Building Urban Resilience in the Face of Climate Change in Harare

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Abstract

The paper focuses on aspects of Harare's urban environment (Harare CBD in particular) that influence the city's climate change adaptive capacity. The paper acknowledges that climate change has escalated from simply being an environmental issue to becoming an aspect of human lives. Whilst the initial emphasis was on mitigating climate change, the trajectory has changed to adaptation. Cities are now aiming for urban resilience as the effects of climate change on urban settlements are worsening by the day. Scholarship points out that climate change is caused by both natural and anthropogenic activities. As such, climate change adaptive capacity is linked to various issues including urban construction material and urban management institutions. The paper is informed by both qualitative and quantitative research techniques. Purposive sampling and randomised sampling were used in coming up with various samples. Interview guides, questionnaires and observation checklists were employed in data collection. Content analysis and statistical measure of central tendencies were used to analyse the data. The research established that the CBD of Harare is succumbing to the effects of climate change. The material used in the construction of pavements and buildings, the design of the city and the institutions for urban management within the city are not properly adapted to the change of climate demands. The paper recommends that a cycle lane be added within the CBD, a change of the type of material used in the construction of pavements and the conversion of Speke and First Streets into garden streets were proposed so as to encourage walking and place making in the CBD.

Keywords: climate change, urban resilience, adaptation.

INTRODUCTION

Climate change issues began shaping up in 1987 with the Montreal Environmental Protocol. Though it had no climate change directly on the agenda, scholars believe it has made more impact on climate than the Kyoto Protocol (Intergovernmental Protocol on Climate Change, 2001). The agenda of climate change was then brought into play with the World

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Meteorological Organisation and the United Nations when they initiated the Intergovernmental Panel on Climate Change (IPCC). The developments of the initiated board manifested in 1992 with the formation of the United Nations Framework Convention for Climate Change (UNFCCC). Though UNFCCC was later enforced in 1994 as a matter of disagreements among governments, it has had significant impact on global climate. In 1997, through the UNFCCC, governments met in Japan and the Kyoto Protocol was agreed upon. This was a convention on climate change which was later ratified in 2005 because of conflicts between governments (IPCC, 2007). Most recently in 2015, IPCC met in Paris COP15 under the UNFCCC and concluded that the procedures of the Kyoto Protocol were globally binding (IPCC, 2001). This has brought about a revolution, with UN Habitat focusing on climate change adaptation on designs.

The construction of Leadership in Energy and Environmental Design (LEED) approved buildings is evidence of the revolution (United Nations Environmental Program, 2009). The IPCC report indicated that Africa will suffer most from the consequences of climate change (Rankomise, 2015). In response, the African Union has also refocused its attention towards climate change. This focus has brought about the draft African Strategy on Climate Change of 2014 which aims to reduce emission of carbon as well as to adapt to climate change. Southern African Development Community (SADC) has also cemented the African effort to deal with climate change by producing the climate change adaptation strategy that came to being in 2011. Locally, climate change has also gained recognition by the government of Zimbabwe. The government acceded to the Kyoto Protocol in 2009 and re-acceded on the convention agreements in Paris UNFCC Conference in 2015 (GoZ, 2015). In reinforcing this the Government of Zimbabwe, through the Ministry of Environment, Water and Climate setup the Department of Climate Change that came up with Zimbabwe's National Climate Change Response Strategy of 2015 (GoZ, 2015). All these efforts have had little impact on the designs that are under production in Zimbabwe (Rankomise, 2015). Harare has fallen victim to a series of climate change-imposed calamities that include heat waves, flash foods, erratic rainfall, and high temperatures among others (Chirisa et al. 2016).

LITERATURE REVIEW

Whilst climate change was less discussed in the 20th century, in the 21st century it has gained recognition in many global facets. Projections to

determine the dangers of climate change dates to 1987 (UNFCC, 2009). Findings show that the dangers of climate change internationally, regionally and locally have led to the decline of many economies and loss of human lives (UN Habitat, 2014; NASSA, 2011; UN, 2014). In response to the alarming discoveries, the initial trajectory of dealing with climate change was mitigation. However, upon realisation that the climate has changed, nations have refocused towards adaptation as a way of developing urban resilience. (Revi, 2008; De Vries et al. n.d) Urban resilience is gaining popularity in line with climate change adaptation as it offers better options of co-existing with the changing weather condition (UN Habitat, 2014; NASSA, 2011; UN, 2014). Climate change is not an isolated component but is rather interlinked with the socioeconomic aspect of an urban setup and thus requires a systems approach (EEA, 2011). To develop urban resilience, designs and policies policy need to be reoriented towards climate change adaptation. In line with this, cities need to enhance their adaptive capacities through designing for flexibility as well as placing relevant policies to deal with climate (European Environmental Agency (EEA), 2016). Harare in particular is also suffering the effects of climate change. This is resulting in flooding; heat waves and unreliable rain fall patterns being experienced in the city. These vulnerabilities prove the need for consideration of climate change in cities' plans, development control and urban management.

The atmosphere has five different layers which are troposphere, stratosphere, mesosphere, thermosphere and exosphere (Hanwell, 1980). In the stratosphere lie the different gases which are transparent to solar radiation [short wave] from space and terrestrial radiation [long wave] into space (Whyte, 1995; Tanaka, 2006; Godrej, 2002). This is a natural process that cools or warms up the earth. If the atmosphere's greenhouse gases are increased, more radiation and heat will be trapped between the Earth's surface and the layer and therefore result in global warming. Global warming is one of the greatest factors that contribute to climate change. Figure 1 shows how the climate system operates in relation to the modifications by human and natural systems.

The earth has been facing high levels of emissions that have led to the modification of the ozone layer. Thus, greenhouse gases, mostly carbon have been increasing in the atmosphere. IPCC (2001) notes that in 200 years the carbon concentration has risen from 275 parts per million to 369 parts per million. This is a huge change that has resulted in the increase in temperature, hence the change in climate trends.

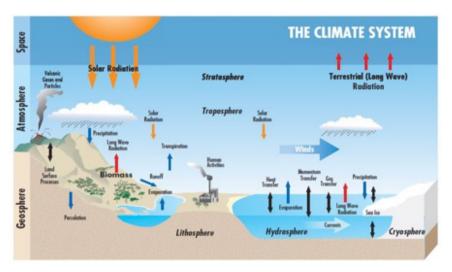


Figure 1: The Climate System (Whyte, 1995: 29)

The greenhouse effect is a process that is mostly pinned to development as it is a process that requires energy (Whyte, 1995). It is through the production of various energy forms that emissions are made, hence modifying the climate system. The process in which humans modify the natural environment to come up with settlements has driven us to another concept termed the ''urban heat island effect" which is a product of concrete jungles (Brown *et al.* 2005).

URBAN HEAT ISLAND EFFECT

Urban areas are generally warmer than their rural counterparts (Brown et al. 2005). This is because of developments, the replacement of natural vegetation and permeable surfaces with tarmacs and buildings that not only generate terrestrial radiation but also absorb more solar radiation. It means the environments are warmer during the day and at night. This process affects all areas, and they all become heat islands. The existence of these islands also modifies the climate of its surroundings and hence climate change occurs. When humans develop a virgin piece of land into a settlement, vegetation and the natural ground are modified. The buildings and pavements that are constructed generate more terrestrial radiation than what natural grounds generate (Tanaka, 2006). At the same time, the developments in

the area imply storage of extra solar radiation from space thus the area becomes hotter than normal and hence causes modification of the local climate.

DEALING WITH CLIMATE CHANGE

The modification of climate by the greenhouse effect, and urban heat island effect among other processes [natural/anthropogenic] has left most urban areas vulnerable to drought, floods, high temperatures, decreased water quality and quantity among others (Chirisa et al. 2016). This change implies a transformation of human behaviour, environments as well many other aspects to suit the climatic trends. In trying to suit to the new climate patterns (EEA, 2016) drafted 3 forms of adaptation that cites adapt to generate urban resilience. The three are coping approach, incremental approach and the transformation approach. The coping approach is a method that entails decision makers / planners choosing to cope with the stresses that the change in climate would have imposed. This is a reactive approach that involves methods to try and restore the quality of life in an area as well as trying to reduce the impacts of the disaster. This method only focuses on current problems and is not futuristic. The approach is more dependent on emergency budgeting and only focuses on problems that have happened and not what might happen for instance when Ernakalum (A city in Asmall City in India) flooded on the 9th of October 2011, the government began to send food aid to the people in temporary shelters as a means to survive. This is evidence of a coping strategy (Mathew et al, 2012). The incremental approach is a method of improving on existing structures to reduce the effects of the changes as well as increase the potential benefits that may arise. To augment the coping approach, the incremental approach adds the protection of current lives as well as reduction of potential negatives. This method focuses on trying to keep the current operations active. This approach has futuristic benefit but limited budgets. When cyclone Idai hit Mozambique, the governments entered a project of rebuilding clinics and covering the health sector to avoid water borne diseases (Hope, 2019). The transformational method approach tries to employ technology and human behaviour to transform the human lives to meet the needs of a potential climate change hazard or benefit. This is a proactive method of dealing with climate change-imposed stresses. It entails integration of all relevant stakeholders but remains flexible to ensure dealing with all changes that may arise. This approach can be evidenced in the introduction of conservative agriculture methods in areas like Chivi to deal with drought in the region.

CLIMATE CHANGE AND CONSTRUCTION MATERIAL

The construction sector has been contributing much in the emission of greenhouse gases (Institutional Investors Group on Climate Change, 2004). Buildings alone have been contributing 40% of the world's energy usage, thus responsible for approximately one third of the world's greenhouse emissions (United Nations Environmental Programme, 2009). The emissions in a building life span ranges from the manufacturing of the building material up to the demolition of the structures. Building material like cement has been noted to produce 8% of global green house during its production (Rousseau, 2009). Cutting down of wood for construction has also been contributing highly in deforestation and climate change. Consequent of the effects of building material on climate change, the concept of green buildings has been introduced. Green buildings have been defined as buildings with increased efficiency. This cover, energy, water and the construction material employed to reduce hazard in human health and well-being. In defining the green concept in architecture, nine indexes of buildings have been coined (Bauer et al. 2007). These include:

- **Green index** these focuses mainly in greening the place from walls, roof, water drains among other components of a building
- Daily energy saving index- this looks at the energy efficiency of a building on a day to day basis. They include the window areas, sun, glass openings, heat insulation, air circulation, building material among others.
- Water resource index-it takes cognisance of the water efficiency of a building. This also includes issues like rain water harvesting and grey water reuse.
- **Bio-diversity index** the index signals how a building includes components of the ecosystem for its continuous existence.
- **Carbon dioxide reduction index** It considers how a building reduces carbon dioxide emitting materials
- Waste reduction index- includes good use or recycling of material, to reduce pollution.
- Base water index- Includes permeability of floors
- **Sewage and trash improve index** Includes rainwater and sewage diversion, the enhancement of waste collection.
- **Interior Index**-Simply the interior pollution control, and air purification.

Therefore, weighing each building in relation to the 9 indexes of green building can help in identifying the extent to which it skewed towards being a green building or not. This will also be determined by whether the construction material used is green material or not.

Building construction material bears certain elements of thermal comfort. Bricks have been known for having high thermal mass which make them relatively slow in heat conduction (Rousseau, 2009). Therefore, walls that are constructed with bricks are cool even in hot temperatures. Reinforcing steel for all structured buildings are fast conductors of heat but have relatively low impact on thermal comfort of buildings compared to bricks (UNEP, 2009). Construction and construction material of public infrastructure is also a factor that determines the adaptive capacity of an area. The construction of bitumen road surfaces for instance, plays a huge role in climate modification. Tar sands are one of the dirtiest and carbon intensive fuels on planet and thus are not sustainable given the climate status (Bauer et al. 2007). The emissions from production of bitumen currently are greater than carbon dioxide which is produced by Kenya and New Zealand combined. Thus, the American Concrete Pavement Association (Bauer et al. 2007) has come up with green highways as a substitute of asphalt roads that have a very high sustainability cost form its production up to maintenance. The concrete pavements are made from cement which besides its high carbon emission during production has relatively, larger advantages like minimal fuel consumption in vehicles because of its reduced deflection, construction of pavements requires lesser fuel than that of asphalt and the process of laying concrete pavements needs fewer raw materials as it is processed from by-products of industrial process like fly ash and slag cement (American Concrete Pavement Association (ACPA), 2007).

RESEARCH METHODOLOGY

The study by its nature was inclined in line with the pragmatist worldview; therefore, it engaged the mixed method approach. Questionnaires, observation checklist, interview were employed during the collection of quantitative data. Questionnaires were used to collect data from the vendors along the George Silundika, First, Angwa and Speke Streets. 40 respondents were engaged, 40 was selected as it lies within a range that assures statistical relevance (Bartlett, Kotrlik & Higgins, 2001). From a head count that was carried on the 6th of January 2017, it was found out that the area had 73 vendors in all. So, for the selection of the forty a code number was given to

each of the 73, all the 73 codes were written on pieces of paper and placed in a hat, they were mixed then randomly chose the 40 from the hat. In identifying the adaptive capacity of the area, observations and plates were engaged.

Street observations were carried on against a street observation checklist and a building checklist was used for all buildings. The process involved walking around the study area taking pictures to fully identify the adaptive capacity of the area in relation to infrastructure. These observations aimed at buildings, roads, walkways, trees, green spaces, drainage, water harvesting techniques among others. Pictures were taken with the consent of the people involved. Plates of climate change related features were taken, some of them included pictures of clogged drainages, forms of pollution present, buildings with interesting features, air-conditioning systems, lighting systems, flooded streets, tar macs among others. The selection of these features will be guided by literature review for example elements of LEED designs (United Nations Environmental Programme, 2009).

Interview guides were used in collecting qualitative data. In determining the area of research purposive sampling was engaged. In collecting data from climate change related institutions, semi structured interviews were engaged. These were done as they allowed me to interact with the key informants. These interviews were done in a face to face setting and therefore it allowed me to probe different questions of interest. An interview guide with properly structured questions was used. Statements like "tell me", "as an expert what is ..." were used as they allowed the interviewee to feel dignified and therefore bonded with me and gave me extra information. In collection of data of how institutions have dealt with climate change, documents were reviewed. Data collected through interviews and questionnaires were first coded then Statistical Package for Social Scientists was used to derive the means medians and modes among other statistical variances. In collection and dissemination of data, respondent protection was ensured.

RESULTS

According to interviews carried out the causes of climate change from public perspective were divided into three, emissions [mostly from ex-Japanese cars and industries], deforestation and God's time. 50 % of the interviewed members of the public believed that climate change was a result of emissions from cars, 35% from deforestation and 15% thought it was due to natural

change or God's time. Emissions of greenhouse gases lie in first part; deforestation fits within the concept of urban heat islands and concrete jungle and God's time can be linked to natural occasions like the El Niño effect. Whilst the public had this perception, officials from the Ministry of Environment Water and Climate placed the blame to emissions. In their policy document of intended contributions submitted to UNFCCC in 2015, a chart of the distributions shows that 49% of the emissions are from the energy sector. Their view is that the major contributor of Zimbabwe's emission is the energy sector. This is attributed to the fact that 40% of Zimbabwe's energy production is thermal and therefore emits greenhouse gases. This implies the need for Zimbabwe to shift its energy (off national grid) reliance patterns and move towards other alternative energy sources like solar energy. There is need for a shift from material and designs that need too much energy for heating, cooling or lighting. Figure 2 shows the emission contributions of different sectors to the carbon emissions of the nation as indicated by records from the Ministry of Environment, Water and Climate.

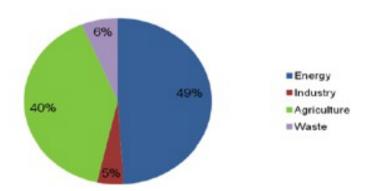


Figure 2: Zimbabwe Sector Emissions (The National Climate Change Response Strategy: Ministry of Environment, Water and Climate, 2017: 42)

EVIDENCE OF CLIMATE CHANGE

The climate has changed, the records of climate from the meteorological department, proved that Harare had a maximum temperature of 27°C and minimum of 17°C in 2016 and in June the average maximum was 22°C and a minimum of 9°C comparing with the temperature from the same source,

in 1980, the maximum was 24°C and the minimum was 14°C in January and 21°C maximum and 10°C minimum in June. These statistics evidence that hot days have become hotter and cold days have become colder. Figure 3 is a comparison of the data acquired from the Meteorological department shows a graph of temperature variation during the year 1980 and Figure 3 shows climate in 2016, the variances shows a change of climate. Comparing them to the climate variables in earlier studies, evidence that there are hotter days and less cold days and also show that general temperature has increased although it's a slight change.

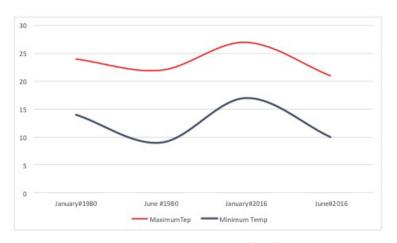


Figure 3 Comparison of minimum temperature: 1980-2016 (Adapted from Met Department, 2017)

EFFECTS OF CLIMATE CHANGE

Climate change effects tend to be affecting people differently. 67.5% of the interviewed members of the public confirmed that the heat waves affected them the most. 35% mentioned cold temperatures and 15.5% flooding. Figure 4 shows various climates' elements' effects to different people. Most people prove to be suffering most from the heat waves. Amongst other variables this can be attributed to the fact that the CBD of Harare is 100% paved. The material used to pave the surfaces is mostly oil tars which absorb heat quickly therefore making the area generally warmer. Furthermore, Harare has fewer trees in the CBD and therefore the sun hits direct on people and surfaces exacerbate its effects.

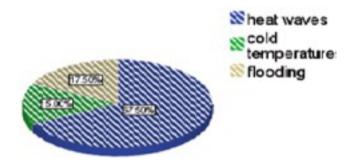


Figure 4: Effects of climate change (Survey, 2017)

Inside buildings, climate change affected occupants differently. Data collected using questionnaires showed that occupants did not complain a lot about temperatures as most had air conditioners but however 63 % complained about the flooding in the streets and the rains claiming it was slowing down their business. Data collected using observation checklists indicated that the problems of flooding to business can be felt in Harare as the area does not have pervious surfaces and the drains are flooded. When the streets are blocked, movement is reduced in the CBD and therefore business is disturbed.

CLIMATE CHANGE ADAPTATION METHODS AND VULNERABILITIES

Climate change adaptation was done through various ways. Of the distributed questionnaire targeting the general public in the outdoor space, the effects of climate change were divided into heat, cold temperatures and flooding. In dealing with each of the effects, the public employed different approaches. During hot days, 60% took fluids (i.e. water, juices). 25% stayed under shade, 7.5% stayed indoors and the remaining 7.5% used other methods like sun screen, and hats among others. The intake of fluids by many respondents proved to be a way of refreshing and replacing fluids lost through sweating. The percentage also proves the need for clean water supply in Harare as most of the fluids taken in was water which they bought claiming that Harare water "was not safe to drink."

The reason why 25% responded to the use of shade proved not to be a matter of choice but rather scarcity of cool places. Whilst they would want

to walk in direct sunlight, they had no option. Observations made proved that the outdoor area had more than 80% tarmac roads with trees less than 3, 80% again had no public shades or sitting areas. Thus, the people who responded that they go for shades were mostly concentrated in one street, first street. Besides First Street the other options were verandas, which are not conducive for sitting because of customers moving around. This meant that the CBD of Harare required trees and shades to help reduce the effects of the sun on people

Plate 1 shows people sitting in First Street in a very hot day. However, because of the few trees in the street, some have to suffer the excruciating pain of broad sunlight. This proves how deforestation has left Harare CBD prone to the effects of climate change particularly heat. Consequently, Harare CBD is now an urban Heat Island and thus worsening to climate change



Plate 1: First Street (Fieldwork, 2017)

During cold weather, 67.5% of the respondents to questionnaires confirmed they wore jerseys or jackets, 17.5% took in hot beverages (tea, coffee) and 15% stay indoors. The responses showed that most people wore warm clothes to help with the cold temperatures. By its altitude, Harare is bound to be very cold in winter. This is worsened by clear streets that allow free passage of wind, thus pointing to the need for trees in the CBD. In the context of artificial flooding, 75% confirmed they stayed indoors or on verandas, 22.5% claimed to use cars and 2, 5% said they did nothing. Flooding has been

blamed for killing business by property occupants. This can be confirmed by 77.5% of the public stating that they do not move. Maps show that Harare CBD is built on Mukuvisi River catchment area, therefore it is bound to flood. The poor urban management systems have seen litter clogging the drains and therefore water flows on pavements. This is added on to the fact that 100% of the street surfaces are impervious surfaces, therefore runoff results in flooding.

In dealing with hot days, 60% confirmed that taking fluids was their way of dealing with the heat. The sources of water they took in varied. 80 % of the interviewed confirmed that they bought bottled water. 10% either brought from home or got it from restaurants, 7.5% drank from council toilet taps and 2.5% said they had nowhere to find the water. The alarming statistics of 80% of the population buying bottled water proved the reduced quality and quantity of water in Harare. The CBD of Harare had no public water drinking points in the area of study. This is disturbing as the area is has two pedestrianised streets 50% of the office users depended on air-conditioning for cooling. The 50% rate of air conditioners proved why the energy sector had the highest emission level of greenhouse gases. Air conditioners are known for their high-energy demand. This also confirms the extent to which the infrastructure in the CBD is not adapted to current climate patterns. Plate 2 shows a fan inside a building that is used as a method of cooling the building. The picture shows a very old fan which is not very energy efficient. It requires more energy and hence more emissions. This method of adapting to climate change reveals that the building material is not conducive enough to self-regulate the heat levels of Harare CBD, thus rendering the buildings less resilient to climate change.

As an approach to dealing with hot day, property occupants mentioned water. The water was drawn from various sources, 38.9% drank council water from taps and 2.8% either bought from home or drank from restaurants. 58.3% of people who had taps in their offices confirmed that they bought drinking water. This showed the level of trust that the respondents had in the purity of council water quality. However, it is worth noting that 38.9% still depended on water from council sources, implying the need for securing the continuous supply of council water.

CLIMATE CHANGE VULNERABILITIES

The area of study had 5 streets namely; George Silundika, First Street, Speke, Angwa and Jason Moyo Avenue. 80% of the total street surface was paved

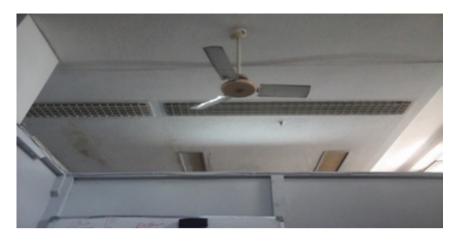


Plate 2: Fan for Cooling (Fieldwork, 2017)

with bitumen tarmacs. Only First Street had partially permeable surfaces in it. This proved that the CBD of Harare is what has been termed a "concrete jungle". Observation of the material used in the design of the impervious surface, most of it absorbs heat and thus the area has qualities of urban heat island. The existence of many impervious surfaces may also explain why the CBD is affected by a series of artificial flooding. The surfaces do not allow for the infiltration of water resulting in high amounts of overland flow causing flush. Exacerbated by the poor drainage system in the CBD, the CBD suffers a lot from artificial flooding. The flooding in the CBD is also worsened by the fact that the CBD has few trees. From the 5 streets that were observed, it was noted that 60% of the streets had less than 10 trees. Jason Moyo Avenue had 1, Angwa Street had no tree, George Silundika had 2 Speke had 2. Only First Street had trees above 10. Table 1 shows different ranges of numbers of trees in the streets. The reduced numbers of trees implies that the area is now hotter than usual and given the changes in climate patterns, it can be even worse. Trees have been known for reducing greenhouse gases as they hold them in what has been termed carbon sink (Rankomise, 2015). Given the number of trees in the CBD, Harare CBD is a net emitter of greenhouse gases.

Table 1: Trees in the study area (Survey, 2017)

Number of trees	Frequency	Percent
0-10	3	60.0
11-20	1	80.0
0	1	100.0

The few trees observed in the CBD imply that there were few sitting spaces under the shade. Four of the streets had no sitting spaces for the public and neither did they have shades. Observations proved that of the populations under study only First Street had sitting spaces that were either under trees or under the sun. The unavailability of sitting space can be attributed to the uses of surrounding properties Most of them are offices and parking spaces. However, Speke Street is a pedestrian dominated street, and therefore requires seating spaces. Table 2 shows a table that evidences the availability of sitting spaces in the area of study.

Table 2: Sitting spaces in the streets (Survey, 2017)

Availability	Frequency	Percent
Intermediate	1	20.0
No	4	80.0
Total	5	100.0

Around the few sitting spaces available, finding drinking water was a problem. The only visible water reticulation structures were observed malfunctioning water fountains in First Street meant for scenic purposes. This shortage makes Harare CBD occupant very susceptible to climate change, particularly heat waves. The unavailability of water in pedestrian streets needs to be addressed since some people fail to find water in the CBD, thus jeopardising their lives.

The area of study had pedestrian walk ways in every part of the street. However, there were no cycle lanes or cycle parks. Harare CBD accommodates pedestrian traffic and vehicular traffic this is clear as pedestrian paths are everywhere. However, according to secondary records it is worth

noting that the safety of public when crossing roads is not guaranteed as the infrastructure that was built for that purpose was installed in 1989 (Local Development Plan 22).

The CBD of Harare does not accommodate cyclists. As a result of having no infrastructure present to accommodate cycling, it gives the CBD focus on two modes of transport which are driving and walking. Whilst walking is the most sustainable way, driving on the other hand involves a lot of emissions and congestion which make the area hot. This corresponds with the responses of the public on the use of bicycles with one saying in an interview "kuchovhachiii? N dokutsvaga kufa manje!" Meaning riding what? Its suicide! This approach towards cycling explains why 70% of the people chose footing and 30 mentioned cars as a way of transport.

Observations also identified that the CBD is still depending on old technology of street lighting. The lights were close together with a light after every 10 metres. This density can be justified by the darkly coloured asphalt roads that require more lighting. In the sampled area, all the lights depended on electricity from the national grid. Thus, the continued use of the lights means more electricity demand and hence more emissions during production



Plate 3: Street Lighting Technology (Fieldwork, 2017)

¹ A vendor interviewed on the 4th of February 2017

Plate 3 shows the image of the street lighting technology that is used in the CBD of Harare, Angwa Street. The technology relies on the national electrical grid. The lights are old models and thus are not energy efficient. Thus, their continued use implies intense pressure on energy meaning need for generation of more electricity and high emissions.

Besides the 100% tarmac used in street design, 94, 4% of the buildings were constructed using glazing and brick. Finishes like wall cladding (mostly using clay) and plastering were dominant within the study area. This type of material has a low thermal mass implying that it is slow in heating as well as cooling. This explains the need for artificial warming and cooling which has been seen by the existence of fans, air conditioners and heaters. Since most buildings are multi storeyed, the reinforcing steel makes fast conductors of heat contributing to the effects of heat waves in buildings in the CBD.

The buildings observed in the study area had different roof types. 69, 4% of buildings in the area has IBR sheets covering the roof. 16.7% were concrete slabs, 8.3% asbestos and only 16.7% had concrete tiles. Figure 5 shows the percentages of different types of construction material used in the CBD. Roofing that is mostly used in the CBD is made of steel which is a very good conductor of heat. This is exacerbated by the fact that most of the roofs are made of dark coloured material that retains heat. As a result, they are always hot. Concrete slabs used to cover some buildings offer an opportunity for green roofs. Whilst if dark coloured roofs are painted in light colours, they can reflect the short wave (extra-terrestrial radiation) and reduce the effects of heat waves on buildings.

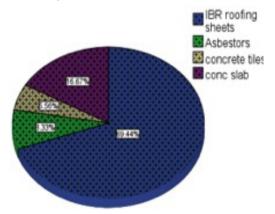


Figure 5: Roofing Material Used (Survey, 2017)

Observations on buildings also proved the limited existence of water harvesting. From the 36 buildings observed, only 5 harvested water. The water was harvested using the bucket, and from interviews with the occupants, it was used for mopping the floors mostly. The shortage of water in Harare and the poor quality of Harare City water demands for the engagement of water harvesting. The reason for occupants not harvesting water can be linked to the response that water in the CBD was flowing from the tap 24 hours a day. As a result, the occupants had no need to harvest water. However, harvested water is cleaner and less contaminated than the city's water (as confirmed by 51,8% water buying rate of occupants and 80% drinking water buying rate of the public), thus need for considering water harvesting as an option.

DISCUSSION

Urban Heat Islands and Emissions, Harare CBD can be considered as an urban heat island and it also attributes highly to emissions. This is attributed mostly to the design of Harare buildings and infrastructure. The observations showed that of the 36 buildings observed, only two, Batanai Gardens and ZB building had elements of a Low Energy Efficient Designs, meaning that most buildings were not properly adapted to the current climatic conditions. Climate change impacts in Harare are being made worse by the type of material used in the construction of buildings. The material employed all has high thermal mass, making them hot during hot days. Rating the buildings with the index shown none can be called a green building as the water and energy indices cannot be met. Though some buildings have a good greening index like that of Batanai Gardens, most of them have 0 on green index. In trying to adapt to climate change, various approaches have been mentioned, Harare proved to be applying the incremental approach. This can be seen in the introduction of solar lighting in some parts of the city. However, it is worth noting that climate change issues are not yet fully appreciated by authorities and they are still taken lightly. Whilst the city authorities are working towards climate change, the major body of physical planning, the Department of Physical Planning is not yet adapted properly. This therefore reduces the capacity of the CBD as it is also affected by institutional rigidity.

CONCLUSION AND RECOMMENDATIONS

Using a sample of the CBD of Harare, particularly the area bounded by Angwa, George Silundika, First and Speke Street, the study was focused on

assessing the climate change adaptive capacity of the CBD in search of potential for generation of urban resilience. It aimed at identifying the material employed in the design of the infrastructure for retrofitting purposes. The research identified that the area of study was mostly pavement and thus exposing the area to various effects of climate change. The impervious surfaces that had 80% asphalt roads and 20% concrete rendered the area a concrete jungle. The material used mostly absorbed extra-terrestrial radiation, thus making the area an urban heat island. This status implied that the area was not adaptive enough for the shocks of climate change.

The research also proved that the CBD had fewer trees and most of them were only on First Street. The levels of deforestation in the CBD also made it vulnerable to direct sunlight. This makes the CBD very hot during the hot days.

The CBD of Harare mainly depends on electrical energy in powering the light, cooling and heating the buildings and every other activity. This makes the CBD less adaptive as it depends on non-recyclable energy that involves emissions during its production.

Whilst the National Climate Change Response Strategy (2015) corroborating with the Zimbabwe Intended Nationally Determined Contributions (2015) identified ways of managing climate change mostly via reduction of vulnerabilities, the planning policy framework is still outdated and has not yet included climate change, making designs that are under production climate change vulnerable.

The evidence in the CBD indicates a high degree of vulnerability and limited climate change resilience. For the CBD of Harare to improve in terms of climate change resilience there is need for an improvement of both hard and soft infrastructure. In the context of soft infrastructure, the major planning bodies should add climate resilience as part of the planning systems, with the government through the Department of Physical Planning taking centre stage. In the context of hard infrastructure, resilience is linked to a reinvestment in climate change adaptive infrastructure. This includes water systems, solar harvesting mechanism, and adaptive road infrastructure among others. Having a combination of adaptive infrastructure both hard and small will pave way for climate change resilient city centre in Harare. In addition, the study recommends their cycle lanes be included within the CBD and Speke Avenue and First Street be converted into garden streets to reduce carbon emissions.

REFERENCES

- ACPA. (2007). Environmentally and Economically Sustainable Concrete Pavements. Skokie: American Concrete Pavement Association.
- Bauer, M., Mösle:, & Schwarz, M. (2007). *Green Building*: Guidebook for Sustainable Architecture. Stuttgart: Springer.
- Brown, M. A., Southworth, F., Stovall, T. K., Ridge, O., & National Laboritory. (2005). Towards a Climate-Friendly Built Environment. Pew Center on Global Climate Change.
- Chirisa, I., Bandauko, E., Mazhindu, E., &Kwangwama, N. A. (2016). Building Resilient Infrastructure in the Face of Climate Change in African cities: Scope, Potentiality and Challenges. *Development Southern Africa*, 33(1), 113-127. doi: DOI: 10.1080/0376835X.2015.1113122.
- De Vries, H. J., Revi, A., Bhat, G. K., Hilderink, H., & Lucas,: (n.d.). India 2050: Scenarios for an Uncertain Future. Bilthoven: Netherlands Environment Assessment Agency (MNP).
- EEA. (2016). Urban Adaptation to Climate Change in Europe 2016: Transforming cities in a Changing Climate. Copenhagen: European Environment Agency. doi: 10.2800/021466.
- Hope, M. (2019). Cyclones in Mozambique may reveal humanitarian challenges of responding to a new climate reality. *The Lancet Planetary Health*, *3*(8), pp.e338-e339.
- IIGCC. (2004). Climate Change and the Construction Sector. Institutional Investors Group on Climate Change.
- IPCC. (2007). Cambridge University Press. UK: Intergovernmental Panel on Climate Change (IPCC).
- Mathew S., Truck S and Henderson-Sellers, A (2012). Kochi, India Case Study of Climate Change Adaptation to Floods: Ranking Local Government Investment Options. *Global Environmental Change*. 2012 February 1: 22 (1): 308-19.
- Rankomise, O. A. (2015). Climate Change in Zimbabwe: Information and Adaptation. Cape Town: Konrad-Adenauer-Stiftung. Retrieved from www.kas.de/Zimbabwe/.
- Revi, A. (2008). Climate Change Risk: An Adaptation and Mitigation Agenda for Indian cities. *Environment and Urbanization*, 20(1), 207-229.
- Rousseau, D. (2009). Environmentally Friendly Building Material. Sustainable Built Environment.
- Tanaka, S. (2006). Climate Change. Toronto: Ground wood.
- UN Habitat. (2016). Climate Change Adaptation and Resilience.
- UNEP. (2009). Buildings and Climate Change: Summary for Decision-Makers. Paris: United Nations Environment Programme.

- UNFCC. (2009). Climate change: Impacts, Vulnerabilities and Adaptations in Developing Countries UNFCCC: Least Developed Countries under the UNFCCC.
- United Nations. (2014). Open Working Group Proposal for Sustainable Development Goals. Retrieved 12 04, 2016, from http://undocs.org/A/68/970.
- Whyte, J. P. (1995). The Green House Effect and Climate Change. Springer Publishers. London.
- Zimbabwe, G. o Z. (2015). Zimbabwe Climate Change Response Strategy. Government Publishers Harare.