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Article

Proposal for a Methodology for Sustainable Rehabilitation Strategies of the Existing Building Stock—The Ponte Gêa Neighborhood

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Abstract: Having in mind the objectives of the United Nations Development Agenda 2030, which refers to the sustainable principles of a circular economy, it is urgent to improve the performance of the built environment. The existing buildings must be preserved and improved in order to reduce their environmental impact, in line with the need to revert climate change and reduce the occurrence of natural disasters. This work had as its main goal to identify and define a methodology for promoting the rehabilitation of buildings in the Ponte Gêa neighborhood, in the city of Beira, Mozambique, with an emphasis on energy efficiency, water efficiency, and construction and demolition waste management. The proposed methodology aims to create a decision support method for creating strategic measures to be implemented by considering the three specific domains—energy, water, and waste. This model allows for analyzing the expected improvement according to the action to be performed, exploring both individual and community solutions. It encompasses systems of standard supply that can reveal greater efficiency and profitability. Thus, the in-depth knowledge of the characteristics of urban space and buildings allows for establishing guidelines for the renovation process of the neighborhood.

Keywords: rehabilitation of buildings; energy efficiency; water efficiency; waste management; climate change; urbanism

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1. Introduction

This study aimed to investigate and design a methodology to define strategies that promote the rehabilitation of buildings in the city of Beira, Mozambique, and contextualize their importance, emphasizing their energy efficiency, water efficiency, and the management and recovery of construction and demolition waste (CDW), as well as urban solid waste.

Many African countries have outgrown their colonial past and are currently in the process of expanding their economies and providing resources to other countries. This creates instability between and within countries. This reality allows for a widening gap between social classes, thus possibly creating social friction, unrest, and an unsafe environment in which to live. Urban growth in Africa is associated with two structural processes: first, endogenous growth, which results from high birth rates and explains the continued population growth in urban centers, and second, the exogenous process, which is the result of the rural-city migratory dynamics, is the main cause of this expansion since the migrant population, once arrived in the city, tends to settle next to the areas of greater density [1]. In Mozambique, 69% of the inhabitants live in rural areas, according to projections made by the United Nations in 2011 [2].

Beira city, whose population of 397,368 inhabitants in 1997 grew to 533,825 in 2017, is a complex and unique case study on implementing modernist ideas in tropical countries [2].

The city became prosperous due to the high yields provided by its railroad–port interface. This constituted the basis of its wealth, which attracted ambitious young and talented Portuguese architects and civil engineers who built a paradoxical city and technical solutions that fill a unique urban plan in Portuguese colonial Africa [3].

At present, the city of Beira, Mozambique, is one of the African cities that are most vulnerable to climate change, where the most recent occurrences were cyclone "Idai" in 2019, one of the most devastating since records began in the Southern Hemisphere [4], with winds that reached 200 km/h [5]; the tropical storm "Chalane" [6] and cyclone "Eloise" [7] in 2021 were also devastating weather events. The importance of Beira city in the commercial context of Mozambique, and even in Africa, is recognized due to its strategic location and existing links, where the port houses an essential freight warehouse. Beira has grown organically and responded immediately to the increase of its local population [8]. It is essential to incorporate current strategies to achieve sustainable growth. The city must be reordered, recovered, and developed in a structured way by considering the new urban trends based on climate change [9].

In the city of Beira, the neighborhood of Ponta Gêa (highlighted in Figure 1) has a wealthy and diversified architectural heritage [10], in which different periods that are associated with social, political, and economic dynamics and the cultural and artistic trends of each era are naturally distinguished [11]. The Ponta Gêa neighborhood is a clear example of a well-defined urban structure, with modernist architecture and colonial urbanism, organized according to a reticular mesh. Due to the rural exodus, the neighborhood presents problems regarding the water and energy supply, and the infrastructure displays a high level of degradation due to the large increase in the population and no maintenance.

Figure 1. Location of the Ponte Gêa neighborhood [12].

This disordered growth has given rise to marked social differences; therefore, it is essential to incorporate sustainable growth strategies to reorganize the city, recover its buildings and infrastructures, and develop it in a structured way [13]. A city that is without planning, consumes large amounts of resources, has inefficient waste management strategies, and is subjected to the occurrence of increasingly severe natural disasters deserves increased care regarding its development and expansion strategies.

Considering that Beira city's construction is essentially characterized by self-construction, with rudimentary, traditional techniques and the use of local material, cyclone Idai caused irreparable damage, with thousands of people displaced. Thus, it is urgent to rethink the built space's management strategies, with guidelines that address both natural phenomena and growth [9].

The lack of electricity access is still a reality, even though Mozambique has abundant energy resources. In rural areas, for example, only about 1% of the population has access to electricity supply. In urban areas, access and consumption remain limited due to its high costs and irregular supply. Most residents still use firewood or charcoal to meet their energy needs [14].

Thus, it is urgent to find measures that allow for rehabilitation [15] that is focused on energy efficiency and interior comfort, use passive systems to minimize the energy needs, and define new strategies that promote rehabilitation with an emphasis on water efficiency and management of construction and urban wastes, mainly reducing the Beira city market's lack of aggregates and reusing and incorporating other materials, such as those provided by waste [16].

2. Urbanism, Buildings, and Climatic Changes

The modern period is one of the most characteristic of the city such that the middle of the 20th century was the stage for the works of a generation of notable modern architects, such as João Garizo do Carmo, Paulo de Melo Sampaio, Francisco José de Castro, João José Malato, Bernardino Ramalhete, Luís Vasconcelos, and Francisco Castro. The railway station, the "Casa dos Bicos," the Palace of Weddings, the Scala buildings, Cathedral of Beira, University Center for Culture and Arts in the Ponta Gêa neighborhood, and the "Grande Hotel," among many others, are examples of the modernist architecture of this city. It is precisely for the wealth of this heritage and the need to preserve it that this work aims to draw attention [17].

Modernist architecture was symbiotically integrated into the landscape, denoting adaptability to climatic specificities (Figure 2), as demonstrated by various solutions with the property that, when transposed outside the "claustrophobic Portuguese rectangle" into a less restrictive society and more distant from the center of administrative and political power, what these architects had in common was this possibility of designing with a modern vocabulary through appropriation and incorporation in their work [17,18].

Figure 2. Example of passive solar systems present in modern buildings.

Architecture is usually discussed in terms of what buildings look like from the outside [19]. However, how buildings and towns work involves more than how they shape and limit spaces. How buildings order space, especially urban space, is the key issue to identify what is wrong with the built environment today [19].

The subject of interactions between the adaptation and mitigation of urban climate changes gained special importance with the first publications in 2006, in “Adaptation and mitigation in urban areas: Synergies and conflicts” [20]. Urbanism encompasses the social, economic, and political processes that are most closely linked to the rapid transformation of habitats, the destruction of ecologies, the depletion of materials and resources, and the production of pollutants and carbon emissions that threaten human wellbeing. Consequently, the critical concern for 21st-century global urbanism is to critically understand the broader societal and material implications of strategic responses to the pressures of climate change, resource constraints, and their inter-relationships with the global economic crisis [21].

Adaptation and mitigation can be divided into nine major subjects: urban design and land use planning, transportation, building, waste, energy, green and blue infrastructure, water, urban governance, and behavioral issues; most subjects include specific measures applied to each one that are related to both mitigation and adaptation [22].

Increased urbanization has led to land occupation changes, directly influencing the urban microclimate through landscape consumption and the displacement of nature. Many local effects in cities, such as the topography, building geometry and dimensions, density, facade, roof materials [21], reflection coefficient of surfaces, urban canyons, pollution from transport, and the integration of greenery, have significant impacts on the temperature profile of any area or district [21].

Adaptation to climate change can be integrated into the city and regional planning. Disruptive innovation is also critical to mitigation being achieved rapidly. It can now be seen in power and transport [22] through solar, wind, batteries, and electric vehicles, as well as through potential disruptive innovations, such as trackless trams and hydrogen [21]. The theory of urban fabrics can enable city planning to mainstream all the above innovations by focusing on different planning strategies in different cities and regions [22].

In this way, the concept of green urbanism [23] aims to consolidate an approach that balances urban planning and the impacts of climate change. In this sense, urban spaces must respond to social and cultural needs, with an integrated approach in the various areas that incorporates sustainability principles [24]. The need for change impels the definition of policies and strategies that motivate sustainable urban infrastructures and innovative concepts with biophilic urbanism [25]. Urban space strategies should consider an integrated approach to adaptation and mitigation [26] in all its dimensions: transport, waste, resource consumption, telecommunications, etc.

In transport and land occupation, it is important to preserve biodiversity by combining it with infrastructure that responds to social needs [27]. The urban occupation should consider the maintenance of site characteristics and exposure to climate change, minimizing its impact by preserving and improving local conditions [28].

The efficient and rational use of water and energy resources is a fundamental factor for valuing them. Efficient resource management reduces its impact on urban space through optimized consumption and efficient production and reuse. The use of energy is inevitable; however, any production must be cleaned using renewable resources and exploring new technologies that allow for the efficient and rational use of sources [29].

The recent pandemic has alerted us to social relations and the existence of two spaces: virtual and physical. This relationship extends to a new understanding of public and private spaces and new forms of social relationships that condition and renew urban space use and management [30].

The shift from the paradigm of design, planning, and urban management to an approach that prioritizes the human being and its relationship with the environment can be supported by the new emerging concepts of biophilic and green urbanism. To reduce gas emissions and provide sustainable and circular growth and development, it is essential to break with the past through the vision of a new urban space that is focused on quality of life with an emphasis on cultural and societal conditions [31].

The effects of vegetation on human thermal stress in a hot-arid region were tested in two semi-enclosed urban spaces with various combinations of mature trees, grass, overhead shading mesh, and paving [21]. In this highlighted study, the index of thermal stress was calculated hourly using measured meteorological data in the studied sites to evaluate thermal comfort in the different spaces based on radiative and convective pedestrian-environment energy exchanges and sweat efficiency and expressed on a thermal sensation scale ranging from "comfortable" to "very hot" [32].

The efficiency of water use for providing comfort was gauged for each of the vegetative landscaping treatments by comparing the total evapotranspiration to reduce thermal stress, which was expressed in terms of their values in equivalent energy. While conditions in a paved, unshaded courtyard were uncomfortable throughout the daytime hours, each of the landscape treatments made a clear contribution toward improving thermal comfort. With shading, either by trees or mesh, the discomfort was reduced in duration by more than half and limited the maximum severity when the shading was placed above paving. When combined with grass, both shading mechanisms yielded comfortable conditions at all hours. In both cases, the trees' effect was more pronounced than that of the mesh, but by a small margin. With unshaded grass, "hot" conditions in the courtyard were restricted to a short period in the mid-afternoon, which was a considerable improvement over unshaded paving and was mainly attributable to the lower radiant surface temperatures [21].

3. Intervention Principles

Sustainable urban development is an emerging trend in the built environment in general [33,34]. The path to urban sustainability requires diagnosis as a starting point to define rehabilitation policy initiatives [35].

In this context, there is a growing consensus on the need to assess the energy [36,37] and water [38] use of built parks [39,40].

The rehabilitation of the built heritage presupposes the application of intervention methodologies based on processes that respect and guarantee the future of the building and minimize all negative impacts on the occupants, in terms of comfort [41], health, and productivity, among others. The intervention principles proposed by the various international letters and recommendations establish guidelines that have a permanent objective of the recovery of spaces without jeopardizing the built elements' cultural value [34,42]. As such, any intervention methodology must take this fact into account [42].

3.1. Local Characteristics of Beira

Located on the east coast of Africa, Mozambique has a coastline that is about 2770 km long that is bathed by the Indian Ocean and is characterized by a warm tropical climate, which is influenced by the monsoons of the Indian Ocean and the warm current of the Mozambique channel. According to the Köppen–Geiner classification [1,43], it varies according to the regions, between the tropical (A), arid (B), and subtropical (C) climates, with influences from local factors, such as altitude, latitude, and proximity from the coast. The country is divided into three climatic zones: north and south zones, which are characterized by tropical and subtropical climates, respectively, and the central zone, which has a a more arid climate. Average temperatures vary between 20 °C in the south and 22 °C in the north. The northern region is under the influence of low equatorial pressures, while the south is affected by tropical anticyclones and the warm currents of the Mozambique channel [9]. The country has a simple seasonal temperature profile, with the minimum in July (winter) and the peak in November for the maximum temperature. There are two seasons, dry and cold, from April to October, and hot and humid, from October to March. The latter is characterized by rains, which start in October and intensify until March/April, though in the South, the beginning is usually later [1].

In particular, the city of Beira, Mozambique, is characterized by a tropical savanna climate, with the designation "Aw" according to the Köppen-Geiger classification [44,45], which provides information regarding the climatic data, namely the average temperatures during the year, which allows us to make conclusions about the cooling needs (comfort temperature of 25 °C) and the absence of heating needs (comfort temperature of 18 °C). The months of greatest rainfall are December, January, February, and March, with rainfalls of 231.6 mm, 250.7 mm, 302.3 mm, and 274.4 mm, respectively [46].

In particular, this work had the main objectives of identifying and defining strategies that promote the rehabilitation of residential buildings and urban areas in Beira, emphasizing their energy and water efficiency and the management and reuse of construction and demolition wastes. For defining these strategies, it was very important to establish a deep knowledge about the urban and buildings characteristics by using a proper survey methodology that was adapted to local conditions. The Ponta Gêa neighborhood was used as a case study due to its importance and characteristics mentioned before. We intended to explore individual and community (groups of buildings, blocks, etc.) strategies involving standard supply systems that can translate into greater efficiency and profitability by considering the principles of sustainability and a circular economy.

To achieve this goal, the effect of climate change was analyzed first in order to identify the main principles to take into account when intervening in urban areas. Then, some practices related to the main subjects of the intervention's strategies were highlighted: to improve energy efficiency and thermal comfort, water efficiency, and the valorization of construction waste. Finally, the methodology to design the support decision method was established.

3.2. Energy Efficiency and Thermal Comfort

Buildings account for about 40% of the global energy consumption and contribute over 30% of the CO_2 emissions. A large proportion of this energy is used for thermal comfort in buildings [22]. The thermal performance of external walls represents a key factor in increasing a building's energy efficiency and reducing greenhouse gas emissions. Thermal insulation is undoubtedly one of the best ways to reduce energy consumption due to winter heating and summer cooling needs. Insulation materials play an essential role in this scenario since selecting the correct material, thickness, and position allows for better indoor thermal comfort conditions and adequate energy savings. Thermal properties are fundamental, but they are not the only ones to be considered when designing a building envelope: sound insulation, resistance to fire, water vapor permeability, and impact on the environment and human health need to be carefully assessed too [21].

In warm, humid conditions, airflow can be an energy-efficient means to achieving indoor thermal comfort. Airflow does not create sensible cooling of air that can be measured on a thermometer; it conducts heat from our skin. This results in a cooling sensation [47]. Bioclimatic design cannot continue to be a side issue of a technical nature to the main architectural design [47].

In climate-sensitive architecture, strategies should be adopted to meet occupants' needs by considering the local solar radiation, temperature, wind, and other climatic conditions. Different strategies are required for the various seasons. An important heating strategy includes a collection of the sun's heat through the building envelope, storage of the heat in the mass of the walls and floors, the distribution of collected heat to the different spaces that require heating, and the retention of heat within the building [47]. An important cooling strategy involves protection of the building from direct solar radiation; expelling and replacing unwanted hot air; reducing heat from occupants, types of equipment, and artificial lighting; protection from unwanted heat via infiltration or conduction through the envelope; improving natural ventilation by acting on the external air [47]. An important daylighting strategy includes a collection of natural light inside the building, homogeneous spreading or focusing of light into relevant spaces, reducing the sun's rays' penetration into the building by external shading devices, and controlling light penetration using movable screens to avoid discomfort [47]. Continuous improvements in the building envelope's thermal insulation, combined with an increase in the internal thermal gains, ensure sufficient heating in winter and create a need for cooling in the remainder of the year [48]. Furthermore, ventilation is essential to ensure good indoor air quality, but it can have a dominant influence on a building's energy consumption. Therefore, natural ventilation is now considered one of the requirements for low-energy construction projects [49].

On the other hand, the benefits of passive solar design may be considered within the context of three basic types of environment. First, design measures can improve the external areas' environmental conditions through the provision of open courts and courtyards, lightwells, shelterbelts, and micro-climatically protected areas generally [50]. Through considering the details of adequate urban design and construction, the population must be accommodated with better environmental quality and better housing efficiency [51].

3.3. Water Efficiency

The risk of hydric stress will increase significantly across the entire planet [52]. One in six people currently does not have access to drinking water, with Africa being the most affected [1]. Water-related problems are closely related to health. Water frequently appears contaminated by bacteria from organic materials from different sources, such as human waste, animal waste, and industrial waste, causing cholera, dysentery, typhoid, schistosomiasis, hookworm, and trachoma. The scarcity of drinking water is a serious problem that plagues the African continent, but it is worsening at a fast pace worldwide [53].

Decentralization can reduce the piped distribution network scale needed to enable non-potable water reuse in urban areas by producing recycled water closer to its point of use [54]. As the world is facing frequent water shortages, while at the same time, water demands are increasing due to population growth and affluence, identifying energy-efficient and cost-effective alternative water supplies seems inevitable [55].

Given that water is a resource that can and should be well used through simple, sustainable techniques, it is important that we take better advantage of this good [56]. In this regard, the rainwater use system in Figure 3 is no more than a simple, sustainable technique that allows for capturing rainwater from the roof of the house or building, filtering it, and storing it in a reservoir to be used, both internally and externally, by the property [1].

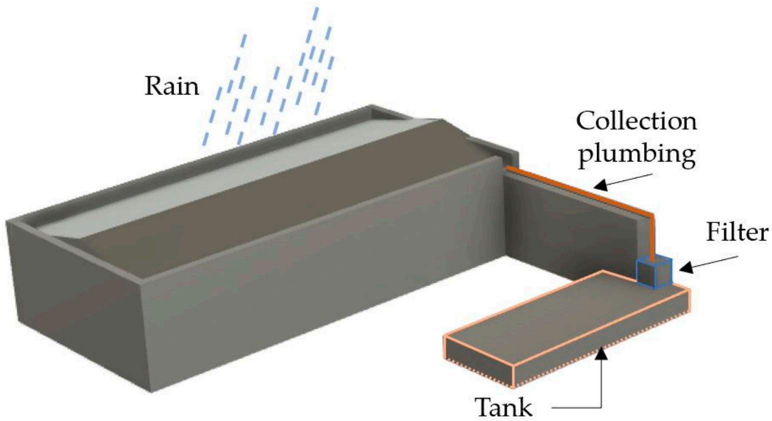


Figure 3. Schema domestic rainwater collection cistern, adapted from [1].

In this way, two types of locations can be distinguished: urban areas and rural areas. In urban areas, rainwater collected can be used for non-potable purposes, such as flushing toilets, irrigating gardens, washing terraces and backyards, etc. The collected rainwater can also be used for drinking purposes if treatment is carried out. Analyses are carried out periodically to ensure the potability of other collection systems, such as condensation, seawater, or brackish water [1].

Lately, equipment to reuse gray water from bathtubs, washbasins, and washers has appeared on the market. This equipment consists of tanks that store the water captured in bathtubs and washbasins in the purification process [57]. Thanks to this purification, water can be used for flushing toilets, garden irrigation systems, or cleaning external terraces. These systems have a considerable advantage in providing savings of about 45% of the drinking water due to the fins in these systems. The equipment can be installed in a cave, where the deposits will be cleaned with an indicator and water treatment. Besides these deposits, there are pipes whose function is to capture water from the bathtub and washbasin.

Potable water methods can be physical or chemical [55]. As a physical method, we filter; the water of dubious quality must be filtered. Although filtration helps to eliminate bacteria, it is not enough to guarantee drinkable water [1].

3.4. Valorization of Construction Waste

Since the building sector was recognized as a significant contributor to global carbon dioxide emissions, major efforts have been aimed at the mitigation of this effect [58]. The transition to a more efficient circular model of economics has ambitions of solving the sustainability problems on a higher level thanks to improved recycling and the creation of material loops [59]. The current linear model of the economy results in the immense consumption of natural resources and the dumping of pollutants at the end of the materials' life cycles [60].

The management of wastes resulting from construction, renovation, and demolition activities has become an important challenge [61]. The composition of CDW comprises mostly concrete, metal, mortar, brick/block, plastic, and timber [62].

The acceleration of the industrialization process and unrestrained consumerism in a capitalist society has generated a reality where solid waste causes serious environmental problems. In this context, several discussions have taken place on how to manage solid waste in society to collaborate toward a sustainable reality in the face of the growing urbanization process and the need to develop environments closer to natural ones [63].

According to World Bank reports (2012), the generation of CDW will reach 5 billion tons globally by 2025. Improper handling and disposal of this inert waste creates environmental hazards and also occupies land space. The recycling and reuse of CDW may help to attain a sustainable ecosystem. CDW largely comprises wood, concrete, brick, glass, tiles, concrete, and brick and is termed building-derived materials [64].

Throughout the building demolition process, we found that electrical wire, other electrical elements, and wooden window frames and doors have been recovered either for reuse purposes or wholesale in secondary markets. Even the small steel length enclosed in concrete is retrieved using gas cutters and sold to steel scrap dealers [62].

Concrete waste comprises a significant part of CDW, calculated as being about 60%. Hence, CDW disposal's key objective is waste concrete dealing, which may be an ideal aggregate source for new concrete production. Promoting recycled aggregates from CDW for producing new concrete will reduce the demand for virgin aggregates [62].

Brick is one of the main components of CDW due to traditional construction habits and old construction technology. Broken bricks can be mixed with cement and adhesive to produce blocks. These blocks are mainly suitable for enclosures, greening, and ground tiles. Utilizing broken bricks as a substitute for raw material for brick production, as well as road foundations, should be other primary recycling uses for crushed bricks [65].

A significant amount of mortar waste (9%) is produced during CDW generation [65]. Several studies investigated reusing and observing the possible application of this recycled material in "green" concrete masonry blocks. These "green" building materials are still limited in their utilization, such as in non-load-bearing partition walls and ornamental urban elements [62]. Although timber is not increasing in the waste stream, the timber waste generation is estimated at 3% of total CDW. Several value-added uses and standard applications for recycled wood, such as chipboard production, erosion control, fertilizer amendment in composting, and energy recovery [62]. The metal waste from construction projects is usually relatively low due to these recycled building materials having the highest values. The percentage of metal waste is 3% of CDW [62]. Different kinds of material can be recycled from construction and demolition projects, particularly plasterboard, metals, glass, plastics, floor and wall coverings, cartons, cardboard, tiles, etc. [66].

New alternative technologies for the recovery of biomass residues and urban residues through different thermal treatments (pyrolysis, gasification, hydrothermal treatment) have gained importance in valorizing new construction materials, which are mainly based on cement [67]. The adoption of biochar in construction materials would create opportunities for carbon sequestration of agricultural biomass residues instead of the methane and CO_2 gases released during disposal [68]. There will be a reduction in the impact of building material production on climate change, which can dramatically reduce greenhouse gases. Investigations indicate that biochar can be incorporated as cementitious compounds or aggregates, and acts as a sustainable mixture for some properties [69].

4. Methodology

It should be noted that the neighborhood of Ponte Gêa consists of architecture that merges the local and colonial traditions, allowing for the analysis of systems and solutions incorporated by Portuguese architecture [70] and engineering techniques in the Mozambican context and, based on the study, establishing guidelines for the process of renovation of this neighborhood.

Within the proposed methodology (Figure 4), we highlighted data collection on the strategies developed by different countries that have adapted to their reality, the "Agenda 21," and "Agenda 2030." According to the reality that is inherent to each region, this adaptation consists of translating the global strategies contained in those documents about environmental needs in the face of endogenous cultural and technological characteristics [71].

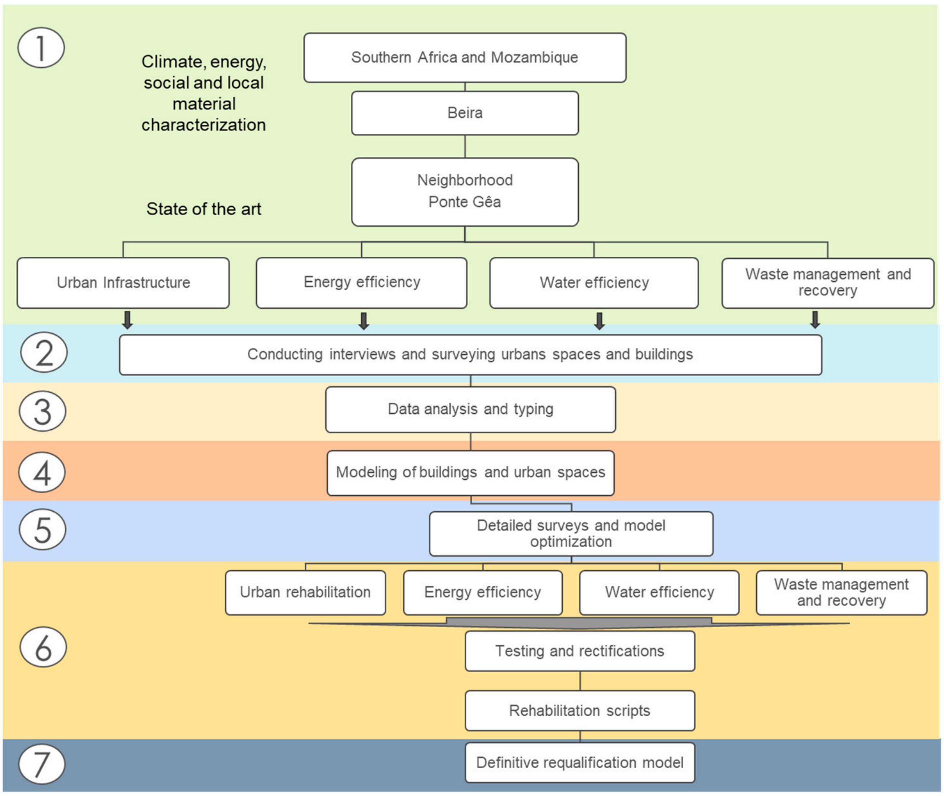


Figure 4. Proposal of different levels for defining a model for rehabilitation for the neighborhood of Ponte Gêa.

The rehabilitation of buildings [16,60], the urban area, and their environmental control systems will only achieve true sustainability value when it ensures the necessary standards of efficiency and comfort for human life [72]. For this to be possible, interventions in existing buildings must be designed according to the social, cultural, and climate conditions of each site.

We also intended to develop a synthesis of Mozambique's environmental issues, identifying the ecological needs and potentialities. It is necessary to deepen the efforts related to the initiatives already implemented so far, both in terms of economic support and strategic planning for sustainable development in waste management, water efficiency, and energy.

The concepts related to urban rehabilitation at the African continent level will also be identified, involving a study of the central interventions that occurred. The main strategies adopted at the bioclimatic architecture level can be developed such that they are compatible with sustainable principles within this urban rehabilitation logic, considering community and individual plans.

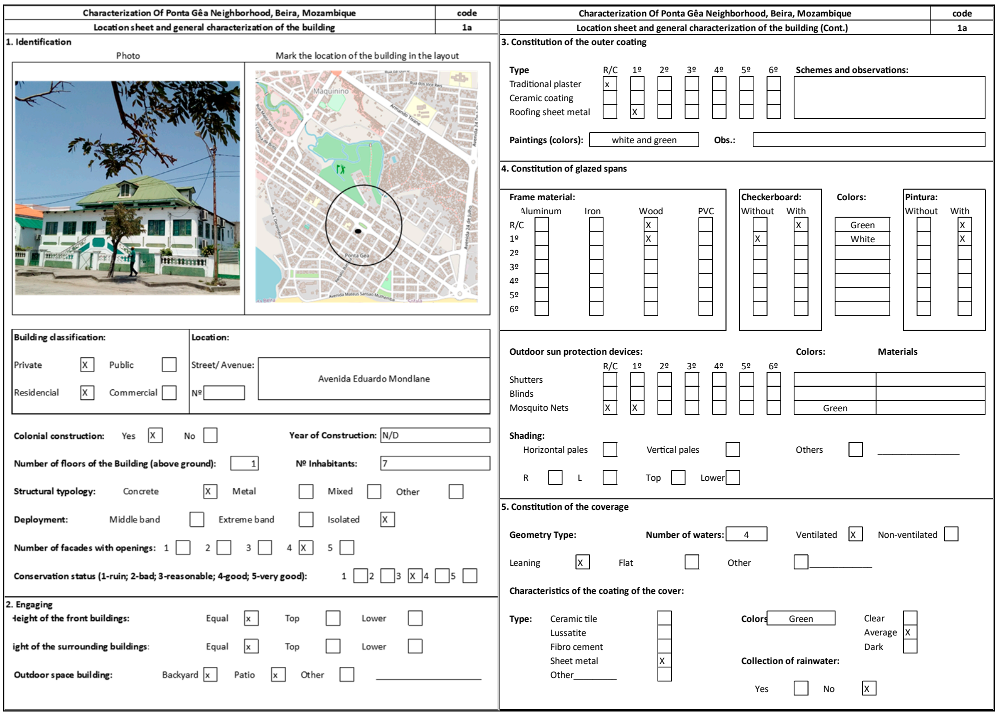
The evolution of the concepts of heritage and sustainability shows that they are related both in terms of their common scope and intention to preserve this ecosystem for future generations. A concise and previously tested methodology can be a useful tool for informing decision-making and ensuring that future impact assessments of the conservation of the built heritage have a basis for comparison [73].

Considering that there is no specific model defined according to the local context, as a result of the assumptions defined above, we defined the scheme shown in Figure 4. In this scheme, the different stages are horizontally defined and complemented with the specific investigation points and each stage.

Initially, in point 1 (Figure 4), a characterization of the local materials, existing rehabilitation solutions, and climatic, social, economic, energy, water, and waste management conditions are to be carried out.

Subsequently, in point 2, data collection is to be carried out in the study area, involving the survey and general characterization (urban and building), in a total of 3300 buildings in the neighborhood under study with the support of a topographic survey of the urban space, survey forms (Figures 5 and 6), and contacts with local public institutions (provincial government, the municipal council of Beira, universities in Beira, neighborhood's chief). Using the survey forms, data are to be collected regarding the individual classification of buildings in the neighborhood according to their use and surroundings, types of coverings, window frames, types of roofs, passive strategies, water supply, drinking water storage, sewage network, sources of power, and cooling equipment and heating equipment. The types of coverings, the constitution of glazed openings, external sun protection devices, and types and cover materials are investigated in more detail. With this preliminary survey, it will be possible to group the buildings according to their use, structural typology, roofs, and external surroundings. Furthermore, data on the water supply, sewage network, cooling equipment, energy sources for cooling hot water in the interior, and even food preparation are to be collected at this stage.

In point 3, the data collected using the survey forms will describe the buildings in the area under study. In the first phase, the separation between private and public buildings takes place. A subdivision in residential and commercial buildings must be done to allow for rehabilitation proposals according to the function. The structural and surrounding typologies are also checked with respect to the building. Thus, the in-depth knowledge of the characteristics of the urban space and the buildings, the knowledge of the intervention strategies, the levels of efficiency and improvement that can be achieved, and the potential and local limitations will allow for defining intervention criteria and predicting the best strategies.



Characterization Of Ponta Gêa Neighborhood, Beira, Mozambique | code
Location sheet and general characterization of the building | 1a

1. Identification

Photo | Mark the location of the building in the layout

Building classification: Private [X] Public [ ] Residencial [X] Commercial [ ]

Location: Street/ Avenue: Avenida Eduardo Mondlane Nº [ ]

Colonial construction: Yes [X] No [ ] Year of Construction: N/D

Number of floors of the Building (above ground): 1 Nº Inhabitants: 7

Structural typology: Concrete [X] Metal [ ] Mixed [ ] Other [ ]

Deployment: Middle band [ ] Extreme band [ ] Isolated [X]

Number of facades with openings: 1 [ ] 2 [ ] 3 [ ] 4 [X] 5 [ ]

Conservation status (1-ruin; 2-bad; 3-reasonable; 4-good; 5-very good): 1 [ ] 2 [ ] 3 [X] 4 [ ] 5 [ ]

2. Engaging

Height of the front buildings: Equal [x] Top [ ] Lower [ ]

Height of the surrounding buildings: Equal [x] Top [ ] Lower [ ]

Outdoor space building: Backyard [x] Patio [x] Other [ ] ______

Characterization Of Ponta Gêa Neighborhood, Beira, Mozambique | code
Location sheet and general characterization of the building (Cont.) | 1a

3. Constitution of the outer coating

Type	R/C	1º	2º	3º	4º	5º	6º
Traditional plaster	x						
Ceramic coating							
Roofing sheet metal		X					

Schemes and observations:

Paintings (colors): white and green Obs.:

4. Constitution of glazed spans

Frame material:	Aluminum	Iron	Wood	PVC	Checkerboard: Without	Checkerboard: With	Colors:	Pintura: Without	Pintura: With
R/C			X			X	Green		X
1º			X		X		White		X
2º									
3º									
4º									
5º									
6º									

Outdoor sun protection devices:	R/C	1º	2º	3º	4º	5º	6º	Colors:	Materials
Shutters									
Blinds									
Mosquito Nets	X	X						Green	

Shading: Horizontal pales [ ] Vertical pales [ ] Others [ ] ______

R [ ] L [ ] Top [ ] Lower [ ]

5. Constitution of the coverage

Geometry Type: Number of waters: 4 Ventilated [X] Non-ventilated [ ]

Leaning [X] Flat [ ] Other [ ] ______

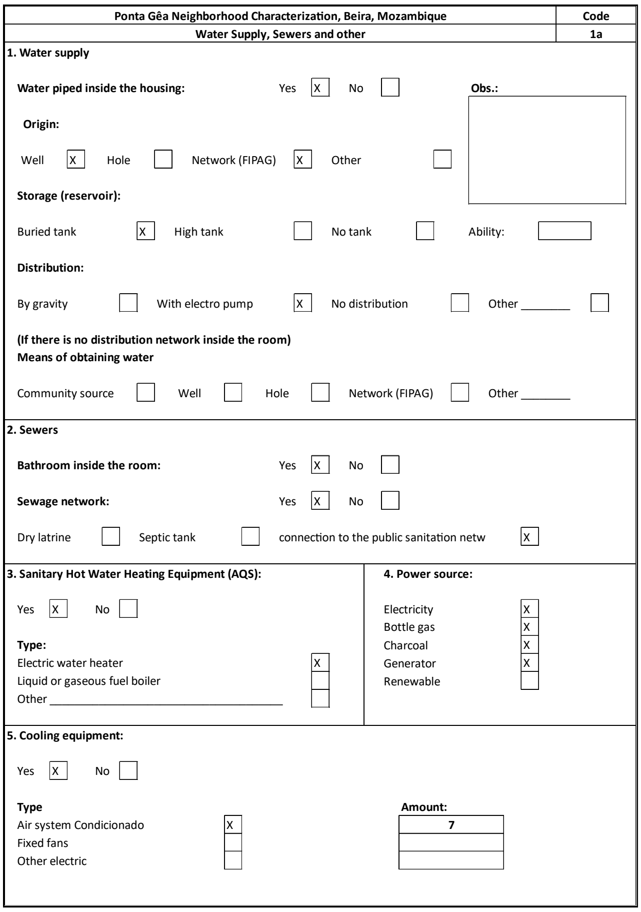
Characteristics of the coating of the cover:

Type: Ceramic tile [ ] Lussatite [ ] Fibro cement [ ] Sheet metal [X] Other______ [ ]

Colors: Green Clear [ ] Average [X] Dark [ ]

Collection of rainwater: Yes [ ] No [X]

Figure 5. Survey forms for the preliminary characterization of buildings: general characterization of buildings.



Ponta Gêa Neighborhood Characterization, Beira, Mozambique | Code
Water Supply, Sewers and other | 1a

1. Water supply

Water piped inside the housing: Yes [X] No [ ] Obs.:

Origin:

Well [X] Hole [ ] Network (FIPAG) [X] Other [ ]

Storage (reservoir):

Buried tank [X] High tank [ ] No tank [ ] Ability: [ ]

Distribution:

By gravity [ ] With electro pump [X] No distribution [ ] Other ______ [ ]

(If there is no distribution network inside the room)
Means of obtaining water

Community source [ ] Well [ ] Hole [ ] Network (FIPAG) [ ] Other ______

2. Sewers

Bathroom inside the room: Yes [X] No [ ]

Sewage network: Yes [X] No [ ]

Dry latrine [ ] Septic tank [ ] connection to the public sanitation netw [X]

3. Sanitary Hot Water Heating Equipment (AQS):

Yes [X] No [ ]

Type:
Electric water heater [X]
Liquid or gaseous fuel boiler [ ]
Other ______________________ [ ]

4. Power source:

Electricity [X]
Bottle gas [X]
Charcoal [X]
Generator [X]
Renewable [ ]

5. Cooling equipment:

Yes [X] No [ ]

Type
Air system Condicionado [X]
Fixed fans [ ]
Other electric [ ]

Amount: 7

Figure 6. Survey forms for the preliminary characterization of buildings: water supply, sewers, and others.

Subsequently, in point 4, the modeling and testing of the urban environment and buildings, the construction's energy performance, and the environmental conditions before and after the intervention actions are carried out. We intend to perform energy and water simulations using modeling tools. Simulations will be done using "EnergyPlus 9.4.0 software", from USA, for the single building and "CitySim Pro", provided by Kaemco LLC, from Switzerland, for the block scale. Based on the literary review, a set of different modeling tools will also be studied, such as "Green Building Studio", provided by Autodesk, Inc, USA; "UrbaWind 2.2", provided by Informer Technologies, Inc.; and "Design builder V6", provided by DesignBuilder Software Ltd, UK, to select the best one [56,74,75].

In point 5, after the modeling/simulation, a comparative analysis of the effects of the type of simulations is to be undertaken and the models are to be optimized based on the different results obtained, in agreement with the principles of sustainability. This experimental phase includes overlapping the matrix of constructive pathologies recorded in the buildings located in the neighborhood and the thermal conditions (macroclimate and microclimate). Analysis of the results and definition of the most appropriate strategies will be carried out with a comparative analysis of the results of the simulations of the building types, more appropriate strategies and analysis of the consumption reduction, improvement of the efficiency (the parameters for evaluating the consumption and the efficiency must be defined), and the construction and demolition waste management

Point 6 defines a decision support model, which is a guide for implementing strategic interventions that consider the three areas covered. This test model will make it possible to establish the expected improvements, depending on the action to be taken, by exploring individual and community strategies according to the climatic and social conditions.

Finally, in point 7, after testing the previous model, the final definition of the model and rehabilitation guidelines are to be produced, where the interim relations of each point will be reviewed, and the final and proposed considerations will be presented. The possibility of generalization at an adapted national level will also be assessed.

In this development phase, it will be possible to design strategies that will improve thermal comfort and the consequent reduction in energy and water consumption through individual and community strategies, as well as propose techniques and solutions adapted to the building that allow for prolonging the useful life; all of these take into account local and cultural climatic characteristics.

5. Conclusions

Awareness of the importance of the built heritage has prompted a previous assessment that intersects heritage and sustainability. This proposal's results for the preliminary study show that it is important to provide prior information related to the attributes and values of the building in a baseline assessment, making it the first proposal for a definitive methodology to assess the area under study. However, this approach has the disadvantage of making the evaluation process more time-consuming but more accurate in practice. It focuses on individual buildings' existing characteristics and defining the building's conservation state before starting the requalification project phase in order to accomplish sustainability indicators regarding the location, energy, water, construction, materials, interior environment, community, and values.

The application of this survey methodology will allow for the definition of strategies that promote the rehabilitation of residential buildings in Beira's city, taking into account local, architectural, and social climate issues and emphasizing their energy efficiency, water efficiency, and the management and reuse of the CDW of the proposed interventions and management of urban waste. We intended to develop a model to support strategic intervention decisions that are to be implemented by considering the three domains addressed, namely, energy, water, and waste. This model will make it possible to establish the expected improvements, depending on the action to be taken, by exploring both individual and community strategies that involve standard supply systems that can translate to greater efficiency and profitability (such as energy production and the collection, recycling, and reuse of water and waste).

This model is the baseline that allows for the data to be collected before producing a definitive model and proposing intervention strategies. It is a tool for developing a guide for interventions at the individual and urban levels for energy and water strategies in building rehabilitation and the management of CDW through the proposal of guidelines in the construction and repair of residential buildings. Finally, all proposals will be supported by sustainable solutions based on the principles of a circular economy.

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