psychological elaboration of attitudes and how they are subdivided into rational, affective and motor components.

Therefore, the message for green building awareness campaign should consist of:

- a. **Informative message (rational):** hard facts which show that green buildings are more sustainable than conventional building. Graphs and other Medias can be used to show the statistical evidence of the spatial, social and environmental attributes of green buildings.
- b. **Persuasive message (affective):** this are messages related with comfort and well-being. Green buildings can be promoted by persuasive message by mentioning its association with healthy and productive environment, clean and fresh air, environmentally friendly, better life quality through improved IEQ and reduced operation cost.
- c. **Specific activities (motor components):** promoting green buildings through actions such as visiting certified green buildings, going to the laboratory to experiment on green materials, organizing recycling days and others.

Therefore, by using the combination of the above techniques a convincing message can be used to increase public awareness as well as promote behavioral and mindset change towards green buildings. In addition, logo, slogans, themes even characters that convey the key message about green building can be used to attract groups.

V. Select communication tool

There are a variety of communication tools that can help get the messages about green buildings across, these may be constrained by budget and time. Some of the tools are discussed below.

- Mass media
- Tradeshows and events
- Print advertising
- Outdoor advertising
- Seminars and workshops
- Websites and social media
- Outreach and trainings

VI. Cost of activities

A breakdown of cost of each activity and funding source should be provided. The activities should be cost effective and receive the support of the campaign team.

VII. Implementation

In this stage decisions are made about who will do what and when. The project should be broken down into small easily doable tasks with identified inputs, outputs and indicators. Actions must be taken according to the timeline of activities and appropriate target groups.

VIII. Monitoring and Evaluation

Evaluation to determine the outcome of the event should be completed after each public awareness event. It should assess how effective the activity was in reaching the target audience by using evaluation sheet that ask the participants' overall opinion of the event and any suggestions to improve future events.

6.3.2. Economic and Financial incentives

The finding of this study shows that after public awareness and education, the third essential strategy to implement green buildings principles in the city is financial incentives. These indicates that incentives from the government and other private parties, such as financial institutions, has an enormous influence in driving construction stakeholders to embrace green building concept.

This is a prevalent finding in many researches including (Chan, Darko, and Ameyaw, 2017) which professes, financial incentives provide a valuable economic support for the industry, particularly individual stakeholders or firms as economic issues remain the most essential issues for the business survival of every stakeholder. Moreover, (Maxwell et al. cited in Chan, Darko, and Ameyaw (2017) maintained that unless green building developments have a sufficient market demand, financial incentives are necessary conditions to help share the additional costs in green buildings. Below are economic and financial incentive strategies helpful in implementing green building principles:

- Create incentives within tax, insurance, procurement systems to reward green building projects
- Direct grants, funds and subsidies for green building projects
- Provide larger loans for green buildings
- Development density bonuses, such as exceptional height or floor area ratio permissions
- Expedited permitting and fee reductions

- Higher financial value of certified green buildings
- Lower premiums for green buildings
- Utility discount such as electric bill discounts
- Public recognition and marketing advantage

6.3.3. Green building rating system

Establishing a green building rating system such as LEED, BREEAM and others is ranked as fourth vital strategy in applying green building principles. This finding confirms the viewpoints of various researchers suggesting, green building rating systems are important to green building adoption because they provide useful and helpful guidance and information concerning green building to the industry professionals and the public. Furthermore, green building rating systems are helpful in producing more accredited and skilled green professionals.

Nonetheless, it is important to note that green buildings differ among countries due to the different climatic conditions and construction practice, hence it is essential to develop authoritative green building rating systems that suits the specific local environment and climate to promote wider application of green buildings principles in a more efficient manner.

6.3.4. Green building related research

Green building is fairly a new concept in Addis Ababa as the findings above show and it is no wonder to find green building related research as the fifth strategy to implement green building principles. This shows that informative researches in which the spatial, social and environmental attributes of green buildings and its benefit compared to conventional buildings are deliberated is very important.

In addition, carrying out researches such as cost and benefit study providing stakeholders with adequate, accurate, and better information and knowledge of the attendant lifecycle benefits of applying green building concept in comparison to the higher initial investment is vital to its implementation. This finding is confirmed by (Chan et al, 2017) which states, conducting robust and credible studies that are devoted to clearly and accurately show, verify, and quantify the real cost and benefits resulting from the implementing green buildings is very important for attracting the interest of stakeholders, such as investors and developers. Another important factor when

conducting these researches are allocation of funding and dissemination of information which should be dealt with ahead.

6.3.5. Policies and Regulations

It should be noted that the mean value differences of these strategies are not statistically large as there is no more than 0.52 points between the first and last issue suggesting, all of these strategies are very essential to the implementation green building concept.

Yet, the least ranked strategy is improved involvement by government through policies and regulations. (Wong cited in Chan et al, 2017) shows that mandatory environmental regulations by the government were the most important factor for the success of implementing green procurement in Hong Kong. In addition, in China, policy pressure was identified as the main reason why developers adopt green procurement. Formulating mandatory policies and regulations is important for stimulating market interest in green buildings, because that motivates, forces, or exerts pressure on the industry practitioners to take relevant actions in order to avoid fines or penalties for implementing traditional technologies.

Therefore, policies and regulation play an important role in applying green building concept and few are described below:

- Analyzing and revising the building codes to better align with sustainability goals and green building programs
- Developing a regulatory framework such as International Green Construction Code that recognizes an entire set of green issues not otherwise addressed in the building codes.
- Make building permits require environmental impact assessment
- Building codes should pay attention to a region's climatic particularities
- Development of standards for sustainable materials, systems and buildings
- Establish National Laboratory and programs for sustainable material development
- Implement taxes on emissions, energy consumption, resource consumption in order to internalize external costs
- Urban planning and land use regulations promoting green building development

- Well-defined and stricter energy requirements such as energy performance labeling for major electrical appliances, periodic inspection of building and facilities, use of solar heating and annual energy report for municipalities among others
- Mandate building Performance Codes and impose penalty on non-compliance
- Improved access to policies, laws and regulations
- Financial incentives described in the section 6.6.2.

6.3.6. Design and development of vertical greenery

As stated in Sharp et al. (2008), green walls can contribute to securing up to 18 credits under the LEED for new buildings. With this in mind, this research has designed a vertical greenery in EiABC campus at urban building with the intention of demonstrating and raising awareness about the design and cost of at least one aspect of green building.

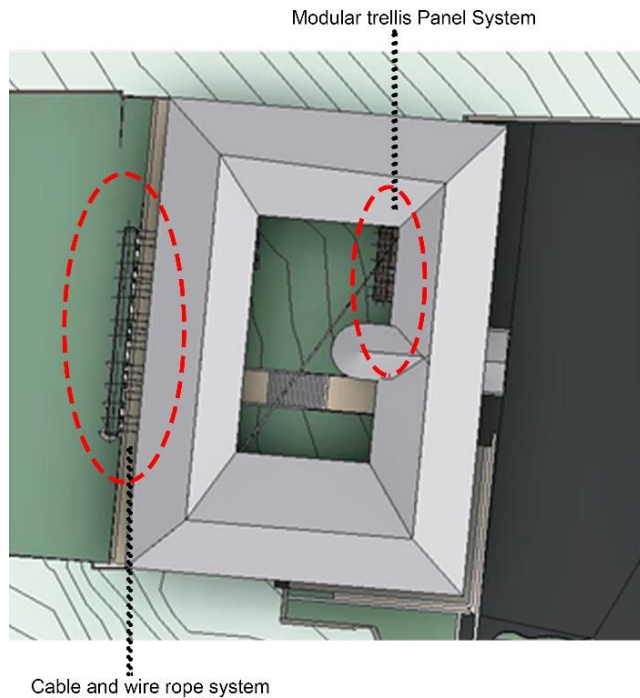
6.3.6.1. Location of the action area



Figure 78: Location map of the action area

(Source: computed by the researcher, 2017)

6.3.6.2. Design details of vertical greenery



Two types of green façade are designed, the modular trellis panel or mesh system used inside the courtyard of the urban building and the cable or wire rope system used on the rear side of the building.

Figure 79: Types of green facade designed

(Source: computed by the researcher, 2017)

I. Modular trellis panel or mesh system

Diamond mesh framed with steel is used as a panel providing support necessary for plant propagation. The climbers are planted on the green area found on the right side within the courtyard. Three 1m by 8m steel framed mesh are placed at equal interval along the circulation of the building. It extends the length of the two story building providing shade for the circulation and the offices behind it. The panel is bolted on the ground and the slabs. The university name is written on the mesh for aesthetic purpose until the plant are fully grown and can cover it.



Figure 80: Designed mesh system green façade

(Source: computed by the researcher, 2017)

II. Wire or Rope System

This type of green facade is used at the back side of the building where the harsh afternoon sun causes glare on the offices. Therefore, by applying a green façade at this location, in addition to other benefits of vertical greenery, the indoor environmental quality of the offices is improved by regulating temperature and reducing glare. The 24 ropes extend diagonally from the green area in front of the building to the roof. Hooks are used to attach the rope to the ground and the wall. Vertical ropes are placed every 40cm while 4 horizontal ropes with 1.5cm spacing connect the vertical ones providing space for the plant to extend and grow.



Figure 81: Designed Wire or Rope System 3D and section

(Source: computed by the researcher, 2017)

III. Irrigation

Irrigation is an important part of vertical greenery design. In this case, the plants will be watered using rainwater harvested and stored in the water storage unit located in the green area of the urban building courtyard. Water is harvested from a small portion of the of the building's roof. The selected roof catchment has an area of $136.7m^2$. The storage is designed to store the sum of four-month average rain fall i.e.659mm. It will be constructed from reinforced concrete to avoid leakage and has a capacity of $25m^3$.

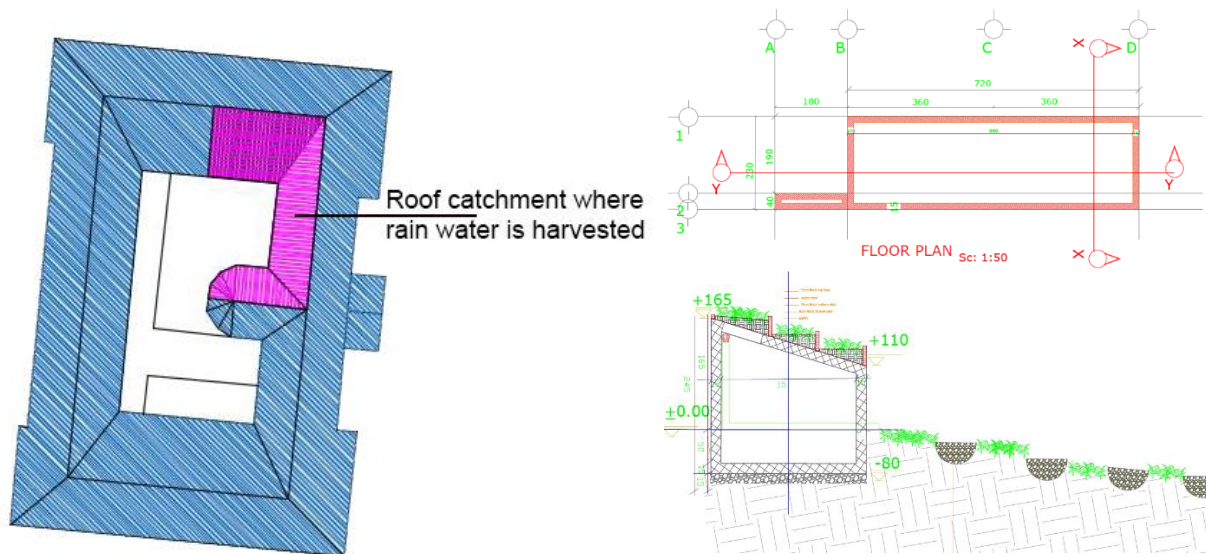


Figure 82: Roof catchment and storage plan and section

(Source: computed by the researcher, 2017)

IV. Species

Climbers are used for both type of green facades. Indigenous and naturalized species adapted to the climate are preferred. Some of the selected species can be found within the EiABC campus. The chosen species include *Zehneria anomala* (areg resa), *Ipomoea purpurea* and *Ipomoea tricolor* (morning glory), *Hedera helix* (ivy) and *Vitis vinifera* (weyn) in the backside where it has access to direct sunlight.



Figure 83: Selected Species

(Source: captured by the researcher, 2017)

V. Cost

The table below summarizes the material required to construct the design vertical greenery and the total cost in birr without the water storage.

Table 6: Cost breakdown of the vertical greenery

Item	Description	Material	Unit	Qty	Unit cost	Total cost(in Br)
Soil and preparation	Supply & install 30 cm depth topsoil for garden beds, including sub-grade preparation and cultivation	Soil	m ²	10	10 per m ²	200
Green wall	Mesh system green wall	Diamond Mesh	m ²	24 m ²	200 per m ²	4,800
		Angle Iron	m	24 m	250 per piece	6,000
	Rope/wire System	Extension Cable	m	400 m	13 per m	5,200

		Hooks		24	20	960
		Cable Clamps	Each	104	8	832
Vegetation/ plants	Supply and install advanced climbers	Climbers	Each	34	350	11,900
Irrigation	Supply & install automatic irrigation system	Pipes	ml	50	35	1,750
Manpower	Welding and Installation	---	---	---	---	7,000
	Planting	Daily /laborer	per/d ay	3	150	450
Total (vertical Greenery only)						39,092

(Source: computed by the researcher, 2017)

VI. Construction

During the construction phase little of the vertical greenery design is changed, however, the design of the rainwater storage is altered, in which fiber glass water containers are used instead of the proposed reinforced concrete storage. The pictures below show the installed vertical greenery and irrigation system.



Figure 84: Constructed rope system vertical greenery (left), Constructed mesh system greenery (middle) and Fiber glass water storage for irrigation (right)

(Source: captured by the researcher, 2017)

Chapter VII

7. Conclusion and Recommendation

7.1. Conclusion

Maintaining a sustainable urban environment is considered a crucial aspect of attaining a livable city. Addis Ababa being an important city in the continent needs to manage and control the effects of the thriving construction industry so as to enhance the quality of life in the city.

This study was conducted to analyze the building practices of selected buildings in comparison with green building principles in order to clearly understand the gap and the necessary actions required to implement its principles in Addis Ababa. Moreover, it investigated the challenges and opportunities presented along with the appropriate strategies. Data was collected from building occupants, managers, owners and professionals to utterly understand their perspective about green buildings. Furthermore, to better comprehend the issue, physical inventories of the selected buildings were executed.

In most buildings, open spaces and vertical greeneries are limited and sustainable stormwater management techniques are nearly absent. The main source of water is municipal waterline which is overused with no intention of recycling and reusing. There is unnecessary energy consumption and renewable energy sources are very limited. Concerning material and resources, reusing and recycling of wastes, use of local and low impact materials is a very new concept in most buildings. The poor IEQ has caused health problems and decrease in efficiency.

The major gaps between the surveyed buildings and green building lies under the concepts of sustainable site, water efficiency and sustainable material and resources which require sufficient space, professionals of different disciplinary and different technologies, these reasons and others have resulted in its rare implementation and if so, it is not properly designed or maintained. In addition, these principles were also deemed the most difficult by the practitioners suggesting this area requires great attention, thus different experiments and researches should be conducted so as to bring about greater success in the green building movement.

Unintentionally, some principles of IEQ are seen in most buildings as many of these ideas are already incorporated into normal designs, furthermore, most buildings do not use HVAC so by taking advantage of the city's weather, selecting the appropriate orientation and material, paying attention to small details and the human aspect of buildings, green buildings can be applied and implemented in Addis Ababa.

The overall study leads to the understanding that a lot has to be done to bring the concept of green building in Addis Ababa. Challenges such as lack of clients' interest, lack of awareness and education, shortage of professionals, lack of incentives from the government, economic challenges and absence of certification system such as LEED are the main obstacles to the application of its principles. Furthermore, the study revealed raising awareness about the idea, benefits and technologies about green buildings as the most important approach. In addition, financial incentive, research and policies were also identified as necessary strategies. But, for all to work integration of all actors including developers, designers, government, material producers, contractors and building managers from the start to finish of the project is very vital.

It is said that the "wise learn from the mistakes of others" and it's time for Addis Ababa to take advantage of its ideal weather, the current construction boom and collaborations from different international firms as the study reveals and shift from conventional buildings to green buildings. Whether it is building a new one or retrofitting an existing building, this research proves there is still hope to achieve sustainability and mitigate the negative consequences of conventional buildings before it is too late by applying the strategies discussed and issues recommended.

7.2. Recommendation

Beyond investigating the current situation about green buildings, the aim of this study is also to make suggestions in order to improve its weaknesses and to protect or enhance its positive attributes.

Therefore, based on the findings of the study the following general recommendations were drawn for the implementation of green building concept and bring about sustainable development:

7.2.1. Design and Construction Recommendation

I. Sustainable Site

- Use of alternative transportation such as bicycle, electric cars and so on.
- Encourage carpooling and provide access to nearby mass transit.
- Preserve existing habitat and natural resources as much as possible and maximize open and green spaces.
- Proper stormwater management can enhance surface moisture and reduce urban heat islands as well as solve flooding problem seen in two of the surveyed buildings.
- Experiment on different sustainable stormwater management techniques such as bio-retention, bio-swales, rain gardens, ponds and rain water harvesting.
- Design and construct vertical greeneries especially for building in the inner city where land is limited.
- Installing pervious surfaces that allow infiltration rather than asphalts which is seen in most buildings.

II. Water efficiency

- Educating people on water efficient fixtures that reduce excessive usage of water and direct them towards sustainability.
- Reduce dependence of municipal waterline by decreasing consumption through water efficient fixtures.
- Reusing and recycling of both wastewater and rainwater.
- Using drip irrigation technique to reduce water loss during watering of plants.
- Applying locally adapted plants and xeriscaping.
- Utilizing recycled water or rain water for irrigation instead of municipal water.

III. Energy Efficiency

- Attention should be given to the orientation of building as it is the first step in any green building project.
- Exploring different renewable energy sources especially for building with high energy consumption.

- Construct Buildings that are responsive to local conditions such as climate, social aspect, and local materials.
- The reduction of the energy consumption of buildings by combining different techniques so as improve thermal quality with the use of up-to-date alternative passive cooling and lighting techniques.
- Running energy simulation and designing an energy commission plan
- Designing the building envelope and systems to maximize energy performance.
- Use high efficiency appliances and lighting.
- Raising awareness of building occupants about proper and efficient energy usage.

IV. Material and resources

- Investing on locally produced materials to reduce transportation and enhance the nation's economic growth
- Experimenting on low impact and environmentally friendly materials such as sustainable timber, bricks and building blocks, and affordable green paint, finishes and aesthetics
- Recycling of waste during building construction and operation to reduce the waste hauled to the landfills
- Reusing and recycling building materials and products to reduce demand for virgin materials
- Use of low albedo, low emitting and reflective materials to reduce urban heat island effect
- Promote reusing and recycling of waste as well as composting

V. indoor environmental quality

- Increase productivity and efficiency of building occupants by having well lit rooms with views to the outside environment
- Making use of different methods of natural lighting such as open downs, skylight, dormer windows and others
- Providing occupants control over ventilation and lighting thus allowing them to create their own comfortable indoor environment
- Make use of appropriate shading such as louvers, over hangs and awnings
- Monitor air quality to help promote occupant comfort and well-being

- Use low emitting materials and paints to limit odorous, irritating and/or harmful contaminants such as VOCs
- Make use of proper materials and different noise reducing techniques such as acoustic panel fins to reduce acoustic from outside and within the building
- Use proper window to room ratio in order to have proper lighting and cross ventilation
- Constant maintenance to prevent leakages

7.2.2. Recommendation for main actors of green building

A successful green building project should be planned in a well-managed and with careful integration between all actors. Whether it is raising awareness, policy or economic issues, each actor has a responsibility and contribution to bring about green building movement in the city. Therefore, the following are recommended to each main actors.

I. Professionals and Educational Institutions

- Organizing awareness and education programs to increase public awareness
- Universities and colleges should make research and development on the topic of green building
- Examining the financial implications of green building by carrying out cost benefit analysis
- Designers should showcase their green building design so that it can be exemplary and inspire others
- Promoting for the feasibility and economic, social and environmental benefits of green projects to owners so as to start upgrading the construction market
- Awards/Recognition system for remarkable green design professionals/organizations
- keep proper documentation throughout the whole process

II. Government and Local Authorities

- Government policies should be structured in a supportive manner for green building construction
- A national green building certification system adapted to local and regional climate, geographical and environmental conditions should be developed

- Policies such as green loans and tax reduction policies can be implemented for green buildings
- Government should develop reference green building projects and publish their benefits to increase awareness
- Government can impose and implement mandatory regulations, environmental policies and legislation to support the green building market
- Governmental should intervene through upgrading local mandatory building codes and enforcing sustainability practices at least in public buildings

III. Building material and construction industry

- Building material importers should focus on local and low impact materials so that the cost of green materials reduces.
- Establishment of qualified independent third party authority for quality and environmental control of locally manufactured construction materials. This third party shall be responsible for materials green labeling, and verifying environmental data such as the recycled content, the source of the material, the SRI value, and the VOC content.
- Investors do not prefer green buildings because of high initial capital cost. To decrease the initial cost, local manufacturer should become strong, incentive programs should be prepared, existing buildings should be renovated.
- For building systems commissioning and energy modeling, an independent qualified authority shall be responsible for authenticating and certification of qualified third party commissioners who would make sure that energy building systems are built according to environmental preferences.

IV. Financial and Non-governmental institutions

- Facilitate larger loans on green and certified properties
- Establish green building council and rating tools for green building
- Fostering research activities and transfer of knowledge

7.3. Areas of further Research

More research is needed for understanding and improving the green building movement in Addis Ababa for its successful implementation. There is a need for more professionals to study green buildings so that there could be many solutions to the problems at hand. First and foremost, comprehensive studies focusing on single green building principle to prove its effects and benefits is necessary. Secondly, this research addressed the challenges and strategies particularly focusing on practitioners but additional study is required to understand the perspective of other main actors such as government, developers and so on. In addition, further research investigating the most effective and appropriate financial incentives, policies and green rating system for the city and the country as a whole is very essential. Financial cost and benefit analysis for green buildings with strong and sound statistical basis should be carried out.

Reference

Adebayo, A.A. (2002). *Sustainable construction in Africa*. Agenda 21, pp.1-11.

Africa Business Pages. (2013). Retrieved June 07, 2017, from Africa Business Pages web site: <http://www.africa-business.com>

Agboola, O.P. (2011). *Importance of climate to architectural designs in Nigeria*. Journal of Environmental Issues and Agriculture in Developing Countries, 3(1), pp.15-28.

Bernstein, H. and Mandyck, J. (2013). *World Green Building Trends, Smart Market Report*. New York: McGraw-Hill International Edition.

Bezawit, T. (2013). *Energy Conserving Electrical System Design and Performance*. (Doctoral dissertation, Addis Ababa, Addis Ababa University).

Biggs, B. (2017). *Domestic Water Saving Fixtures*. Cape Town: JG AFRIKA

Brundtland, G. (1987). *Our common future: Report of the 1987 World Commission on Environment and Development*. United Nations, Oslo.

Cassidy, R. (2003). *White paper on Sustainability*. Building Design and construction,

Chan, A.P.C., Darko, A. and Ameyaw, E.E. (2017). *Strategies for promoting green building technologies adoption in the construction industry—an international study*. Journal of Sustainability, 9(6), pp.969- 987.

Ching, Frank, Jarzombek, Mark, Prakash, Vikramaditya. (2011). *A Global History of Architecture*. Wiley, Hoboken, N.J.

Davis L. (2007). *The cost and Benefit of achieving green buildings*. Sydney, Australia. Second Quarter.

Dunnett, N. and Kingsbury, N. (2008). *Planting green roofs and living walls*. Portland, OR: Timber Press.

Elgizawy, E.M. (2016). *The Effect of Green Facades in Landscape Ecology*. Procedia Environmental Sciences, 34, pp.119-130.

El Yamany, S., M. Afifi, and A. Hassan. (2016). *Applicability and Implementation of US Green Building Council Rating System (LEED) in Egypt (A Longitudinal study for Egyptian LEED Certified Buildings)*. Procedia Environmental Sciences, 34, pp. 594-604.

Emirates Green Building Council, Green Building Rating Tools. (2012). Retrieved December 14, 2013, from the official Website of the United Emirates Green Building Council:
<http://www.emiratesgbc.org/index.php/academy/green-building-rating-tools>

GIZ. (2010). *Promoting sustainable and inclusive growth in emerging economies: Green Buildings*. India.

GTZ. (2006). *Strategic Communication for Sustainable Development: A conceptual overview*. Bonn: GTZ. Environmental Policy and Promotion of Strategies for Sustainable Development.

Gündoğan, H. (2012). *Motivators and barriers for green building construction market in turkey*. Turkey. (Master's thesis, Middle East Technical University)

Hankinson, M. & Breytenbach, A. (2012). *Barriers that impact on the implementation of sustainable design*. In: Proceedings of Cumulus conference, hosted by Aalto University School of Art and Design, Helsinki, Finland, Pp. 1-11.

Haselbach, L. (2010). *The Engineering Guide to LEED-New Construction: Sustainable Construction for Engineers* (Green Source): Sustainable Construction for Engineers. McGraw Hill Professional.

Hwang, B.G. and Tan, J.S. (2012). *Green building project management: obstacles and solutions for sustainable development*. Sustainable development, 20(5), pp.335-349.

Jacobs, E. (2011). *Sustainable Building awareness in the Free State Province, South Africa*. In: Proceedings of 6th Built Environment Conference, Johannesburg, South Africa, pp. 215-225.

Jayes, K. (2015, November). Retrieved December 28, 2017 from the website
<http://www.earthworksmagazine.co.za>

Ji, Y. and Plainiotis, S. (2006). *Design for Sustainability. Beijing: China*. Architecture and Building Press. ISBN 7-112-08390-7.

Johnson, B.T. (2005). *Barriers to certification for LEED registered projects*. (Doctoral dissertation, Colorado State University).

Kats, G. (2003). *Green building costs and financial benefits* (p.1). Boston: Massachusetts Technology Collaborative.

Kula, R. (2005). *Green roofs and the LEED green building rating system*. In Proc. of 3rd North American Green Roof Conference: Greening rooftops for sustainable communities, Washington, DC (pp. 4-6).

Labuschagne, P. and Zulch, B. (2016). *Green Rooftop Systems: A South African Perspective*. SBE16 Tallinn and Helsinki Conference; Build Green and Renovate Deep, (pp. 710 -716). Tallinn and Helsinki.

Malanca, M. (2010). *Green Building Rating Tools in Africa*. In Conference on Promoting Green Building Rating in Africa. pp. 16-25.

Matthiessen, L.F. and Morris, P. (2004). *Costing Green: A comprehensive Cost Database and Budgeting Methodology*. Davis Langdon. pp 1-27.

Ministry of Urban Development and Construction. (2013). *Ethiopian Building Code Standard: Building Spatial Design*. Addis Ababa, Ethiopia.

Oberlander, C.H., Matsuzaki, E. and Whitelaw, E. (2002). *Introductory Manual for Greening Roofs for Public Works and Government Services Canada*. Public Works and Government Services Canada, Technology Directorate.

Ottel , M. (2011). *The green building envelope*. Civil Engineering and Geosciences.

Pardo, C. F. (2006). *Raising Public Awareness about public transport*. Eschborn.

Planning and Growth Management. (2012). *2012 green building promotion program*. Ottawa.

Potbhare, V. and Syal, M. (2008). *Adoption of Green Building Guidelines in the Developing Countries Based on U.S. and India Experiences*, M.S.CM Research Report, Construction Management, SPDC, Michigan State University, MI

Ries, R., Bilec, M.M., Gokhan, N.M. and Needy, K.L. (2006). *The economic benefits of green buildings: a comprehensive case study*. The Engineering Economist, 51(3), pp.259-295.

Rode, P. (2011). *Towards a green economy, investing in energy and resource efficiency*. New York: UNEP.

Rydin, Y., Amjad, U., Moore, S., Nye, M., & Withaker, M. (2006). *Sustainable Construction and Planning*. The Academic Report, Centre for Environmental Policy and Governance, The LSE SusCon Project, CEPG, London School of Economics, London, United Kingdom.

Sharp, R., Sable, J., Bertram, F., Mohan, E. and Peck, S. (2008). *Introduction to Green Walls: technology, benefits & design*. Toronto: Green Roofs for Healthy Cities.

Slabbert, G. (2013). *The emergence of green building practices: case study of Stellenbosch*. (Doctoral dissertation, Stellenbosch, Stellenbosch University).

Spaliviero, M. and Cheru, F. (2017). *The State of Addis Ababa 2017: the Addis Ababa we want*. UN-habitat

Taeka, H. (2015). *Evaluation of Selected Addis Ababa Buildings with respect to the*. (Master's Thesis, Addis Ababa University, Addis Ababa).

Tagaza, E. and Wilson, J.L. (2004). *Green buildings: drivers and barriers e lessons learned from five Melbourne developments*. Report Prepared for Building Commission by University of Melbourne and Business Outlook and Evaluation.

Tessema, F., Taipale, K., & Jan Bethge. (2010). *Sustainable Buildings & Construction in Africa*. Johannesburg: Basehabitat

Umar, U.A. and Khamidi, M.F. (2012). *Determined the Level of Green Building Public Awareness: Application and Strategies*. 2012 International Conference on Civil, Offshore and Environmental Engineering.

Umar, U.A. and Khamidi, M.F. (2012). *Green Building for African Countries: Opportunities, Approaches and Challenges*. Malaysia.

U.S. Green Building Council. (2008). Retrieved November, 2017 from www.usgbc.org.

USGBC. (2011). *Intro–what LEED is*. Retrieved November, 2017 from www.usgbc.org

Were, S. (2015). *Investigation into the adoption of green building concepts in commercial buildings: A case of Nairobi County*. (Master's thesis, Jomo Kenyatta University)

WNCGBC, W. N. (2013). *Why Green Building is Important*.

Woolley, T. and Kimmins, S. (2000). *Green Building Handbook: A Guide to Building Products and their Impact on the Environment*, Vol. II. E& FN Spon.

World Bank. (2015). *Enhancing Urban Resilience: Addis Ababa*. Washington D.C.

Yellamraju, V. (2010). *LEED-New Construction Project Management (Green Source)*. McGraw Hill Professional.

Yudelson, J. (2010). *The green building revolution*. Washington D.C. Island Press.

Zegeye, C. and Helawi, S. (2012). *Building Ethiopia, Sustainability and innovation in architecture and design*. EiABC. Vol. I, pp.185-193

Zuo, J. and Zhao, Z.Y. (2014). *Green building research—current status and future agenda: A review*. Renewable and sustainable energy reviews, 30, pp.271-281.

- a) Mechanical or ventilator
- b) Opening windows
- c) Mixed system
- d) None

Are you faced with microbial growth, dampness or ventilation problems?

Do you have garden or green structure in your house or around your house hold?

- a) Yes, I have a green structure / garden
- b) No, I don't.

Is there a separate smoking and non-smoking area?

- a. Yes
- b. No

Do you a view outside your room?

- a. Yes
- b. No

How often is your room cleaned?

- a. Everyday
- b. twice a week
- c. once a week
- d. other _____

During hot weather your room is:

- a. Very cold
- b. Cold
- c. Normal
- d. Hot
- e. Very hot

During cold weather your room is:

- a. Very cold
- b. Cold
- c. Normal
- d. Hot
- e. Very hot

Air quality in the building

- a. Stuffy/Stale
Fresh
- b. Variable in a bad way
- c. Normal
- d. Variable in a good way
- e. Clean /

Your room is:

- a. Too dark
- b. Dark
- c. Normal
- d. Bright
- e. Very bright

Is there a glare problem in your room?

- a. Yes
- b. No

Acoustic of your work room

- a. Too noisy
- b. Noisy
- c. Normal
- d. Quiet
- e. Very quiet

Have you ever had health problems caused by the indoor quality of your room?

- a. Yes
- b. No

Does your productivity and efficiency fluctuate because of the change in temperature and air quality of your room during the day?

- a. Yes
- b. No

Interview with building owners or managers

1. What was this place like before the building was built?
2. Is there a transportation problem to and from the building? Has anyone ever complained?
3. Are there green areas or garden?
4. Have you ever had a water leakage problem and how soon did you fix it?
5. What is the main source of water? Do you reuse waste water and collect rainwater and what do you use it for?
6. What is the source and consumption of water for boilers, chillers and cooling system?
7. How much do you spend on water?
8. Does all the room have windows and access to daylight?
9. Do you make sure all the lights and appliances are turned off when occupants leave?
10. What is the main energy source? Do you use renewable energy?
11. How does the Mechanical system (Air conditioners HVAC, heating, ventilation, fans) function?
12. How much do you spend on electricity?
13. What type of material is used for the exterior and interior of the building? Local or imported?
14. What is the waste management technique? Do you recycle or compost?
15. Are you faced with microbial growth, dampness, and lighting or ventilation problems?
16. Have you ever had a complaint about the indoor quality of the building?

Checklist for physical review of buildings

	Yes	No	Remark
Sustainable site			
Building function			
Access to transportation			
<ul style="list-style-type: none"> • Access to mass transit • Bicycle • Pedestrian access • Services 			
Brown field development and high density area			
Landscaping			
<ul style="list-style-type: none"> • Impervious surface 			
<ul style="list-style-type: none"> • Use of reflective surfaces 			
<ul style="list-style-type: none"> • Open spaces and Green areas 			
<ul style="list-style-type: none"> • Erosion control methods such as seeding, mulching, earth dikes, silt fencing, sediment traps and sediment basins 			
<ul style="list-style-type: none"> • Reduce impact on surrounding habitats 			
Stormwater management techniques			
Rain water harvesting			
Distance from noise areas			
Orientation of building			
Water efficiency			
Detecting water leakage			
Use of efficient Fixtures:			
<ul style="list-style-type: none"> • On-demand faucet units automatic shut off system Dual flush toilet 			
<ul style="list-style-type: none"> • Reuse of water 			
<ul style="list-style-type: none"> • Source and consumption of water for boilers, chillers and cooling system 			
The irrigation technology to water green areas			
Native or exotic plants			
Potable or reused water for irrigation			
Energy efficiency and atmosphere			
Natural light			
Natural ventilation			
Artificial lighting			
Skylights			

windows			
Insulation material			
LED light bulbs or Fluorescent bulbs Dimmers and controls Daylight sensors Movement sensors			
Building envelop			
Mechanical system (Air conditioners HVAC, heating, ventilation, fans)			
High-efficiency appliances			
Use of thermal energy storage			
Green roofs or walls			
Renewable Energy			
Material and resources			
Type of materials			
Green materials: biodegradable or have little impact on the environment			
Local or imported materials			
Recycling			
Waste Collection and management techniques			
Compost			
Indoor Environmental quality			
Smoking and non-smoking areas			
Use of low emitting materials			
Cleaning routine and habits			
Volatile organic compound			
Damp conditions inside a building cause microbial growth			
Temperature			
Operable windows			
Access to views			
Occupants control or lighting and temperature			
Acoustical finishes and building geometry			

Questionnaire for consulting offices

This questionnaire is prepared by a Master's Program student in Addis Ababa University, department of Environment Planning and Landscape Design. It aims to collect information related to the application of green building concepts in Addis Ababa. The information given is for academic purpose only and will be treated as very confidential. Any form of support is greatly appreciated. Thank you

Name of Company: _____

Respondent's profession/Job title: _____

Professional Experience

- a. Below 5 b. 6 - 10 c. 11 - 15 d. 16 - 20 e. over 20

On a scale of one to five how familiar are you with the concept 'green building'?

1 Not familiar	2	3	4	5 Completely familiar
-------------------	---	---	---	--------------------------

Has your company ever been involved in a green building project?

- a. Yes b. No c. I'm not sure

If yes, which principles of green building did you apply in your project?

	YES	NO
Water Efficiency		
Energy Efficiency		
Sustainable Materials		
Sustainable Site Practices		
Indoor Environmental Quality		
None		

In your view, which aspects of green building are difficult to apply in Addis Ababa?

- | | |
|--|---|
| <ul style="list-style-type: none"> a. Rain Water Harvesting b. Water recycling c. Water efficient Fixtures d. Use of renewable energy Sources e. Use of Day lighting f. Use of Artificial Lighting Control g. Site Landscaping h. Management of stormwater i. Use of local materials (no imports) j. Use of materials that can be reused or recycled after the building life | <ul style="list-style-type: none"> k. Use of materials with low environmental impact l. Ventilation to public and circulation spaces m. Waste management and recycling |
|--|---|

From the table below please **Rank** in a **scale of 1 – 5** the factors you feel largely challenge the application of Green Building Concepts in Addis Ababa, where **1** is the lowest rank and **5** the highest.

Economic	1	2	3	4	5
Initial construction costs of green buildings are very high.					
Cost of green technologies and materials are too high.					
Clients are unwilling to pay for the green building projects					
Awareness / education					
Lack of awareness about green building					
There are not sufficient consultant and education program about green building concept.					
Because green building knowledge (technologies, materials) is new, there are not enough resources or documentation.					
There is a shortage of professionals and workers with suitable experience.					
Limited Research on Green Building Concepts					
Lack of Interest from Clients					
Market					
Building sector is resistance to change and innovation.					
There is not sufficient number of investors for the construction of green buildings.					
It is difficult to find local, greener, recycled and certified green building materials.					
There is no certification system such as LEED					
Lack of Urban planning and land use Policy					
Lack of from incentives from the Government					

What other challenges are hindering the application and implementation of green building concept?

In your view, which aspects of green building are the easiest to apply in Addis Ababa?

- | | |
|---------------------------------------|--|
| a. Rain Water Harvesting | i. Use of local materials (no imports) |
| b. Water recycling | j. Use of materials that can be reused or recycled after the building life |
| c. Water efficient Fixtures | k. Use of materials with low environmental impact |
| d. Use of renewable energy Sources | l. Natural ventilation to public and circulation spaces |
| e. Use of Day lighting | m. Waste management and recycling |
| f. Use of Artificial Lighting Control | |
| g. Site Landscaping | |
| h. Management of stormwater | |

Rate the following statements, on a scale of 1 to 5, according to the best of your knowledge. 1 represents 'I fully agree' and 5 represent 'I fully disagree'

	1 Fully agree	2 Agree	3 Neutral	4 Disagree	5 Fully disagree
I usually recommend to my clients to incorporate green design in their designs					
Recently there has been more interest in green building by your clients					
Information and training about green building is available to all employees					
There is an interest in green building by building practitioners (e.g. town planners, builders, etc.)					
I mostly recommend that natural materials are used in the walls of buildings					
You design your buildings to provide the most natural light practically possible					
Recycled materials are incorporated into my designs					
When designing and constructing a green building waste is sorted in as many possible fractions to be recycled					

What are the opportunities present for applying the principles of Green Buildings in Addis Ababa?

Which of the following strategies do you think would promote uptake of Green Building Concepts in commercial Buildings in Addis Ababa? Use a 5-point scale to Rank the strategies where 1 is the lowest and 5 the highest Rank

	Strategies	1	2	3	4	5
1	Education and training focusing on green buildings					
2	Financial incentives e.g. green loans etc.					
3	Improved enforcement by local governments					
4	Public Awareness and campaign					
5	Investment in Green Building related research including cost-benefit					
6	Promoting Green Procurement					
7	Establishing a green building rating system such as LEED					

In your opinion, what can be done to accelerate green building movement in Addis Ababa?
