SMART SLUM. WITHOUT

The case of Quelimane, Mozambique.

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Smart without Slum

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▪ Abstract

Currently, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050. Projections show that urbanization, the gradual shift in residence of the human population from rural to urban areas, combined with the overall growth of the world's population could add another 2.5 billion people to urban areas by 2050, with close to 90% of this increase taking place in Asia and Africa, according to a new United Nations data on May 2018.
SMART without SLUM focuses on the often-neglected Medium sized cities specifically in the case of Africa. With the use of the IMM methodology this thesis explores an integrated approach towards investigating the city as a complex adaptive system and the city of Quelimane was selected as a study case. The study case is developed in five themes developed from the integration of the IMM (Integrated Modification Methodology) and the SDG (sustainable development goals). The five themes drive the prototype projects that are proposed within the focus areas of the city.

▪ Astratto

Attualmente, il 55% della popolazione mondiale vive nelle aree urbane, una percentuale che dovrebbe aumentare al 68% entro il 2050. Le proiezioni mostrano che l'urbanizzazione, il graduale spostamento della residenza della popolazione umana dalle aree rurali a quelle urbane, combinato con il complesso la crescita della popolazione mondiale potrebbe aggiungere altri 2,5 miliardi di persone alle aree urbane entro il 2050, con circa il 90% di questo aumento in atto in Asia e Africa, secondo i nuovi dati delle Nazioni Unite di maggio 2018.
SMART senza SLUM si concentra sulle città di medie dimensioni spesso trascurate, in particolare nel caso dell'Africa. Con l'uso della metodologia IMM questa tesi esplora un approccio integrato per indagare la città come un sistema adattivo complesso e la città di Quelimane è stata selezionata come caso di studio. Il caso di studio è sviluppato in cinque temi sviluppati dall'integrazione dell'IMM (Integrated Modification Methodology) e dell'SDG (obiettivi di sviluppo sostenibile). I cinque temi guidano i prototipi di progetti proposti nelle aree di interesse della città.

The Preface

Slum Vs Shanty

A slum is composed of delapidated permanent construction. A shanty town is composed of temporary dwellings built from materials at hand. So the basic difference is that a slum is permanent, a shanty town is temporary. In general, however, a slum is an area of "normal" buildings that has fallen into disrepair due to the poverty of their inhabitants. So a slum is poorly maintained housing stock that would have originally been built "to code". It would generally still have municipal services like water, electricity, and telephones.

A shanty town is a collection of makeshift housing thrown together with no recognizable organization. From its beginnings a shanty town is very poorly constructed. It generally lacks even basic municipal services. Even in its disrepair, a slum generally has far superior housing stock than a shanty town.

1

Smart_Slums.

Overview of slums and why Quelimane?

What to Expect

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1.1 Slum or Informal settlement

According to Cities Alliance more than one billion people in the world live in slums today. As of 2012 studies had shown that out of every 3 people in developing countries one lives in a slum (Cities Alliance 2019). The UN has reported that while slums have reduce from 39% to 30% from 2000 -2004 the actual numbers continue to rise. The UN has projected the numbers to increase to about 1.4 billion by 2020 if nothing is done.

1.1.1 Slum or Informal?

But what is a Slum to begin with? The use of the word slum and informal settlement have been interchangeably used since the inception of cities. Other names such as the shanty town, the ghetto, favela, barrio, Basti are used in different countries. Slums are informal settlements within cities that have inadequate housing and squalid, miserable living conditions (Cities Alliance 2019). In an approach to define this term, UN HABITAT (Nairobi 2014) introduced five characteristics that would define a slum. These are:

- Poor structural quality of housing
- Overcrowding
- Inadequate access to safe water
- Inadequate access to sanitation and other infra structure
- Insecure residential status.

They define a location a slum if it has at least on of the above-mentioned characteristics. In their definition it would mean that slums exist in larger and more common places than we think. Common to slums around the world is the fact that they are all in informal settlements. Their development over the last decades have become a major concern sparking numerous studies. Its important to note that another fast-developing form of informal settlement is the spontaneous housing. This form of informal settlement occurs within the urban periphery on city land. Land tenure is assured, but dwellers subdivide the existing land. This practice, semi -legal and illegal, in turn causes the location to grow gradually into a slum or informal settlement. this happens because the initial services provided to the area becomes inadequate and overcrowding also sets in. Reports from the UNHABITAT (Narobi 2014) shows that roughly 200 million people in Sub Saharan Africa live in slums. This was reported the highest slum rid part of the world as of 2010. This is obvious in the Figure 1.1.

1.1.2 Development of Slums

Cities have become a symbol of success and development. Cities are seen by many as the grounds to find the better prosperity that the rural areas cannot provide. Formally lucrative jobs as farming in the rural areas now produces lower income than before. This has mainly been due to the shift from rural methods to more industrial approaches. The advent of industrial approaches has been coupled with opportunities and higher job prospects in cities. Thus in other to survive rural settlers sort to a move to the cites (Cities Alliance 2019). Upon moving, Slum dwellers undergo three main phases in their lives. This process moves them from the poor to lower middle income status and neighbourhoods which they develop themselves. The first is the Bridge headers: This refers to initial stage where the family decides to move from the rural area to the urban. And upon arrival, their main priority is to find some form of shelter. A shelter that can be called home which more than often is temporary and close to the employment opportunities. The next phase is the Consolidators; at this phase they start occupy a piece of land on the fringes of the city and consolidate its place in the city. The status seekers represents the final stage; they now aim at legalizing the tenure of the land they consolidated. They further aim at acquiring urban services and the extend and improve their housing

This notion urban migration has been one of the greatest pulls in urban migration. With this migration, city populations have been growing at faster rates. A further look at Figure 1.1above shows how this trend has been evident in sub-Sahara Africa over the last 3 decades of study. Its noticeable that with advent of cities migration and the slums have also increased. Such growths in cities now have become the responsibility of the government. Their solution over the years have been by urban planning.

At the African Urbanscapes 2019 workshop, Roberto Rocco argued that informal settlements are products of "modernization" through an urban planning approaches that excluded certain classes of people. It is an important observation Roberto made since urban planning policies and decision makes have all always left the poor out of their plans. Relating to his previous conversation with political leaders of developing nation, Rocco mentioned these leaders ignore the existing of the poor. Cities Alliance(2019) have mentioned that government failure to incorporate the poor into the urban planing schemes have led to the poor finding their own ways, thus leading to informal settlements and eventually slums. The poor have consisted mainly of urban migrants. These urban migrants prefer to squat in informal settlements since no plans have been made for their existence by the government (Un HABITAT Nairobi 2014). Clearly ignoring the presence of the poor by the governments have indirectly sped up the growth of slums.

Other minor practices that have led to the creation and continuous growth of slums is the housing standards. According to the UN HABITAT (Nairobi 2014) report, standards created by the government through their planning for housing are only achievable by the rich. This has made construction outside these standards illegal and increased the slums.

Today, Slum upgrading has become one of the ways of tackling the problem of slums. Its an alternative to completely dislocating the people in the slums. Relocating slum residents have come with a major conflict of interest. Slum dwellers find areas closer to their economic opportunities. Thus relocating them into new areas becomes unviable.

Figure 1.1 Indicators of slums

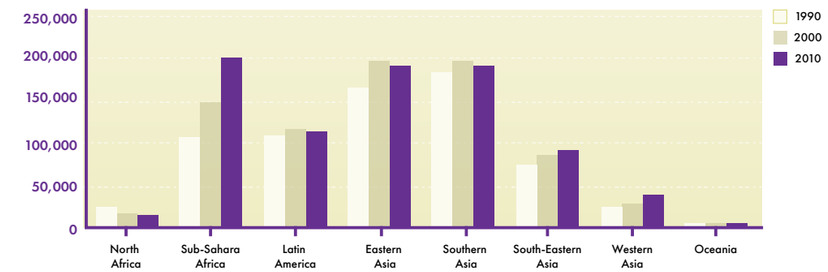


Figure 1.2 Urban Population Living in slums ,1990-2010,(Un-Habitat 2008A:32)

1.1.3 Slum Upgrade.

This alternative considers the need to gradually improve, formalize and incorporate the slums into the city (Cities Alliance,2019) Slum upgrade does not just aim at bringing water, sanitation and amenities as some governments have implied by their actions. On an even narrow scale, slum upgrade is improving on the housing and basic amenities of the slum areas. Rather Cities Alliance (2019), points out a much broader definition, i.e.; it should be towards putting economic, social, institutional and communal activities into motion to improve the lives of the people. This is very crucial to the soul of the community as upgrading only the physical community ignores its organizations, cultural activities and facilities UN HABITAT (Nairobi 2014).

Upgrading slums help to improve on the social inclusion of the dwellers. Slum dwellers are victims of illegality exclusion and lack of social protection for the vulnerable. These issues that are prominent in slums later affect the city. Therefore, their inclusion solves a problem for the city also.

Slum upgrade provides the opportunity to elevate the quality of life of the people. This achieved through the provision of shelters at larger scales but low cost. By improving the quality of life, the untapped resources of slum dwellers which were once held back by status and marginality can be exploited.

Slum upgrade is cheaper and cost effective than relocation to public housing. This alternative as mention earlier would be beneficial to the slum dwellers as it maintains their proximity to city opportunities. Slum dweller are more open to this approach as it improves on their services and homes.

Slum upgrading methods exists at different administration levels. They include; the national level, the citywide slum upgrading and the settlement level

- Nationwide slum upgrading

At the national level the decision is made to upgrade slums. The decision-making process is centralized and slow at this level. At this level the upgrade is not tailored towards specific settlement levels. The level typically would enable the recognition and the legislation of major sectors such as land in the slums.

- City wide slum upgrading

At the city level an integrated approach is adopted to address the slums. It is based on three main underpinnings namely; streets, participation and the spatial dimension. Based on these underpinnings major designs are made. City wide . The UN has over the years pioneered programs to improve on slum upgrade. A major program was the participatory slum upgrading program which is based on the Citywide slum upgrading.

- Community level Slum upgrade

The settlement level projects can be tailored towards the needs of the settlement. According to the UN HABITAT (Nairobi 2014) scaling up from this level is hard. They further add that its not an easy process to link this projects at this level to the wider planning process.

Figure 1.3 Dense occupation in a slum in Nairobi. There are few streets which permit circulation.(Un-Habitat 2008A:32)

Figure 1.4 Slum upgrading of MEDELLÍN a. Before

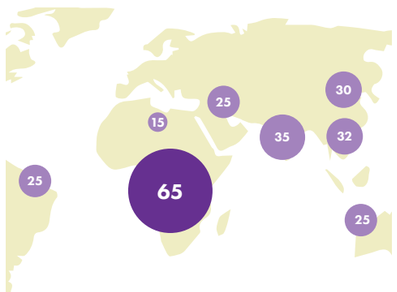
Figure 1.5 Slum upgrading of MEDELLÍN b. After

1.2 Relevance

Figure 1.7 World maps showing the continent slum percentages

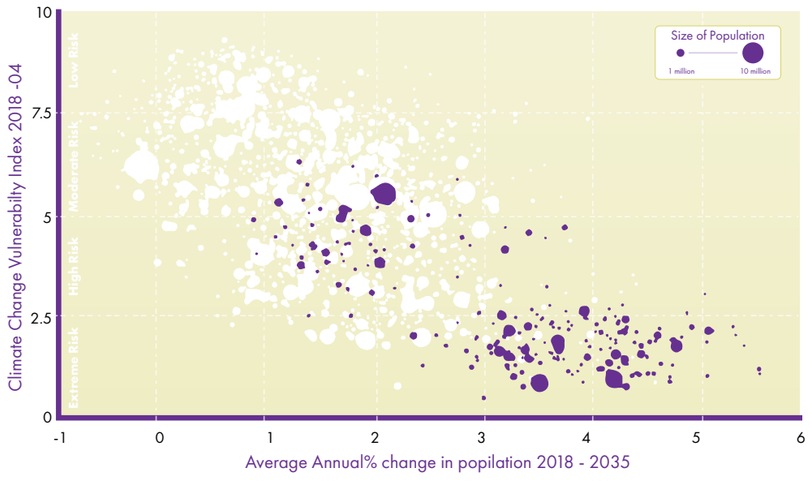
1.2.1 The African context.

Most of sub sahara Africa's urban expansion has been characterized by unplanned and unregulated growth. This has boosted the unregulated peri-urban constructions in the form of either slums or low-rise sprawl development. It explains also why Sub-Saharan Africa holds the largest percentage and population of slum dwellers **(Add image of world maps with slum %)**. Currently about 39% about Sub Sahara Africa's urban population is living in urban areas (add source). There is an expected tripling of Africa's population in the next 40 years. Most of this growth is expected in the midsize cities of the Mid latitudinal Africa, where this thesis is location. Although population growth is good for the cities in terms of labor force, there are major problems rising. Due to the unregulated and unplanned growth of the cities, current problems that exist due to climate change are expected to increase as well. In the diagram below...
Add image for CCVI and population change.



it is noticeable that the African cites are the most vulnerable to climate change. It is also noticeable that the there is a growing trend between the population change and the climate change vulnerability. This makes is it difficult for the Sub Saharan African countries to reach the 2030 SDGs as well as the African Union's Vision for 2063.

Figure 1.6 CCVI of the



1.2.2 A Scalable model

Participatory Slum Upgrading Programme (PSUP) has been a major progamme that has been looking to address the issue of slums. It was initially coupled with the millennium development goals (MDGs). Today the Sustainable development goals(SDGs) replace the MDGs. The PSUP funded nations in Africa Caribbean and the Pacific. However a common trend was that funds were directed towards the larger cities mainly. In Africa, although cities with populations above 1 million currently hold over 47% of the population they account for only 9% of the cities in Africa. This point to the other 91% of cities that are typically not considered priority in terms aids or research for the improving slums. Currently, 74% of the cities in Africa fall within hundred to three hundred thousand inhabitants. This figure although lesser than the 47% held by the larger cities, represents also the soon to grow cities. These cities currently face the issues of growing slums at different severities.
This drove the decision to tackle the issue of mid size cities. Using a single mid size city , Smart W/O Slum offers a system of integrated actions for a simultaneous improvement in environmental performance, social inclusion, and the urban metabolism. Using this case study a benchmark for development plans for slums upgrading targeting medium-sized African cities can be established. Smart W/O Slum would employ methodological approach based on system thinking and interdisciplinarity. It would start with SDG Number 11 (Sustainable Cities and Communities) as the main catalyst of action and then will systematically correlate several other SDGs (SDG3 - Good health and well-being; SDG6 - Clean water and Sanitation; SDG8 - Decent Work and Economic Growth; SDG9 - Industry and Innovation; SDG10 - Reduce inequalities; SDG12 - Responsible Consumption and Production; SDG13 - Climate Actions; SDG17 - Part-

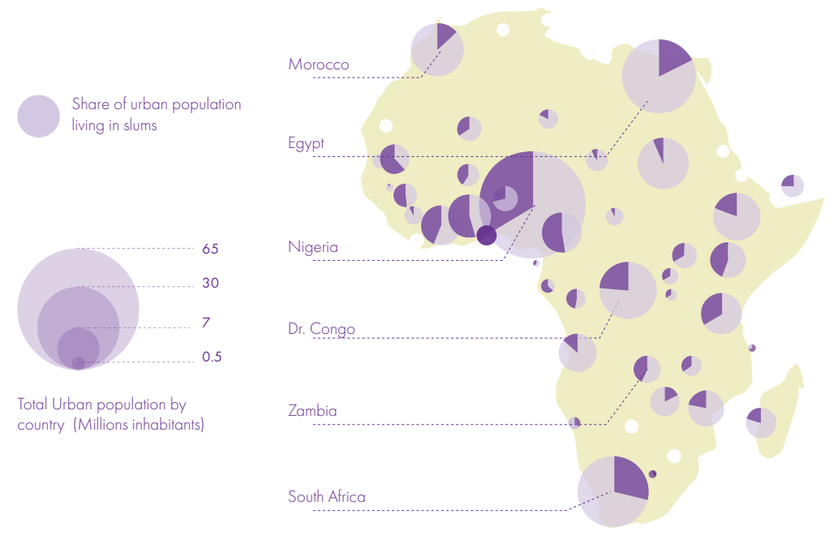


Figure 1.8 Map of African city's share of the slums.

1.2.3 Why Quelimane?

Quelimane is mid-sized city in Mozambique In the coastal city in the province of Zambezi. Quelimane stands as a model of the mid sized African cities that are constantly ignored or overlooked when considering issues as slums. Mozambique is one the countries with the most vulnerable and susceptible to natural hazards such as rising sea level, soil erosion, storms, floods and tsunamis (Garschagen et al. 2014, Lee et al. 2017).

As mentioned eariler funds are normaly directed to larger model cities. This has happened in the past as funds were given directly to profile cities (Maputo, Mampula ,Nacala, Manica and Muhala) under the Participatory Slum Upgrading Programme (PSUP). Funds and attention is given to larger cities while smaller cites like Quelimani are typically overlooked. To help improve on the lives of People in Quelimani, the mayor through the Municipality of Milan consulted the Politecnico di Milano and IMM Lab.

Quelimane at Glance

Figure 1.9 Climate Risk index ranking in Africa. Shows Mozambique within the most vulnerable countries.

Climate Risk Index Ranking 1998 -2017

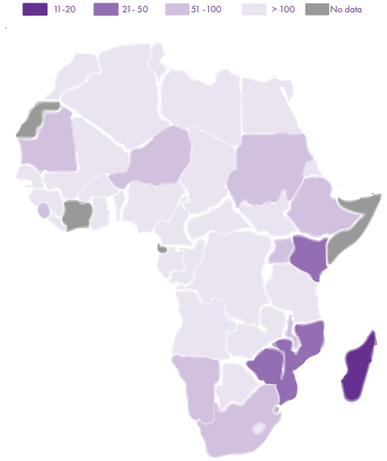


Figure 1.10 Quick Glance at Mozambique.

Mozambique at Glance

3/4

36% of the population lives in urban areas. Of this three quarter of them live in informal settlements

$499

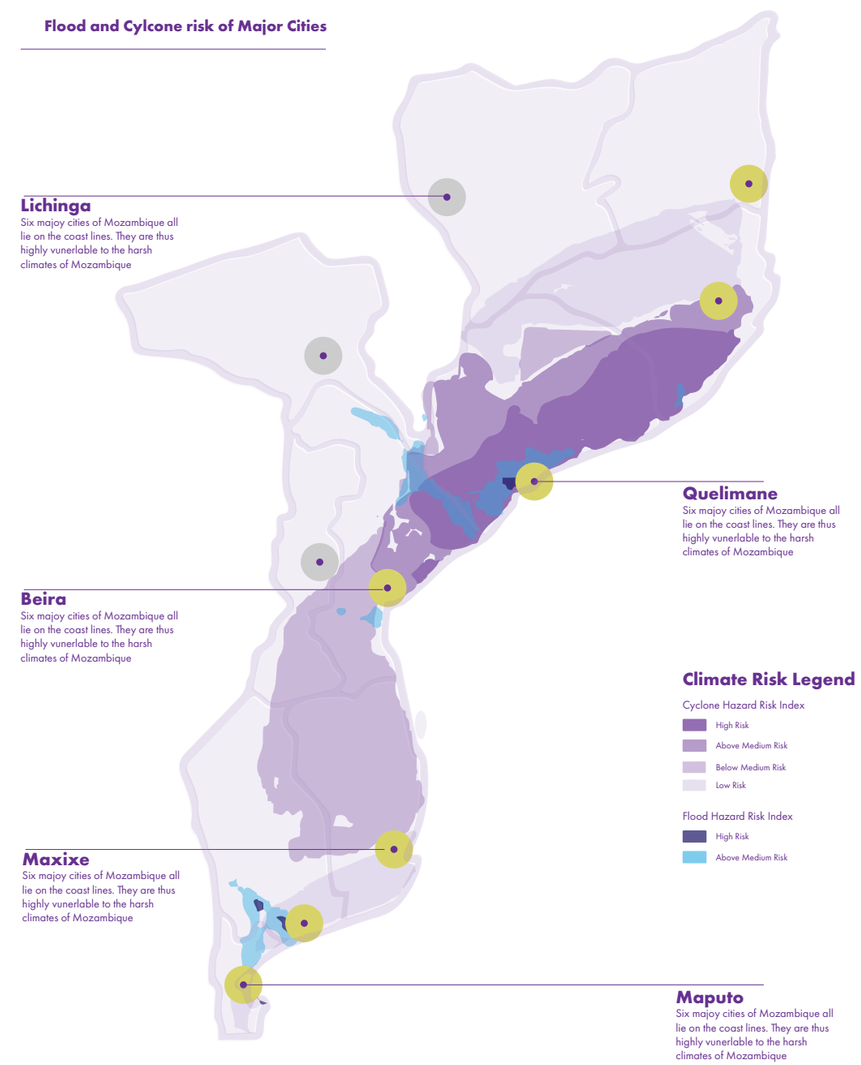
The Gross Domestic Product per Capital of Mozambique is very low. It stands higher than only 5 African Nations.

6/10

Six majoy cities of Mozambique all lie on the coast lines. They are thus highly vunerlable to the harsh climates of Mozambique

Figure 1.11 Vulerability maps off quliemane

Flood and Cylcone risk of Major Cities



1.3 Aim

#Smart_W/O_slum offers a system of integrated actions and assessment tools for the transformation of the built environment in informal contexts, leading to the simultaneous improvement in environmental performances ,social inclusion, urban metabolism and resilience. The proposal, focusing on the city of Quelimane upon an explicit request by its Mayor (please see the attached letter), is fundamentally composed of two pillars.

- The first pillar

The first one is an integrated methodology that will support local authorities and decision-makers in the identification of the areas with the highest potential to improve the environmental conditions of the wider urban system. The theoretical framework is based on IMM (Integrated Modification Methodology), a methodology to support transformation actions in the built environment, aligned to the 17 UN SDGs 2030, developed at the ABC Department of Politecnico di Milano by IMM DesignLab, and already applied to several formal and informal case studies.

- The second Pillar

The second pillar is a set of improvement projects in various domains (ecosystem services, energy, waste, water, food and buildings), that will be applied in the transformation areas identified through the IMM methodology, and that will allow the activation of local economies and a better access to services. Those local areas will be "hubs" of improvement where the specialised actions will be implemented in an integrated way. The localized actions will be integrated into a wider systemic perspective, thanks to the adoption of scientific methods, to test the effects of interventions in slums on the wider city scale, considered as a Complex Adaptive System (CAS). Although this project will focus on the case study of Quelimane, the Development Plan will formalise a systemic multidisciplinary approach in order to create a replicable procedure for similar contexts.

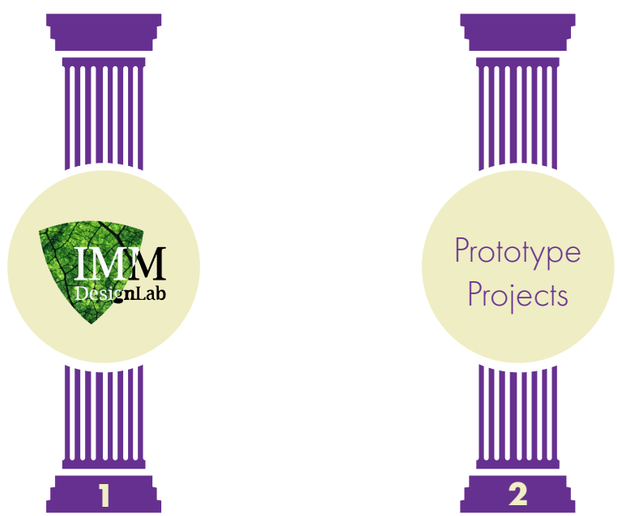


Figure 1.12 Pillars of SMART w/o SLUM

1.3.1 Methodology

#Smart_W/O_slum puts forward a strategic system of integrated action and assement tools to redefine the urban structure of medium-sized African cities. It seeks to improve on their environmental performance while considering the current SDG goals and Africa Union goals. This would be achieved under the auspices of two main pillars under the following methodology:

- IMM Methodology

IMM represents the theoretical framework, aligned on to the 17 UN-SDGs 2030, for modelling transformation actions in the built environment and objectively evaluate its response to different intervention scenarios within the system's boundary. IMM methodology addresses the complexity of spatial (formal and informal) settlements and their multi-level integrative order across different scales. Two main factors distinguish this research from similar studies: 1. the holistic approach through which the built environment is regarded as a multi-layered synthesis of various systems, and 2. the intention of visualizing mathematical-based predictions of transformation reactions to possible intervention scenarios. It represents a decision support tool for transformation and management activities, flexible enough to conceptually expand with respect to the multi-finality of the built environment and its various environmental and socio-economic subsystems. IMM is based on a nonlinear phasing process involving the following structure:

- Phase I. Investigation: Analysis and Synthesis
- Phase II. Assessment and Formulation
- Phase III. Intervention and Modification
- Phase IV. Retrofit and Optimization

Community engagement and Local Participation
the AVSI methodology foresees as first action the establishment of a field office at the core of the slum where all project officers are based, and the creation of a Community Committee to permanently accompany the project. This presence within the targeted community will be fundamental to understand people's habits and socioeconomic situation; to open a permanent opportunity for people to share their concerns, requests, suggestions; to accompany the entire community step-by-step towards the project's implementation and, possibly, many years ahead. Afterwards, AVSI will realise a complete assessment, either by interviewing door-to-door a significative sample of families or through thematic focus groups (rapid appraisal); it shares a first data analysis report with the main shareholders (Municipality, local leader and the Community Committee); at the end, the integrated diagnosis of the area is presented, commented and finetuned through different focus groups within the community, resulting in a list of socioeconomic and physical priority interventions and including suggested solutions by the population.

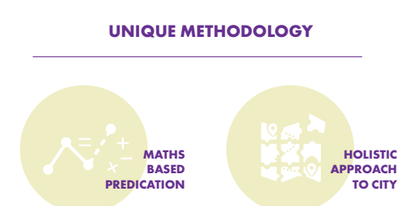


Figure 1.13 Two main factors distinguish this research from similar studies

1.4 Stakeholders

Partners for this project based thesis were selected for the active roles they played during the thesis development and future implementation. With their aid important information and connections were established to aid a smoother project delivery. Below, each partner is describe by their name, type and contributions.

1.4.1 Municipality of Milan

Type of organization - local public authority
Contribution to the project: Development of cooperation among local authorities. Milan municipality has been responsible since 2016 for a city-to-city cooperation program for Waste management with the city of Quelimane in the framework of EuropeAid 150577/DD/ACT/M. It is responsible for the Local implementation of the Milan Urban Food Policy pact signed by Milan and Quelimane. The Milan Urban food pact policy pact is thus an important key theme considered in this thesis project. The

1.4.2 Municipality of Quelimane

Type of Organization – Local public authority
Contribution to project: The municipality would serve as the catalyst and drivers of the local development process. Thus, at the city and settlement levels the Municipality would be crucial in the project implementation. With the support of the Municipality, a sustainable business plan coupled by this project thesis would be easily disseminated. Dissemination plans such as public events, urban labs workshops and project display to the target groups would be achieved with the aid of the municipality.
As regards to data retrieval and collection the municipality at the various authority levels would be consulted.

1.4.3 UNOPS – United nations office for projects services

Type of Organization – Intergovernmental organization
Contribution to project: UNOPs is an organization that helps the Un and its partners to provide humanitarian and development solution. Since this project thesis seeks to use the case study as a model for mid-sized cities, UNOPS becomes important. With their aid, the scalability of the project can be assessed and decremented across other countries. Using its resources (like Sustainable housing solutions holdings, UNOPS Social Impact Investment Initiatives and more) and relations with the UN and other partners the value of this project may reach the mid size cities around the world.

1.4.4 AVSI Foundation

Type of Organization – Non-profit organization, carries out development cooperation and humanitarian aid projects in 31 countries
Contribution to project: This non-profit organization is carries out development cooperation and humanitarian aid projects around the world. They have made it their mission to improve on the people as a resource. This has been achieved by projects carried out around the world. Currently AVSI has partners in Mozambique working on several projects within Maputo, Cado Degado and Zambezia (Quelimane is the capital Zambezia). Over the years, AVSI has developed an extensive knowledge and experience working with Mozambican urban communities. Very key part of this experience and knowledge is the participatory approach.They also supports environmental analysis and socio-economic dynamics of the areas. AVSI would provide expertise in these said areas to better engage the community and foster local participation.

1.4.5 Universidade Eduardo Mondlane (UEM), Maputo

Type of Organization – Higher education and research
Contribution to project: Universidade Eduardo Mondlane (UEM) is the oldest and largest university in Mozambique. It has six schools sub divided into 11 faculties. Of these faculties the Faculdade de Arquitectura e Planeamento will be the main partner within this institution for this project. They have in-depth and through understanding of the Mozambican habitat at various scales. Using their skills, they will serve as the local co-design partner in the field of Local Development and planning with its Centre for Habitat Development Studies.

1.4.6 Metropolitana Milanese S.p.A (MM Spa)

Type of Organization – Public Multi-service company
Contribution to project: MM Spa was created by the municipality of Milan in 1955 to design and build the first underground lines. After their creation they have gained international presence through solutions in the form of designs and redevelopments of urban ecosystems. Their partnerships across different fields of expertise has immensely increased their knowledge base. Today, they able to boast of efficient and sustainable transport design solutions, public property and public water management systems. It is from this vast set of skills we would learn from to tackle the growing urban problems of Quelimane.

1.4.7 a2a S.p.A

Type of Organization – Public Multi-utility company
Contribution to project: a2a is an Italian multi-utility company which is currently leading in the sectors of energy, environment, heat and networks. This company is committed to research and investing in new technologies that are aimed at creating and distributing value. a2a has sectors of development in the fields of innovative energy, smart cities, environmental hygiene, Distribution networks water cycle, power generation and energy efficiency. Its implementation strategies in the said sectors would be vital fist hand knowledge we would seek throughout this project.

1.4.8 Brianzacque S.r.l.

Type of Organization – Public Utility company
Contribution to project: Brianzacque S.r.l industrially manages the integrated water cycle in the province of Monza and Brianza. The company has applied various standards relating to water management over the years. The experience will be sort ot Co-design and create a strategy for the implementation of the water management and sewage sector.

1.4.9 A.P.I

Type of Organization – Association of Enterprises
Contribution to project: A.P.I. (association of small and medium-sized enterprises) is the association representing small and medium-sized enterprises in the Lombardy region; it will provide expertise in the development of new entrepreneurship for the creation of new jobs.

1 2 3 4 5 6 7 8

Mozambique

Facts

Mozambique is a totally unique and awesome African destination offering beautiful pristine beaches, uninhabited island, wild game reserves, culture and heritage, incredible and in many case undiscovered scuba diving sites, swimming with dolphins, whale sharks, rays and turtles and Maputo city breaks and more. It is also a beautiful country most famous for its spectacular white sand beaches – indisputably some of the very finest in the whole of Africa and as such it offers a really world-class beach getaway.

Mozambique is also famous for the quality of its fresh seafood. The Portuguese influence is felt in dishes such as Peri-Peri (hot and spicy) Prawns and Peri-Peri Chicken. Fantastic artwork - the northern regions of Mozambique are famous for their crafts, including sculptures produced by the Makondo people.

2

Understanding the Context .

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2.1 History and Geography

Figure 2.1 Women in Maputo, Photo by Bill Walsh

Mozambique, a scenic country in southeastern Africa. Mozambique is rich in natural resources, biologically and culturally diverse, and has a tropical climate. Its extensive coastline, fronting the Mozambique Channel, which separates mainland Africa from the island of Madagascar, offers some of Africa's best natural harbours. These have allowed Mozambique an important role in the maritime economy of the Indian Ocean, while the country's white sand beaches are an important attraction for the growing tourism industry. Fertile soils in the northern and central areas of Mozambique have yielded a varied and abundant agriculture, and the great Zambezi River has provided ample water for irrigation and the basis for a regionally important hydroelectric power industry.

The only official language of Mozambique is Portuguese, which is spoken mostly as a second language by about half the population. Common native languages include Makhuwa, Sena, and Swahili. The country's population of around 29 million is composed overwhelmingly of Bantu people. The largest religion in Mozambique is Christianity, with significant minorities following Islam and African traditional religions.

Mozambique is a member of the United Nations, the African Union, the Commonwealth of Nations, the Organisation of the Islamic Cooperation, the Community of Portuguese Language Countries, and the Non-Aligned Movement.

• Historical Scenario

During the colonial era Mozambique's history was written as though it had begun with the arrival of the Portuguese, but the people of this region had developed complex communities based on agriculture, cattle raising, mining, crafts, and trade long before the first small groups of Portuguese settlers arrived in the 16th century. Archaeological and historical research since 1950 has begun to reintegrate Mozambique's past with that of East, Central, and Southern Africa.

• Economic Growth

Between 1994 and 2006, average annual GDP growth was approximately 8%, however, the country remains one of the poorest and most underdeveloped in the world. In a 2006 survey, three-quarters of Mozambicans said that in the past five years their economic position had remained the same or become worse.

The resettlement of civil war refugees and successful economic reform have led to a high growth rate: the country enjoyed a remarkable recovery, achieving an average annual rate of economic growth of 8% between 1996 and 2006 and between 6–7% from 2006 to 2011. The devastating floods of early 2000 slowed GDP growth to 2.1%, but a full recovery was achieved in 2001 with growth of 14.8%. Rapid expansion in the future hinged on several major foreign investment projects, continued economic reform, and the revival of the agriculture, transportation, and tourism sectors. In 2013 about 80% of the population was employed in agriculture, the majority of whom were engaged in small-scale subsistence farming which still suffered from inadequate infrastructure, commercial networks, and investment. However, in 2012, more than 90% of Mozambique's arable land was still uncultivated.

• Education

The Portuguese educational system was two-tiered—designed to promote rudimentary skills among the majority African population and to provide liberal and technical education for the settler population and a tiny minority of Africans.

The National System of Education, implemented in the early 1980s, created programs for people of all ages, part-time as well as full-time students, to improve both literacy and technical education. Private and pa-

Figure 2.2 Mohamed Ali in a bout 20 years ago

rochial school facilities were nationalized to facilitate the reorganization and unification of the educational system. Although the number of primary, secondary, adult educational, and vocational centres increased rapidly, demand for education quickly outstripped the state's capacity. Primary school attendance in 1973 was 643,000 and rose to about 1,500,000 by 1979. The figure declined in the 1980s, however, as Renamo destroyed more than 1,000 schools, but by the mid-1990s attendance was again approaching the 1979 level. Literacy increased considerably in the two decades after independence—to some two-fifths of the population—although the figure for males was more than double that for females. Frelimo's Office of Mass The national university, established in 1962 and renamed Eduardo Mondlane University in 1976 for the first president of Frelimo, offers courses through a range of faculties, centres, and schools. Other universities include the Catholic University of Mozambique (1995) and Higher Polytechnic and University Institute (1994), both of which have branches in multiple cities.

• Demography

Mozambique's rate of population growth, though high by world standards, is lower than that of most other African countries. The country's infant mortality rate is among the highest in the world. Moreover, average life expectancy is among the lowest in the world, but comparable to that of other southern African countries. As in most African countries, Mozambique's population is young—more than two-fifths of Mozambicans are under age 15 and almost three-fourths under 30. Demographically, the north has a very spatially dispersed population, whereas the south is characterized by population clusters around major urban areas and transportation networks

• Infrastructure

Transport infrastructure is primarily developed transversally, west–east, connecting mining and agricultural clusters in Mozambique and in neighboring countries to exit ports. There are four clear railroad corridors: (i) Maputo to Gauteng in South Africa (also connecting with Zimbabwe and Swaziland through the railways branches), (ii) the Machipanda line connecting Beira to Zimbabwe, (iii) the Beira to Tete (Moatize) , and (iv) the Nacala to Malawi line.
Only about 47% of the Mozambican population has access to an at least basic water source, and only 24% has access to at least basic sanitation. Consequences on living conditions are multiple, ranging from poor health to lower productivity due to the time needed to fetch water.

Figure 2.3 New constructed roads

	Achievements	Challenges
Roads	High percentage of roads in good or fair condition. Second-generation road fund in place.	Aligning resource availability and funding options for road maintenance with the extension of the network and the existing traffic. Improving rural connectivity and the quality of rural roads.
Railways	Attraction of the private sector into the operation of major rail lines. Recovering the operability of the Sena line.	Meeting increasing demand due to growing trade with neighboring countries and significant increase in domestic coal production. Systematically maintaining the existing infrastructure. Recovering the Machipanda line, taking care of the enormous rehabilitation backlog. Completing the Moatize-Nacalacorridor, now missing 200 kms
Ports	Performance improved through public-private partnerships (PPPs).	Guaranteeing that Beira port works at its fullest capacity. Implementing a routine dredging practice. Developing the Nacala port in a competitive fashion to be able not only to handle the increased mineral production but also to attract traffic now going to neighboring countries.
Air transport	Important growth of all market segments and increase number of city pairs served. Construction of new terminals in Maputo and Nacala.	Getting safety regulations aligned with international practices and standards. Getting LAM (the Mozambican airline) out the EU blacklist.
Water and sanitation	Reduce reliance on surface water and practice of open defection via expansion of wells, boreholes, and traditional latrines.	Increasing the efficiency of water utilities.
Irrigation		Extending the equipped and managed irrigation area. Extending the storage and flood infrastructure to diminish the impacts of hydrological variability.
Power	Relatively good utility performance and service quality.	Increasing access to energy and improving the financial sustainability of the sector. Taking advantage of the opportunities that power trade offers to the country.
ICT	Liberalization of the mobile market. Connection to the submarine cable.	Furthering development of the Internet-access market.

Figure 2.4 Infrastructure development in Quelimane

2.2 Slums in Mozambique

2.2.1 The Urban Growth

The cities in Mozambique tend to do better on all statistical benchmarks compared to rural areas. The largest differences appear when Maputo is compared to other cities or districts. Maputo has a real GDP per capita three times the national average of $320. It is only Maputo and Beira, the second largest city, which have averages higher than the national. While cities have large and complex issues on their own,
they tend to score better on access to basic health indicators, education, income and gender. The downside is that income inequality is also far higher in urban areas. So while cities on the whole tend to outperform rural areas, there are a significant proportion of urban populations who are actually worse off than their rural counterparts.
This does not stop the continuing inflow of migrants to the urban areas, resulting in huge urban pressures. Mozambique may have a lower coping capacity than its neighbouring countries, but the challenges presented by this mass movement of people are similar.

2.2.2 Slums in the Capital

Land tenure is generally regarded as being secure in Mozambique. Residents have constitutional rights to land they live on, even if they hold no formal title. If the government - or the municipal-ity - needs a particular piece of land, they are required to provide a similar situated land elsewhere, with compensation for "improve-ments" of the land. Most reports indicate that this system works reasonably well.
The 2004 constitution reaffirms that access to land for residen-tial and family agricultural use should be free from any payment, including taxes. It is therefore not legal for individuals to sell access to an empty plot of land – only the government and municipalities can grant this right. If a plot is empty for a given time – typically five years – anyone can theoretically
occupy it. This rarely happens in urban areas. Instead, there is a thriving market in "improvements" on the land, with the understand-ing that the "free" land the structure rests on will be part of the deal. With no formal market in land, a UN-HABITAT
report found that "informal mechanisms are by far the most important means of access to land, even for formally planned and demarcated plots".
The informal trade in land does not diminish the rights of its inhabitants. The constitution grants automatic user-rights through good-faith occupation. Any dweller has right to the land he or she has occupied for ten years, provided it has been for residential use. His or her lack of a formal title does not diminish this right, nor is it required.

2.2.3 Slums in Quelimane

Sixty per cent of Mozambique's 28 million people live in low-lying coastal areas, where sea-level rise and frequent intense storms cause flooding, erosion, and landslides, threatening communities, homes, and businesses. Although coastal cities are the country's major population centres and the key drivers of economic growth, city planners frequently lack the technical skills to promote urban adaptation to severe weather events. Compounding this problem, city residents regularly build houses and infrastructure wherever they can find available land, including areas prone to flooding, on unstable slopes, and with contaminated water supplies. Homes are often built with low-quality materials and traditional techniques, which are easily damaged by storms and ultimately contribute to a cycle of vulnerability and poverty. The number of slum dwellers in Africa continues to increase, in large part due to the accelerated pace of urbanization that the continent is experiencing (see Chap. 1). Indeed, more than 25 of the 100 most rapidly growing cities worldwide are in Africa (UN-Habitat 2014b).
In many African cities and towns, an estimated 75–90 percent of all new housing is built outside the official process for land development and housing construction. Most of this construction is done through an informal, incremental process. Similarly, in Quelimane most of the houses are constructed from local materials however, it is exposed to the natural disasters such as flood and cyclones. Moreover, more slums are developing through out the periphery of the city which are only limited where the mangrove makes it difficult to build.

Figure 2.5 Downtown Maputo showing informal settlement in the poverty belt-Photo by Michael Fay,Getty Images

Figure 2.6 Slum in Quelimane

2.3 Quelimane

Figure 2.7 Quelimane the seaport

Quelimane is a seaport in Mozambique. It is the administrative capital of the Zambezia Province and the province's largest city and stands 25 km (16 mi) from the mouth of the Rio dos Bons Sinais (or "River of the Good Signs"). The river was named when Vasco da Gama, on his way to India, reached it and saw "good signs" that he was on the right path. The town was the end point of David Livingstone's west-to-east crossing of south-central Africa in 1856. Portuguese is the official language of Mozambique, and many residents of the areas surrounding Quelimane speak Portuguese. The most common local language is Chuabo. Quelimane, along with much of Zambezia Province, is extremely prone to floods during Mozambique's rainy season. The most recent bout of severe flooding took place in January 2007.
Fishing is an important industry along the coast. Serving as a terminus of a railway line extending northward to the Mocuba area, the city exports tea, sugar, sisal, corn (maize), cotton, tobacco, copra, and coir. Quelimane has one of the world's largest coconut plantations, covering about 50,000 acres (20,230 hectares) and having 4,000,000 coconut palms. Pop. (2007 est.) 192,876.

2.3.1 Zambézia Province

Zambézia is a province in the central region of Mozambique. Its capital is the city of Quelimane, located about 1600 km north of Maputo, the capital of the country. With an area of 103,478 km², it is divided into 22 districts, and has, since 2013, 6 municipalities: Alto Molócuè, Gurúè, Maganja da Costa, Milange, Mocuba and Quelimane.
It has a population of 3,849,455 inhabitants in 2007. With an area of 103,478 km ², the population density was around 37.2 inhabitants per km ².According to the 1997 Census, the Province had 2,891,809 inhabitants and an area of 103,127 km², hence resulting in a population density of 28.04 inhabitants per km².Between 1997 and 2007, the population grew 24.88%, with a total of 957,646 inhabitants, the second highest among all Mozambican provinces. In terms of both area and population, the province ranks second, with an area of 103,478 km² behind Niassa and a total of 3,849,455 residents after Nampula. (Governoda Província de Zambézia)

2.3.2 The Neighbourhoods

In 1763 it was created as a Vila, being elevated to the category of City on August 21, 1942 (under Ministerial Diploma no. 1/42). After national independence, it was designated as a Level C City (Resolution No. 7/78 of 25 April). It currently has 5 administrative posts and 59 neighborhoods. Quelimane is administratively a municipality with an elected local government.

2.3.3 Housing

In most rural areas, people live in mud-walled and thatch-roofed houses that they construct themselves. Though often circular in shape, some are, square or rectangular housing is most common in urban and peri-urban neighbourhoods. Mud and wattle construction (where mud is held in place by a frame of crisscrossed sticks) is widely used in rural areas, while in and near urban areas people more often utilize cement bricks. Most houses in both rural and urban areas are relatively small, built in clusters around a common yard where most cooking and food preparation takes place.
In most of the consolidated buildings in Mozambique, the building's opaque surroundings,structures and internal divisions are built with solid materials, such as concrete, brick,stone, or the earth. The thermal mass acts as heat and cold storage, regulating and smoothing temperature fluctuations. The high thermal inertia of massive construction components decreases the maximum values of radiant temperature in summer, providing better conditions comfort.
The heat stored during the day it can be dissipated during the night by means of nocturnal ventilation. Inertia delays heat exchanges by driving with the outside, which is particularly beneficial during heat waves.
The use ofinertia, associated with night ventilation for cooling buildings is particularly recommended for the cities of Tete, Lumbo, Lichinga,Quelimane, and also Maputo. After a certain point, the heat begins to accumulate in the building mass and the thermal mass.

Figure 2.8 Timber frame construction in Quelimane by local crafts

Figure 2.9 Mozambique walls being constructed using coconut palm spined stacked vertically (Pic by Lauren Fox)

• The seaport

One of East Africa's most important ports, the Port of Maputo handled trade from South Africa, Rhodesia, and Swaziland before Mozambique's independence. When the Rhodesian frontier was closed and relations with South Africa deteriorated, the Port of Maputo declined. The local economy is based on industries that include shipbuilding and repair, canning of fish, breweries, iron works as well as cement, textiles, and other manufacturers. In 2006, over 1.2 million people lived in the Port of Maputo.
Portuguese navigator Lourenzo Marques was sent to explore the Delagao Bay by the territory's governor in 1544. He found a potential site for a port there. Naming the settlement after Marques, the Portuguese soon built forts and trading stations on the river's north bank and abandoning them to escape the indigenous peoples who destroyed the settlement.

Today's Port of Maputo was established in 1850, rising around a 1787 Portuguese fortress. By 1871, it was a poor town with decaying forts, rusty armaments, and a lot of grass huts protected by a two-meter wall with a few bastions.

As the Transvaal in South Africa grew in importance, the Portuguese began to focus more attention on the Port of Maputo. In 1876, they sent a commission to drain the marshes near the town to plant blue gum trees and build a church and a hospital. By 1887, the Port of Maputo was a city, and it became the capital of Mozambique, replacing the Island of Mozambique in that role. When the railroad to Pretoria arrived in 1895, the city began to grow rapidly.

By the early 20th Century, the Port of Maputo was well-established with ample facilities and equipment so that large vessels could move cargo directly to rail transport. Under Portuguese rule, the town became a cosmopolitan city, and the port served Portuguese, British, and German ships bringing goods from Lisbon, Southampton, and Hamburg.

The Port of Maputo and the city's economy continued to grow based on the busy seaport, and Portugal started building a regional network of schools and colleges in the 1940s. While unskilled Africans did not share in the boom, considerable communities of Portuguese, Indian, Chinese, and Islamic communities prospered with the Port of Maputo's growth. Before Mozambique gained independence in 1975, the Port of Maputo was a popular tourist destination for travelers from Rhodesia (Zimbabwe) and South Africa who were drawn to its beaches and world-class restaurants and hotels.

In 1962, the Mozambique Liberation Front formed in Tanzania, beginning the 10-year Mozambican War of Independence. When Portugal's Estado Novo regime was overthrown in Lisbon, the war for Mozambique's independence finally ended, as the new leftist military regime in Portugal granted independence to all Portuguese-held territories overseas.

In 1975, the People's Republic of Mozambique was announced, and the city's name became Maputo. Portuguese soldiers in the Port of Maputo were replaced with black soldiers with rifles from Russia. Almost overnight, a quarter of a million ethnic Portuguese left the country, and Mozambique was left in chaos. With few skilled workers to maintain the country's infrastructure, the economy spiraled. By the 1980s, Mozambique was bankrupt.

From the early 1980s until 1992, the country was plagued by civil war. Since the war ended, stability and growth have returned to the Port of Maputo, but it continues to struggle to live up to its potential. The city suffers crime, poverty, unemployment, and overpopulation [worldportsource].

Figure 2.10 Container at the port

2.4 Climate Analysis

Mozambique has a tropical climate with two seasons, a wet season from October to March and a dry season from April to September (Ndege, 2007). Climatic conditions, however, vary depending on altitude. Rainfall is heavy along the coast and decreases in the north and south. Annual precipitation varies from 800 to 1200 mm (31.49 to 47.2 in) depending on the region (World Bank Group, 2018),with an average of 590 mm (23.2 in). Cyclones are common during the wet season.
Average temperature ranges in Maputo are from 13 to 24 °C (55.4 to 75.2 °F) in July and from 22 to 31 °C (71.6 to 87.8 °F) in February. The highest temperatures occurs between October and February and the lowest in June and July (Britannica, 2019)
In 2019 Mozambique suffered floods and destruction

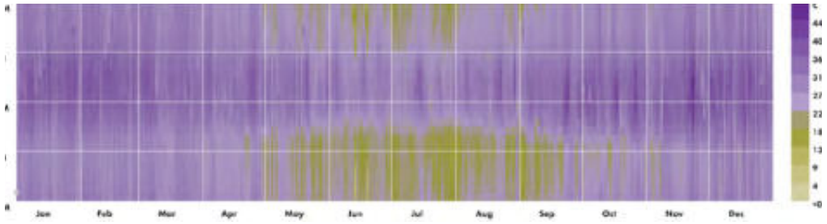

Figure 2.11 heatmap showing annual distribution of dry bulb temperature

from the devastating cyclones Idai and Kenneth. This is the first time two cyclones have struck the southern African nation in a single season (Britannica, 2019)
By the Koppen climate classification, majority of Mozambique falls under the tropical savanna climate zone (Climate Data, 2018). The zone is typically winterless frost-free zones.
Very common to these climates' zones are; monthly mean temperatures above 18°C in every month of the year; the presence of dry months (the driest month having less than 60mm of precipitation. Countries in this zone tend to experience less rainfall than the tropical monsoon climate or have more pronounced dry season(s). Within this climatic zone there exist two major seasons, i.e.: the dry and the wet season (Climate Data, 2018).
The weather data was analysed using the epw weather data, using grasshopper and ladybug with further post-processing in Excel. In relation to climate's analysis this section of the thesis would discuss the weather factors that can affect either comfort or building design; theses are temperature, relative humidity, precipitation, Radiation, wind speeds and directions.

2.4.1 Temperature

Quelimane experiences about 3720 hours in the year above 26°C. This clearly draws attention to the high demand for cooling required for this location. Figure... shows the annual distribution of the dry bulb temperature throughout the year. The annual average temperature recorded is 25.26°C with a maximum temperature as high as 44.4 °C in November and a lowest recorded temperature of 6.1°C in June. The maximum temperatures coincides with the hot season; October to January, while the lower temperatures were recorded within the months of May through to August.

2.4.2 Relative Humidity

Relative humidity is very important in the perception of comfort. In every climate the relative humidity level may either elevate the sensation of the heat or reduce it (USA Department of Commerce, NOAA, 2019). During the year the relative humidity levels drop below 40% on for 76 hours. For the over 7508 hours in the year the humidity levels are above the 60%. This implies that for 29% of the total hours of the year, the relative humidity ranges between 40% to 60%.

- Relative Humidity vs Temperature

Figure...shows the correlation between the relative humidity and temperature. It shows that the climate

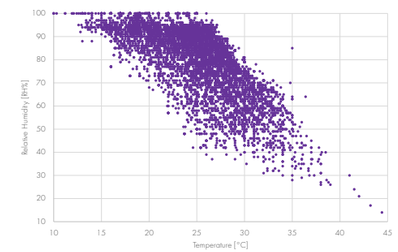

Figure 2.12 scatter plot showing annual relative humidity vs temperaturei

currently on the outdoor is within the moderate-severe stress levels and Mid moderate stress of comfort.
It shows that most temperature range between 20°C and 30°C throughout the year with corresponding relative humidity between70% and 100%.

2.4.3 Solar Radiation

Solar radiation used here refers to the total horizontal radiation. This accounts for the direct and diffused radiation. The diffused radiation is highly influenced by the percentage of cloud cover. Thus, an analysis of the cloud cover was made to understand the number of hours in each month that was either sunny, partly cloudy or overcast.

- Cloud cover chart.

The cloudiest months were May, June and July followed by predominantly clear sky months of August, September, October and November. The very high dominance of cloudy periods in the months may through to June is very reassuring as it increases the diffuse radiation component of the total radiation in the dry season. August on the contrary observed an opposite phenomenon with 527 hours of clear skies. A correlation can be seen also between the presence overcast skies within the rainy reason (mid-November to mid-April)
Throughout the year the sun path is through the north predominantly. During the months June and may the path of the sun be through the south. It is also within these months the longest days are observed. Higher direct radiations between 900wh/m2 -630Wh/m2 were usually observed form 11:00 – 16:00pm coupled with higher dry bulb temperatures ranging from 27C – 45. During the dry months of May through to September lower morning and evening temperatures coupled with lower radiation levels are experienced. The total radiation year-round suggests the west and north to be the most critical points of interest.

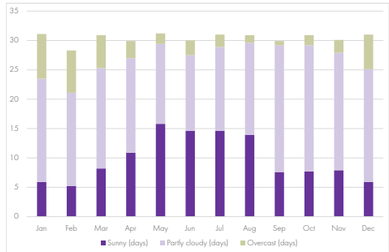

Figure 2.13 Bar graph showing distribution of annual distribution of sunny, cloudy & overcast days

The highest recoded radiation levels were within the NW330 – NW280. The south experiences lower levels of radiation ranging between 360 Wh/m2 – 540WH/m2. The diffuse radiation all year round though was dominant it through the west, north and east. However, the direct radiation was more pronounced and focused on the NW direction.The rainy months observed relatively lower intensities of solar

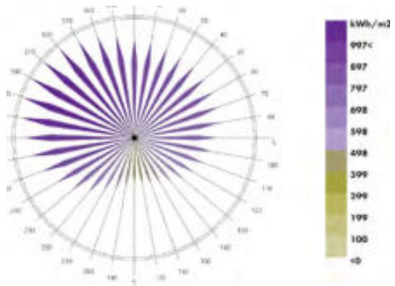

Figure 2.14 Radial plot showing the direction and intensity of global horizontal radiation throughout the year.

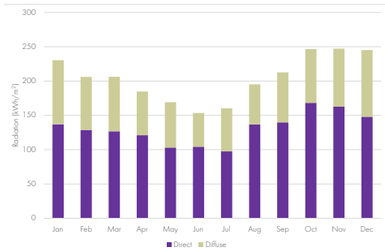

Figure 2.15 Distribution of monthly direct and diffuse solar radiation

radiation. He months of January through to March the direct radiation was more centered on the West while the diffuse radiation was unidirectional. The dry season observed the most total solar radiation. The direction was predominantly from the north.

2.4.4 Wind

This section discusses the wide-area hourly average wind (speed and direction) at about at least 10m of ground level. The wind experienced is subject to the topography and morphology of the context. However, the wind data allows to determine an average direction and speed which can be used in understanding the site. Figure.. shows the quarterly wind speed and direction for Quelimane. The second quarter records the lowest wind speed with 7m/s as the peak speed and dominant wind direction is south-westerly. The major wind direction is south-easterly for all the other quarters of the year with a peak speed of 12m/s occurring in the fourth quarter (during the wet season). The average annual wind speed is 3.08m/s generally characterised by light and gentles breezes for over 87% of the year.

2.4.5 Precipitation

Precipitation is very important in tropical savanna climates. With the precipitation it easy to differentiate the dry season from the wet one. Data on precipitation was outsourced as it was not embedded in the metonorm file. According to weather parks, most of the rain falls around January 27 where an accumulated average of 225 millimeters. The rain fall patterns from the figure identifies the wet season to be in the months Mid-April through to November of while the dry is from Mid-November to mid-April.The minimum and maximum measured rainfall for each month is recorded below.

Further information was gathered from Meteoblue about the precipitation amounts and days. By their data its analysis the very dry days were mainly within the months of April to November. Highest number of dry days recorded was 27.5 in the month of August. Although such high number of dry days were recorded in this month is observed 3.5 days of rain below 20mm. During the raining season the dry days were below 11days.

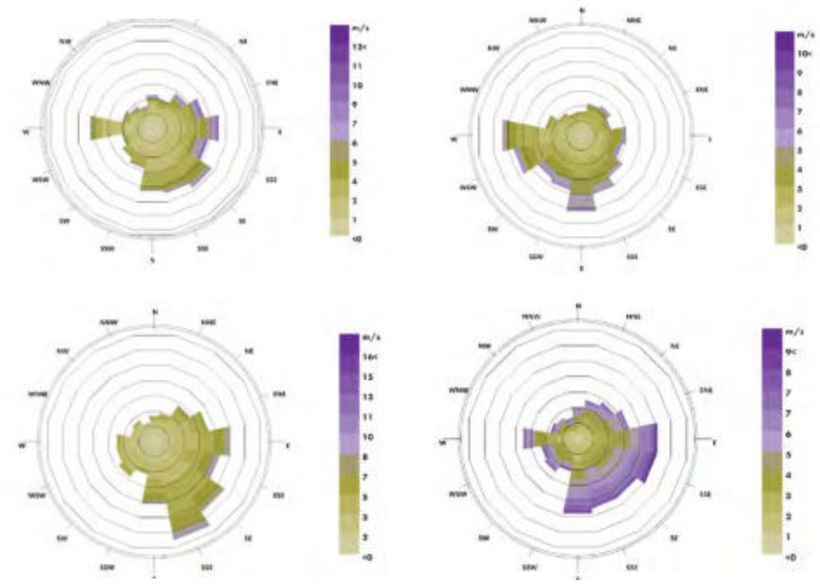

Figure 2.16 Wwindrose showing the quarterly direction and velocity of wind in Quelimane (top left - 1st quarter; top right - 2nd quarter; bottom left - 3rd quarter; bottom right - 4th quarter)

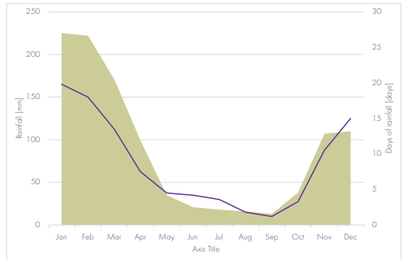

Figure 2.17 Graph showing the monthly rainfall depth vs days of rain throughout the year

IMM

Theoretical background

At its theoretical background, Integrated Modification Methodology refers to the contemporary urban development as a highly paradoxical context arisen from the social and economic significance of the cities on the one hand and their arguably negative environmental impacts on the other. Asserting the inevitably of urbanization, IMM declares that the only way to overcome that paradox for the cities is to develop in a profound integration with the ecology. According to IMM, the fundamental prerequisite of ecologically sustainable development is to have a comprehensive systemic understanding of the built environment.

IMM suggests that the advancement in construction techniques, building materials quality and transportation technologies alone have not solved the complex problems of the urban life simply because such improvements are not necessarily dealing with the systemic integration. The core argument of IMM is that the performance of the city is being chiefly driven by the complex relationships subsystems rather than the independent qualities of the urban elements. Thus, it aims at portraying the systemic structure of the built environment by introducing a logical framework for modeling the linkage between the city's static and dynamic elements.

3

IMM Methodology

Holistic, Multi-Layer, and Multi-scale approach.

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3.1 IMM - General principles

3.1.1 Introduction

IMM is the acronym of Integrated Modification Methodology, an innovative design methodology based on a specific process with the main goal of improving the CAS (complex adaptive systems) energy performance, through the modification of its constituents and optimization of the architecture of their ligands. Its approach is fundamentally Holistic, Multi-Layer, Multi-scale. In this methodology, the city is considered to be a dynamic Complex Adaptive System comprised by the synergic integration of number of elementary parts, which through their arrangement and the architecture of their ligands provide a certain physical and provisional arrangement of the CAS. In IMM the emergence process of interaction between elementary parts to form a synergy is named Key categories. Key categories are the products of the synergy between elementary parts, a new organization that emerge not (simply as) an additive result of the proprieties of the elementary parts. When we alter the interaction between elementary parts recombining them in a different way different organization emerges, but it also may be lost. This explains that added proprieties emerge just when the combination is right. According to this view, the city is not solely a mere aggregation of disconnected energy consumers and the total energy consumption of the city is different from the sum of all the buildings' consumption. This considerable gap between the total energy consumption of the city and the sum of all consumers is concealed from the urban morphology and urban form of the city. The IMM investigates the relationships between urban morphology energy consumption and environmental performances by focussing mostly on the 'Subsystems' characterized by physical characters and arrangements. The main object of this design process is to address a more sustainable and better performing urban arrangement. IMM methodology is based on a multi-stage process composed of four different but fully integrated phases[1].

3.1.2 Investigation

Investigation, being the first phase, is basically creating a model out of the urban system. Just like any other system, built environment is characterized by including parts and subsystem between which there are complex relationships. Accordingly, in Investigation phase, the system is being broken into its parts. Morphologically speaking, these parts for the cities would be Urban Volume, Urban Void, Links, and Types of Uses. [1]

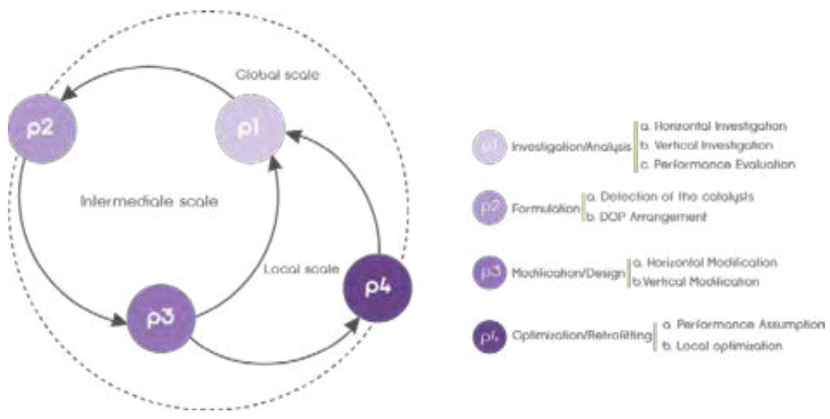

Figure 3.1 IMM phases, Global scale, Intermediate scale, and Local scale.

Investigation/Analysis			
A	Horizontal Investigation	Dismantling the system for Investigation	Investigation/Analysis and Data collection
B/C	Vertical Investigation	The actual value of Key Catagories	
D	Actual performance of the system ased on indicators		Contextual Evaluation Performance

Table 3.1 Investigation/analysis

- A - Horizontal Investigation

The system is broken down into its subsystems, which for the urban context are "Volume", "Void", "Function" and "Transportation".

- B - Vertical Investigation

First Level of Superimposition (F.L.S.)
Acting on a subsystem produces a chain reaction in the other, the Consequently, by reacting the four above-mentioned layers it is possible get new reading indexes, which are defined IMM "Key Categories ":" Porosity "," Proximity "," diversity "," Interface "," accessibility " and "effectiveness".
This phase ends with the estimation of a series of "Indicators", which allow to quantify the morphological peculiarities of the context, directly correlated with its energy configuration.

- C - Vertical Investigation

Second Level of Superimposition (S.L.S.)
By overlaying the layers obtained in point 1.b you are obtained the so-called "Determinants", indicative of morphological, typological and technological city: "Compactness", "Complexity" and "Connectivity. "their overlapping gets the final diagnosis of the city, a sort of plate that allows you to identify the parts that work and those weaker.

- D The current system performance

Through the definition of "main indicators" it makes a first evaluation of environmental characteristics and performance of the DAC. they will also be used in the next step of "retrofitting", for the study of the transformation which took place in the system.

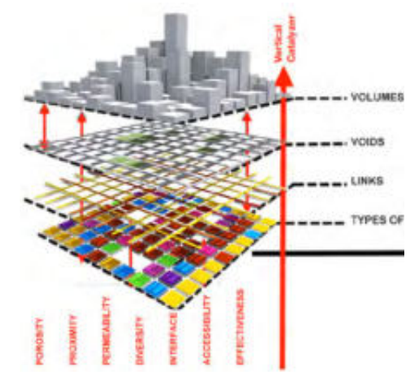

Figure 3.2 Vertical catalyzer

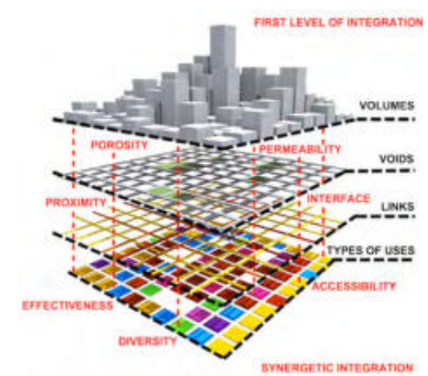

Figure 3.3 First level of integration

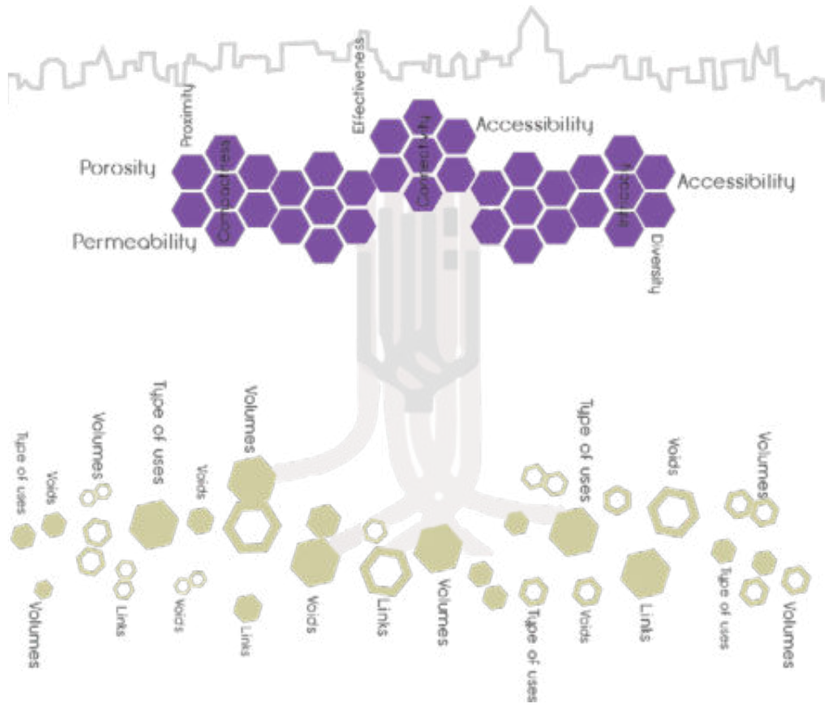

Figure 3.4 Vertical and horizontal investigation relationship

3.1.3 Formulation

Formulation/Assumption is the second phase, and, in this part, the malfunctioning subsystem is identified and takes the role of the transformation catalyst. It means that any intervention with the purpose of optimizing the system should start with improving the weaker subsystem, and only through the catalyst, the scope of the transformation is being defined. In this way, design principals for any project are locally defined according to its very particular situation. The CAS is composed by a hierarchy of multiple levels of organization. Considering that at any scale, the system is actually a sub-system, the cross-scale effects have a great significance in the dynamics of CAS. Meanwhile, the chosen Catalysts plays a tremendous role in the IMM.[1]

- A - Selection of the catalysts

The main objective of this phase is to understand, based on the "Key categories "and their respective indicators, which are the prominent factors on which take action to speed up the transformation process. It then proceeds with the choice of a horizontal subsystem (layer) and of one vertical (key category) to which to assign the role of "catalysts", while the remaining will be "reagents".

- B - DOP, Design Ordering Principles

DOP are the twelve instruments that are used to guide transformation of the CAS toward specific goals. They are classified in Starting from the "Key category" selected as a catalyst and depend by determinants.

Formulation/Assumption		
A	Detection of the Horizontal and Vertical Catalysts and reactants.	Assumption and Interpretation of The catalysts
B	Assumption of the 12 Design Ordering Principles	Assumption and Interpretation of the 12 Design Ordering Principles.

Table 3.2 Formulation/Assumption

3.1.4 Modification

In the third phase, Transformation, various modification scenarios are being tested to the project by means of the same modelling mechanism that is hired in the Investigation phase. Compared to the actual situation, these scenarios are being evaluated and tested over and over until an acceptable modification scenario result. [1]
The combined action of the horizontal and vertical catalysts selected previously leads to a local change that gives rise to a chain reaction that ends with the global transformation of the CAS. The latter emerges when all the layers interact simultaneously.

- A - Modification of the Catalysts

The design phase begins with the modification of the catalysts previously chosen, which creates a local change of the system. this perturbation comes to end-effects described above.

- B - Adaptation of the Reactants

The objective of this phase is to make possible the propagation in the rest of the system changes occurred locally, as consequence of connectivity, thus creating the conditions for a global change

3.1.5 Optimization

Optimization phase which is the fourth phase of the IMM. At this point, although the system is expected to perform much better than it does in the actual situation, but the transformation is not over whatsoever.[1] At the end of the transformation you come to the definition of a new CAS, whose performances will be evaluated with the same instruments analysed previously. In particular, the upgrade process takes place-making a parallel between "old and new".

- A / B - Investigation

the new CAS Indicators Evaluation of the performance of the new system, explaining the measures obtained from the indicators in order to make a comparison with the CAS before surgery.

- C - local optimization

Following this detailed control of the results obtained from the transformation, begins a new optimization procedure. The result of this last phase is still a provisional CAS, a new starting point for an endless process of transformation.

Modification/Design			
A	Horizontal Modification	The Catalyst drives the local transformation, changing the layers of the legands	Modification, Intervention and Design
B	Vertical Modification	Local Transformation acts Globally, changing the entire system configuration	

Table 3.3 Modification/design

Table 3.4 Optimization/ retrofitting

Opetimization/Retrofitting		
A	Performance of the new CAS based on the indicators	Contextual Evaluation Retroffiting
B	Local Modification/Opetimization is a process involving the first level of superimpostion for the improvement of local performance	Design/Transformation, Opetimization
C	Universal Indicators	Universal Indicators

Table 3.5 CAS optimiza- tion process

Complex Adaptive System Optemization Process					
whole	Elements correlation		Systems attributes		whole
	Layers ranked superim- postion	F.L.S	S.L.S	Determinantes	
	volume/void/link/uses	Porosity			
	link/void/volume/uses	Permeability			
	link/use/volume/void	Proximity			
		Interface	Compactness	Morphology	
		Accessibility			
		Effectiveness			
		Diversity			
	link/void/use/volume	Interface			Modified city Robustness level
	use/void/volume/link	Diversity			
	link/use/voids/volumes	Accessibility			
		proximity	Intricacy	Typology	
		Effectiveness			
		Permeability			
		Porosity			
	links/uses/voids/volumes	Accessibility			
	links/volumes/uses/voids	Effectiveness			

Complex Adaptive System Optemization Process				
	links/uses/volumes/voids	Proximity		
		Interface		
		Permeability	Connectivity	Technology
		Porosity		
		Diversity		

Complex Adaptive system - Opetimization process

3.2 IMM and SDG

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.[2]

- IMM

Approach to sustainability is aligned to the 17 UN Sustainable Development Goals 2030. Accordingly, with the approach, cities are regarded as complex adaptive systems and the focus is on simulating their operative mechanisms involving both the internal subsystems and the external systems that the cities are part of. The result will be a methodological interpretation of the SDG Number 11 suggesting locally based actions robustly linked with SDG indicators and evaluation methods. Moving from the SDG 11, as the main catalyser of the action IMM systematically correlates all the other SDGs in a holistic way [1].

Figure 3.5 17 Sustainable development goals

3.2.1 Agenda 2063

Agenda 2063 is Africa's blueprint and master plan for transforming Africa into the global powerhouse of the future. It is the continent's strategic framework that aims to deliver on its goal for inclusive and sustainable development and is a concrete manifestation of the pan-African drive for unity, self-determination, freedom, progress and collective prosperity pursued under Pan-Africanism and African Renaissance.
Agenda 2063 has Seven fundemental aspiration and all of them are built with a set of goals to be achived before the year 2063. The following are the list of aspirations:

a. A prosperous Africa based on inclusive growth and sustainable development.
b. An Integrated Continent, Politically united and based on the Ideals of Pan Africanism and Vision of African Renaissance.
c. An Africa of good governance, democracy, respect for human rights, justice and the rule of law.
d. A peaceful and secure Africa.
e. Africa with a Strong Cultural Identity, Common Heritage, Values and Ethics.
f. An Africa Whose Development is people driven, relying on the potential of the African People, particularly its Women and Youth and well cared for children.
g. Africa as a strong and influential global partner.

Figure 3.6 Agenda 2063

3.3 Defining the context

3.3.1 Study limitations

The team has faced a major problem on finding raw data from the city of Quelimane. Even-though we find some information through long processes, most of them are outdated and of low quality.
In most of the cases, our primary data source was internet search and we were also able to get some direct information from a student living in Quelimane.
''Data gaps across the African continent threaten to hinder the achievement of the Sustainable Development Goals and the African Union's Agenda 2063'', according to the Mo Ibrahim Foundation's first governance report.
In general, it is our recommendation that data, and especially data of good quality, are essential for national governments and institutions to accurately plan, fund and evaluate development activities.

3.3.2 The City scale

The above mentioned issues coupled with the scope of the study, the team defined the study area as shown in the map (figure 3.7) which includes the downtown, the airport, historic places, and the slum areas. In this case, a total of 28 barrios has been studied and also the IMM methodology applied on them. From 28 of the barrios, we were not able to include barrio 13 to 21 due to insufficient data.
The airport is categorized under barrio 14 and 15 which connects with the down town through two major roads. Barrios such as 03,09, 12, and 13 are the major part of the city centre and historic places which also directly connects with the harbour.

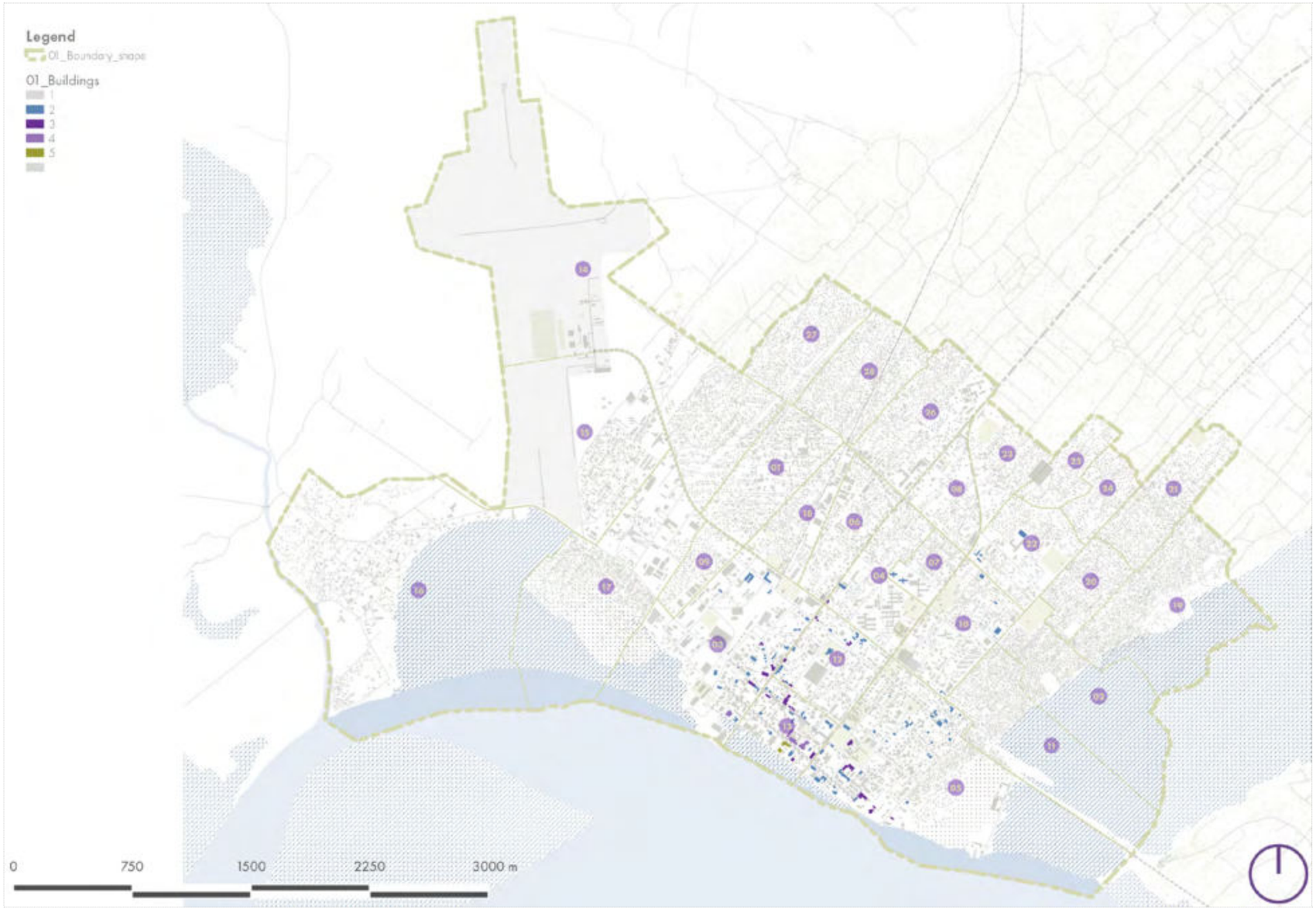

Figure 3.7 The city scale defined context map

3.3.3 The Barrio scale

To select the intervention areas from these 28 locations the team provided a set of parameters which prioritize the final study areas. There are three main criteria which are used to identify the weakest barrios. These are; roof condition, overcrowding & poor services.

The parameters for selecting the two barrios will be discusses in detail from chapter four. Barrio 09 and 11 being the local scale study area, has different characteristics. The former is part of the downtown in which most commercial activities are conducted and it has large scale buildings whereas the second study area has more density of buildings and includes the slum areas with immediate mangrove.

Figure 3.8 The Barrio scale defined context map

IMM Phase 1

Investigation and Analysis

Quelimane

It is the administrative capital of the Zambezia Province and the province's largest city, and stands 25 km (16 mi) from the mouth of the Rio dos Bons Sinais (or "River of the Good Signs"). The river was named when Vasco da Gama, on his way to India, reached it and saw "good signs" that he was on the right path. Quelimane, along with much of Zambezia Province, is extremely prone to floods during Mozambique's rainy season. The most recent bout of severe flooding took place in January 2007.

4

City Scale Analysis

Applying IMM at the city scale .

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4.1 Horizontal Investigation

This chapter entails with the application of IMM methodology over the already defined city scale in the precedent chapter.

4.1.1 Volume

Based on the census conducted in 2017, the population in Quelimane was 349,842 in all barrios with land area of 117 km2, however, due to lack of data our study area is limited to the city centre with its immediate neighbourhood. The studied volumes are part of the 28 barrios and the team analysed the density of buildings as compared to the land area and population, respectively.
The analysis considered the minimum standard area required by the UN habitat (20sqm per person) but the teams decided to add 10 sqm on it to reach 30 sqm per person. This figure then again multiplied by the number of populations residing in the 28 barrios to get the required built up area.

The expected built up area = (30sqm × number of populations in barrio)
We also computed the existing built up area to compare with the expected one, in this case the value of existing built up area is obtained using the formula below:
Existing built up area=(building area – shape area)/(Shape area)×100
The last computation concerns the percentage volume of each barrios this would help us to understand the highest and the lowest density across the 28 barrios
Existing volume %=((building area×number of levels)-Expected volume)/(Expected volume)×100
According to the calculation, Barrio 14 and 16 has the lowest building density compared to the average value of the city which is 26%.
In general, the urban fabric in the study area appears to be medium dense and dominated by informal settlement. The downtown has the tallest buildings (maximum of six storey) with a grid planning manner whereas the settlement around the city centre is predominated by single story residentials.
Moreover, the informal settlement on the outskirt of the city is becoming compacted or unable to expand due to the geographical limitation (mangrove and wetland). The fact that the growing number of slum areas is leading not to have proper infrastructure for the future development of the city of Quelimane in general.

Figure 4.1 Volumes map

4.1.2 void

we assumed voids as open spaces dedicated for the public activity such as sport fields, parks, and open green areas. This leads as to use the minimum green area standard which is 9sqm (UN habitat) to be used in cities for better quality of life. Using the standard, we computed the total void needed per person per barrio using the formula below:
The expected void area=(9sqm × number of population in barrio)
The team also analysed the percentage void value for each barrio to compare it with the expected percentage of void in each location.
void percentage = (existed void area – expected void area)/(expected void area)×100
To conclude, there are some dedicated open spaces which serves as parks and sport fields in the city centre but, on the new expansion, the city lacks open land which leads to congestion and high density of buildings soon.

Figure 4.2 Voids Map

4.1.3 Functions

There were difficulties to locate most type of uses due to outdated data and lack of organized documentation. However, the investigation was conducted by using online digital mapping tools and a direct information from a student at Eduardo Mondlane University in Maputo, Mozambique.
The collected data was analysed for each barrio according to the proportion of habitants in each barrio and gives the result for the percentage of type of uses. Barrio 17 has many types of uses followed by barrio 5 with compared to the other barrios.

type of uses in city %=(average number of type of uses)/(average number of populaion in barrio)×100

In general, most of the functions are concentrated in the city centre while there are also some functions on the north part of the study area. Moreover, the densified function in the centre are concentrated around the void to be more accessible. The scattered functions in the slums have limitations of accessibility and connection with the downtown but functions very well within the dedicated area. According to the analysis we were able locate the most important key functions such as commercial facilities, Bar and restaurants, Post office, Bank/ATM, Educational services, Health services, police, and parks.

4.1.4 Transportation

Based on the availability of transportation systems in Quelimane, it is categorized into motobike and buses. The former has some specific stops especially when there is a junction between roads while the later connects the city of Quelimane to other nearby places such as Milato and Tivire by having three stations.

Figure 4.3 Type of uses map

The Motobike Taxis plays a vital role in connecting the downtown with the surrounding neighbourhood.
On our investigation, we used the stops of moto Taxi as a point to define the catchment radius of 400 meters (about Five minutes' walk). In order to indicate an accurate catchment radius, we made the analysis on a software named ORS (Open Route Services). Regarding the bus (1000m radius), there are three main stations in which two are found in the city centre and the other in the North-East part of the city. We also indicated the main route that the bus follows to connect the city and the nearby places. The percentage amount of links in each barrio is also calculated and the average transport coverage which is about 99.82 links and barrio 10 has the highest link followed by barrio 22 when compared to the least transport coverage in barrio 09 and 17. The values then converted to percentage using:

Link in barrio %=(sum of bus and bike – average of link in the city)/(Average of link in city)×100

Generally, the public transportation network in the city centre is better connected as compared to the surrounding slum areas. The Motobike Taxi network is strong in the areas where more functions are available. It is easier to catch the Motobike Taxies within five-minute walking distance which facilitates the ease of movement in the downtown. Similarly, there are existed road networks which have the potential to integrate other modes of transportation in the future.

Figure 4.4 Transportation map.

4.2 Vertical Investigation - FLS

4.2.1 Porosity

Porosity is the synergy between Volume and Void layers from the horizontal investigation, it quantifies the ratio between volume of voids and the total volume.
"The Volume layer clearly defines the presence of this principle layer; the urban conveys the physical meaning of the city. Indeed, one can imagine the city as a solid porous volume, sponge like, with various sizes of holes linked by linear void layers: whereby the integration of these two layers, urban Volume and Void, porosities".
The porosity factor for each barrio is calculated using the using the formula below and the average value of 0.35 obtained. The percentage porosity value for each barrio is compared with the expected value of porosity which helps to guide the future intervention. According to the values, barrio 09 has the highest demand with -91% as opposed to barrio 3 which is 147%.
Note: the negative figures are indicating the barrios are not providing enough volumes and can be increased with more storey buildings.
porosity % = (existing volume fraction-expected volume fraction)/(expected expected volume fraction) ×100

4.2.2 Proximity

Proximity is the superimposition of volume and function layers. It is the measure of quality of movement by walking to reach to various urban key functions. Proximity is highly related to pedestrian movement, so it is evaluated through a predetermined distance to reach for key functions. Key functions are urban facilities such as administrative services, educational services, commercial facilities, entertainment facilities etc. proximity is dependent on the number of different functions, however it is not dependent on the amount of a single type of function.
The study area covers different neighbourhood which have various sizes and functions. By defining the walking distance, we used Five minute and Twelve-minute walk to cover 400- and 1000-meters radius, respectively. To get better description, we used Open Route Service by setting five- and twelve-minute walking distance in relation to the key functions within the study area. And then, we computed the sum of points given based on the number of activities whose catchment area intersect with the barrio. The result shows the average value of the city as 130.5 whereas barrio 5 has the highest value with 360 and the lowest of 21 in barrio 19.
Moreover, overlaying the maps of volume and function, it is possible to identify areas with better proximity and places with low proximity. The city centre has more intensity of colour as compared to the north-west and south-east part of the study area.
To conclude, the downtown has variety of functions as a result it makes the proximity higher on the area, whereas their area slum areas which have not integrated to the city centre, also lacks the availability of key functions.
We also used an indicator to reinforce the understanding of porosity, such as volume percentage, buildings per hectare, building distribution factor and floor area ratio (FAR).
Density is considered as an indicator for porosity. Firstly, the factor between built-up space volume ratio under the study area to the total of the study area, then the ration between built up area over the study area to the intervention area. Lastly, the ratio of number of populations to the volume and area gives as density indicator. The limits for maximum and minimum porosity are dependent on the other key categories and varies according to the context. In addition, the vertical relationship affects the span of al key categories.
Based on the definition of porosity, we overlaid the volume and void map together to obtain the porosity map. By doing this, we had a better understanding about the height of the buildings.

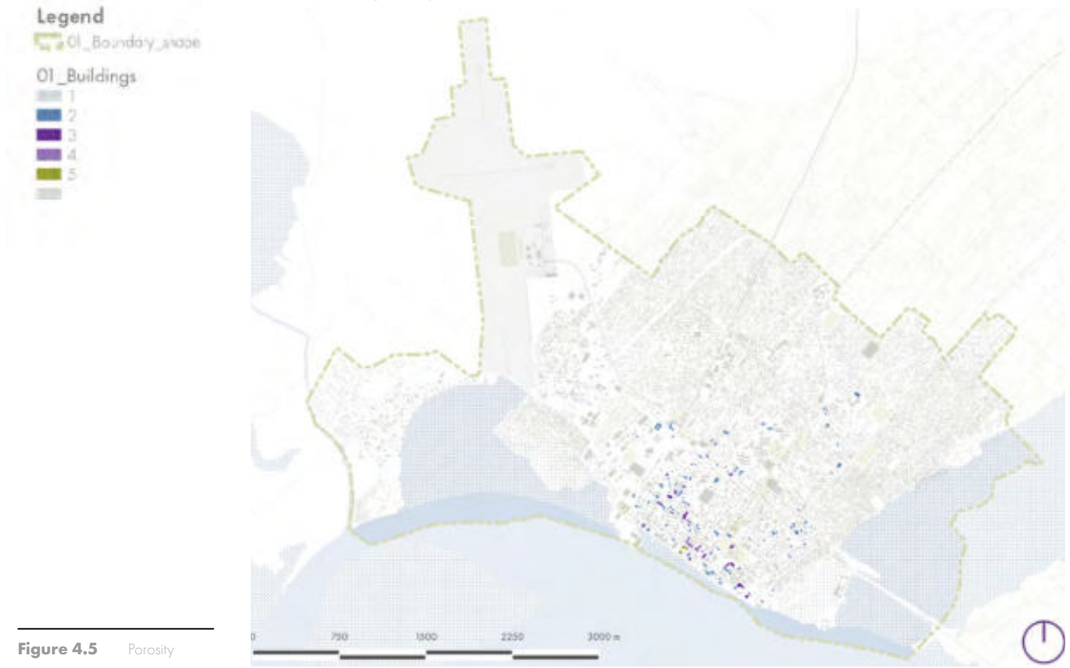

Figure 4.5 Porosity map

Figure 4.6 Proximity map

4.2.3 Diversity

The synergy between the Voids and Functions from horizontal investigation gives diversity map. Cambridge dictionaries define Diversity as ''The fact of there being many different things existing together in a group''. The functions which exist on the voids are categorized in to three, namely, NRA (Necessary Regular Activity), NOA (Necessary Optional Activity) and OA (Optional Activity).

The interrelation between the functions coupled with the immediate void springs the scope of various functions in each area. Based on the availability of data, we classified the key functions in relation to the three categories.NRA: Educational facilities, Health services and food market.

NOA: Bank/ATM, post office, police, park and commercial.

OA: Bar, Restaurants, and sport facilities.

On our process, the first step is to identify the existed functions and categorizing them into NRA, NOA, and OA. The Necessary regular activities are the ones which are used daily by the community, such as educational facilities and marketplaces.

The Necessary optional activities are the ones used occasionally, for instance, police office and park whereas the Optional activities are the ones that are not necessary but exists for leisure, like sport and bars. Secondly, we used ORS software to define the walking distance and travel time and at last, we counted the number of activities within the intersection of the catchment area in the barrios.

For instance, barrio 17 has 77 NRA, 52 NOR, and 1 OPA on the other hand barrio 11 has 3 NRA, 0 NOR, and 0 OPA. In general, the investigation revealed that the city centre is combined with three kinds of functions which makes it diversified compared to the surrounding settlement.

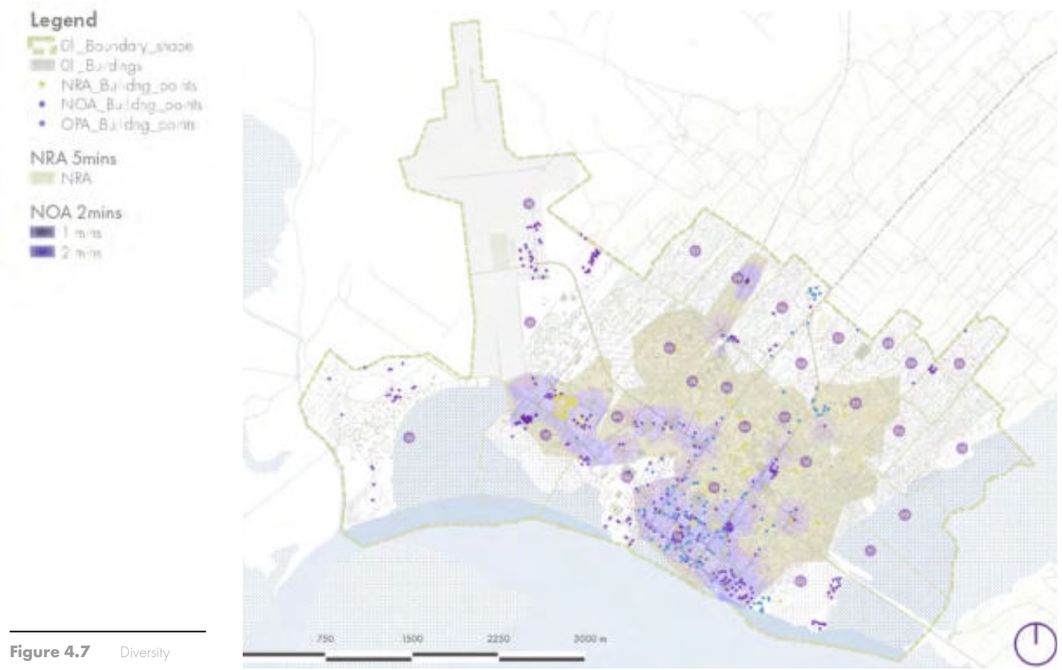

Figure 4.7 Diversity map

4.2.4 Accessibility

Cambridge dictionary defines Accessibility as ''the fact of being able to be reached or obtained easily''. The main aim of creating accessibility map is to understand whether the distribution of key function and transportation nodes are even or not. According to the IMM methodology, accessibility is the superimposition between transportation and function. The distribution of key functions with respect to transportation nodes, is analysed by calculating the percentage of functions over the transport nodes.

The team also formulated an assumption that pushing the percentage to near zero would be best practice for successful accessibility of functions and the negative percentages tells the function are not accessible. The percentage value of accessibility for each barrio is calculated using the formula below:

Accessibility in %=(number of accesibile uses -total number of uses)/(total number of uses) ×100with

Generally, the accessibility map shows that the city centre has better distribution of functions and transportation nodes compared to the Northern, Northwest, and west part of the study area. Due to the uneven placement of the key functions coupled with less availability of data, the informal settlements surrounding the downtown and the places near the airport are found to be less accessible.

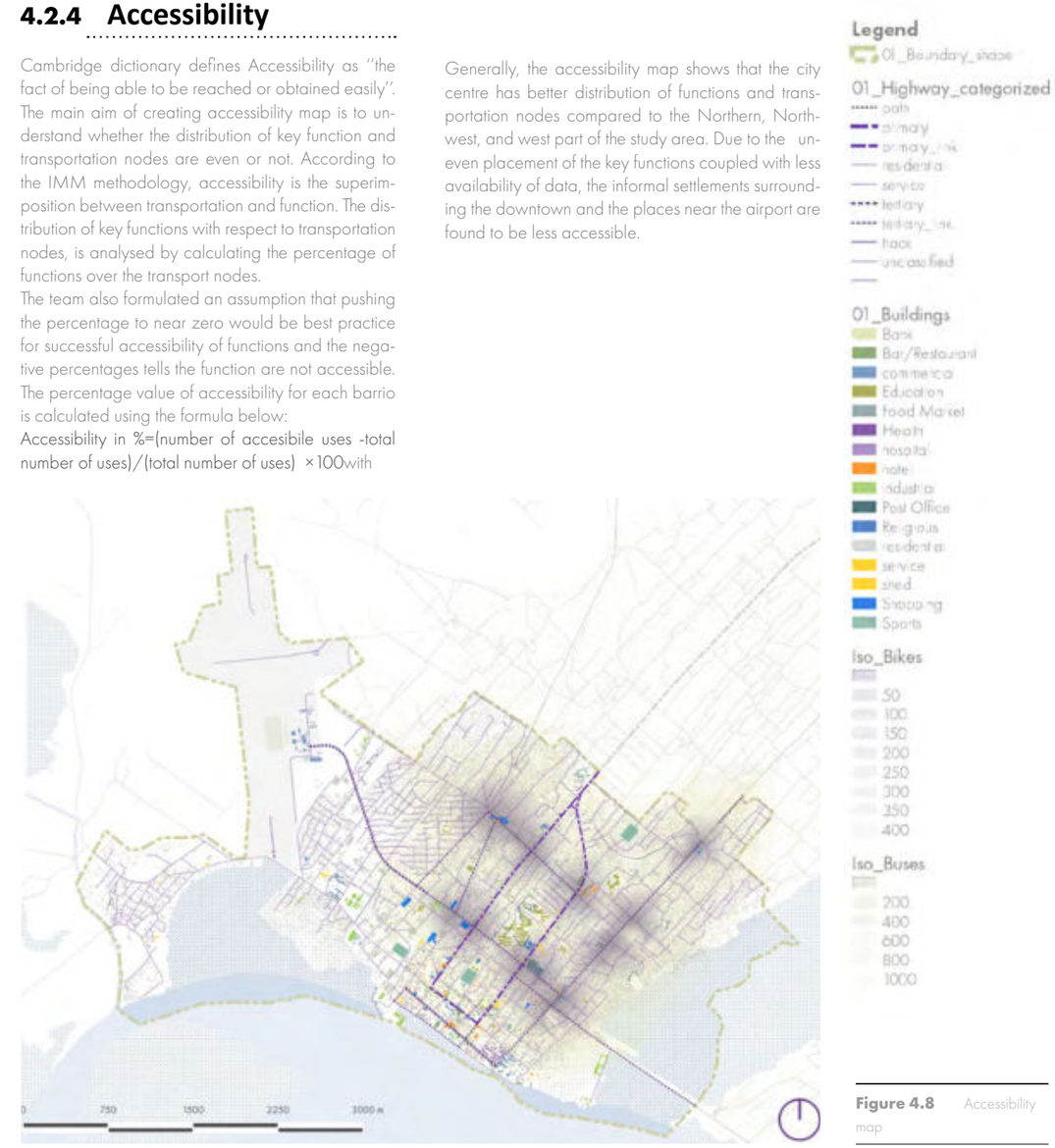

Figure 4.8 Accessibility map

4.2.5 Interface

It is the synergy between Void and Transportation layers from horizontal investigation. The main aim of creating Interface map is to understand the quality of movement within the street network provided as well as the efficiency of the urban morphology. It analyses and evaluate the mean depth of the urban flow and network.

The city scale interface map shows the overall quality of movement and connection at the same time we were also able to find the percentage of quality of movement in each barrio to identify the highest and the weakest locations.

The map was generated by a software named ''UCL Depth map'' developed in the University College of London. The software process 2D CAD file to calculate the number of intersections within the street network. We extracted an accurate street network map from QGIS and processed it in the Depth map software to have a different colour scale map. The Yellow colours represent well-connected, while the Purple colours indicate less-connection and dead ends. There is better connection in the city centre due to proper planning whereas the Northern part and the sides of the study area have less quality of movement.

4.2.6 Effectiveness

Effectiveness is the superimposition between Transportation and Volume layers. It also highlights how transport respond to the request generated by the built volume present in the area, and then, as they are efficient. In addition, it is an indicator for potential development in each intermediate scale. Areas with less or without built up volumes but existing transportation network are potential places for development.

After evaluating the potential areas across the study area, we provided a gradient colour scale representing the most effective areas. In our study area, there are only two means of transportation (bike and bus), which makes us to use 25*25 meters grid for better analysis. We also computed the effectiveness over the 28 barrios except the barrios which lack sufficient data for the calculation.

The efficient areas, based on the analysis, are from the city centre of Quelimane (for example barrio 19 & 20) in which the available transport can help to access the volumes whereas the surrounding areas specially the ones near the eastern part of the mangrove need improvement. As the areas goes from Purple to yellow, they evolve volumes but with poor accessibility. In these areas transport hubs will have to be integrated.

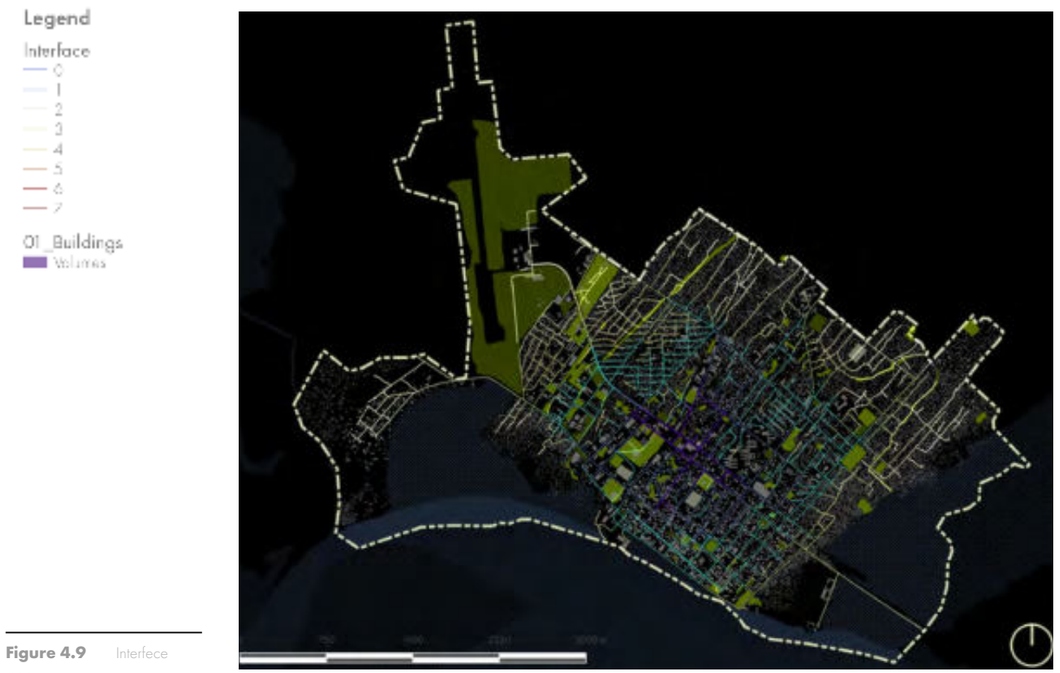

Figure 4.9 Interfece map

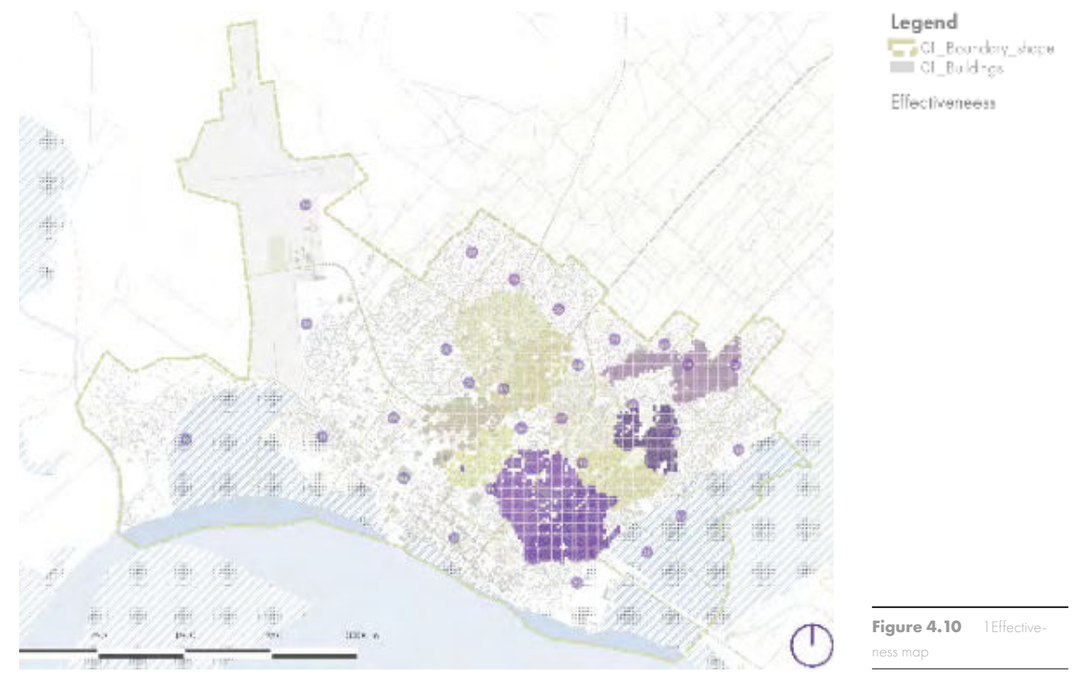

Figure 4.10 Effectiveness map

4.3 Vertical Investigation SLS

The results of the symbiotic integration of the preceding part, or second level of superimposition (SLS), depict the KCs e.g. compactness, complexity and connectivity, which are morphological, typological and technological features of the city.
As briefly mentioned, the sustainable form could be achieved through a correct balance between the second level KCs, such as the compactness, the complexity, and the connectivity. Any of them would not be enough on its own to achieve the sustainable form. However, the balance between the second level KCs is the foundation of a sustainable urban form.

4.3.1 Compactness

According to Wikipedia definition, ''Compact cities are intended to provide everything a person needs to live in one community, including work opportunities. When a person works inside the compact city, he/she can walk or bike to work instead of driving. This reduces fossil fuel consumption and helps to reduce emissions and traffic density on the highways between cities.
However, not everyone finds work inside the compact city, and subsequently, many people commute to neighbouring cities to access their employers. The need to commute creates two concerns for the compact city dweller, commuting time and the impact of commuting''.
Based on the IMM definition, compactness is the integration between proximity and porosity, which are second level integration of volume, function, and void. The morphological arrangements of the city greatly influence the ultimate energy consumption of the city.

Figure 4.11 | Compactness map

4.3.2 Complexity

It has now become important in many disciplines where systems which are highly decentralised require explanations from the bottom up, and where the actions of individual objects and agents combine to produce patterns, morphologies and system structures which cannot be explained using more aggregative theories.
Cities are the quintessential example of such complex systems. Their patterning in spatial terms across many scales is highly ordered but the evolution of such patterns does not depend on some centralised authority, some hidden hand, except insofar as such a hidden hand emerges from the uncoordinated actions of individuals. Planning and design of cities is thus the exception rather than the rule and where planning has altered the shape and structure of cities, its impact is across a limited range of scales and sectors.'' (Michael Batty, https://www.ucl.ac.uk/bartlett/casa/complexity-complexity-theory-and-urban-growth)
Based on the IMM definition, the complexity of the city is defined by the integration of Diversity and Interface, which are second level integration
of Function and Void and Void and Transportation. How high is the integration between different and in or simple is a city and how close or far different functions are within the city, describe the complexity of a city.

4.3.3 Connectivity

The integration of Accessibility and Effectiveness, or superimposition of Volume, Function, and Transportation layers, draws attention to the connectivity aspect of the city. Connectivity is highly related to the transport of goods and data. This new dimension of information and data connectivity clearly correlates

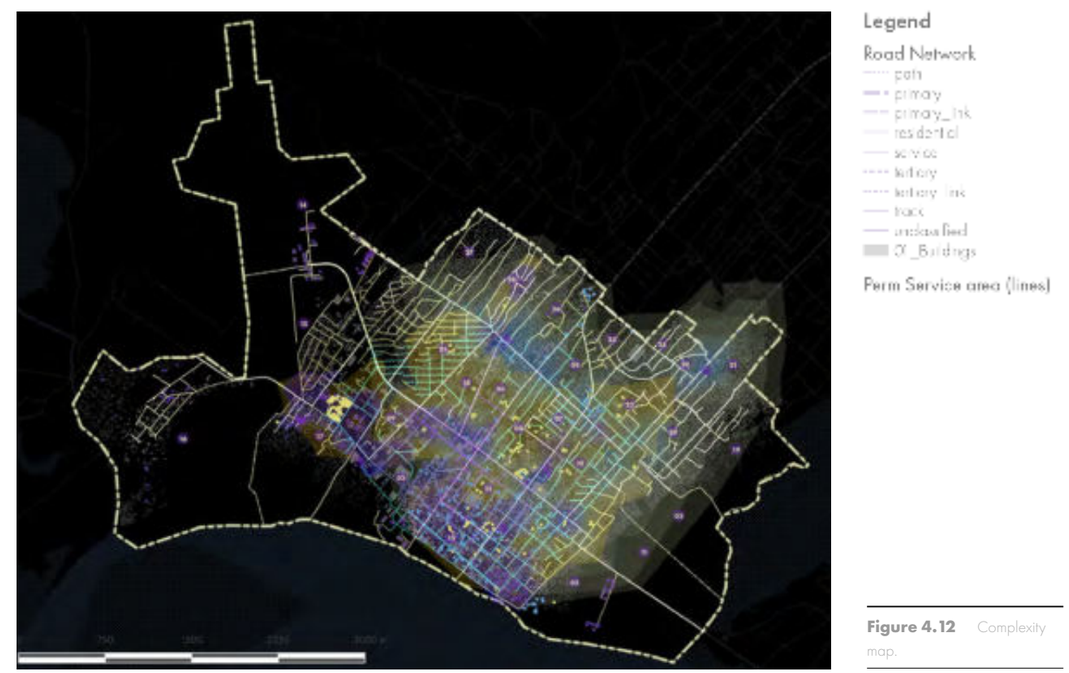

Figure 4.12 Complexity map.

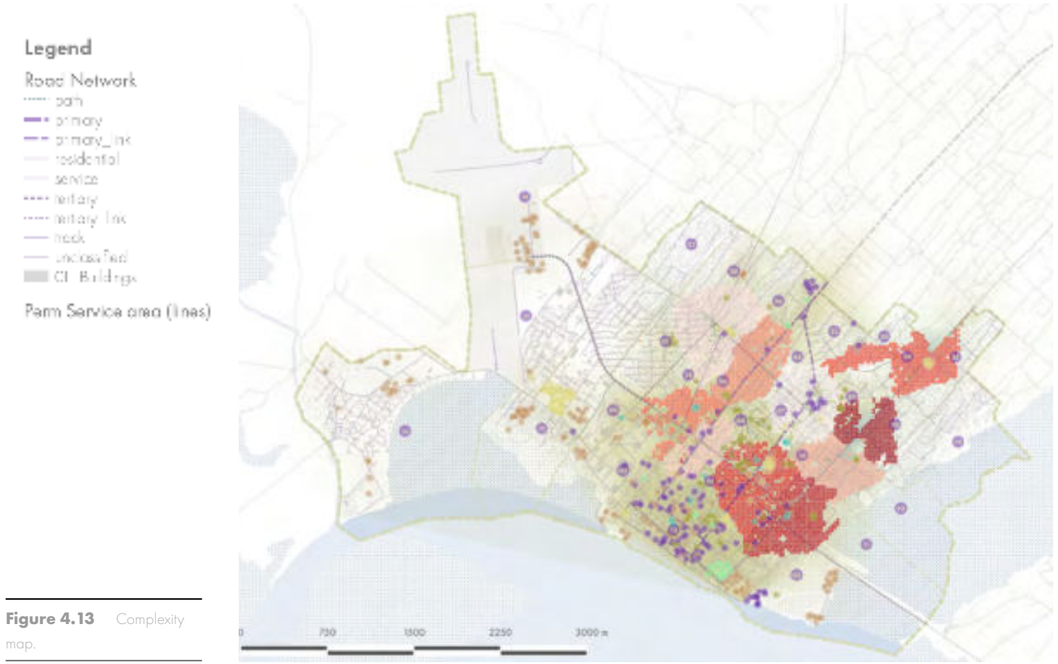

Figure 4.13 Complexity map.

diversity and features of the complex system in a vertical way. "To achieve a well-functioning and economically viable network of public transport, it is required a review of land use's policies, the population density and form, and the structure of city". Connectivity plays the major role in the prevention of data and movement congestion. The connectivity is the main issue to contradict who thinks that compactness is not sustainable form. They believe that the compactness lowers the efficiency of the system, triggered by the congestion of the data and objects.

The Barrio

Barrio is a Spanish word meaning "quarter" or "neighborhood." In the modern Spanish language, "barrio" is generally defined as each area of a city, usually differentiated by functional (e.g., residential, commercial, industrial, etc.), social, architectural or morphological features. In Spain, several Latin American countries and the Queliman, the term is also used officially to denote a division of a municipality.

5

Intervention Areas

in the hands of the next generationw

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5.1 Intervention Areas

The city of Quelimane has divides in to different barrios and among these our city scale analysis take into account 28 of them including the downtown. To select the intervention areas from these 28 locations the team provided a set of parameters which prioritize the final study areas. There are three main criteria which are used to identify the weakest barrios. These are:

Roof condition,
overcrowding &
poor services

the roof structure of the buildings was identified as ''good'' or ''poor'' condition observed from google satellite image and google earth applications. The result shows that most of the houses located near the mangrove (south-east) area and some from the central part of the city has poor roofing condition (see map below).

The second parameter used the population density from 2013 population census to identify overcrowded barrios. For example, barrio 09, 27 and others show high density whereas barrio 11, 03 and others has low population density (see map below).

The last parameter considers poor infrastructure services such as road among the barrios and according to our observation the Eastern part of the study area has less services when compared to the downtown.

Finally, overlapping the above information's together provided us seven barrios (09,01,08,11,02,20,19) to be studied as intervention areas (see map) and from barrio 13 to barrio 21 were automatically disregarded because of insufficient data. For this research, the team has decided to study barrio 09 and 11 as barrio scale intervention areas.

Figure 5.1 Intervention areas, Barrio 09 (left) & 11 (right).

Figure 5.2 Roof conditions in selected barrios

Figure 5.3 Population density in the selected barrios

5.2 Horizontal Investigation

5.2.1 Volume

The volumes are the expression of the built-up area in which the population is habituated or use. Regarding our analysis of volumes, we used the minimum standard area per person which is 20sqm (charting the progress of population UN standard) then the team improved it to 30sqm and this gives us the opportunity to calculate the total amount of built up area needed. This calculation would help us to tell the density of buildings in each barrio.

The expected built up area =
(30sqm × number of population in barrio)

Existing built up area=
(building area – shape area)/(Shape area)×100

Existing volume %=
((building area×number of levels)-Expected volume)/(Expected volume)×100

The first formula is used to calculate the percentage of volumes in barrio 09 and 11 and to compare the value with the expected results. The results show that barrio 09 is -81% less in volume when compared to expected figure similarly, barrio 11 also shows less volume percentage of -74%.

Figure 5.4 Volume map Barrio 09(right- above) .

Figure 5.5 Volume map Barrio 11(right- bottom).

5.2.2 Void

The voids are open spaces and green areas which function as parks, sport fields and open public spaces. For our analysis we considered the standard area of open space per person as 9sqm given by the UN habitat. Based on this assumption the total open area needed for all studied barrios would be 9sqm multiplied by the total population number. However, our study focuses on barrio 09 and 11 also according to the calculation the expected void area in barrio 09 and 11 is 83,637.00sqm and 41,301.00sqm respectively. These obtained values are compared with the existing figures of both barrios to discover the results. Barrio 09 has deficiency by 19% whereas barrio 11 shows -28% lack of voids.

The expected void area=(9sqm × number of population in barrio)

void percentage =(existed void area – expected void area)/(expected void area)×100

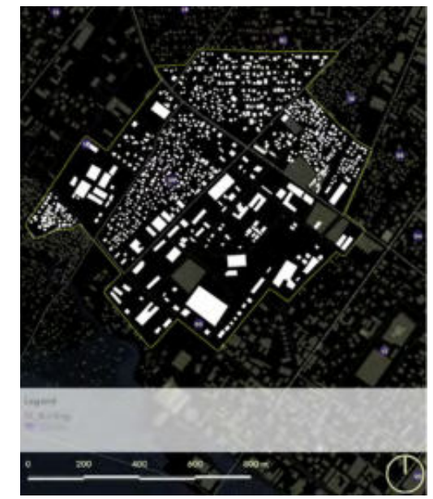


Figure 5.6 Void map Barrio 09(right -above)

Figure 5.7 Void map Barrio 11(right bottom).

5.2.3 Type of Use

Based on the available data, we spotted out the location of different type of uses within barrio 09 and 11. The listed out uses are about 17 different types and there exact location is identified using the help of google maps and a student from Mozambique. The data was processed according to the proportions of population residing in each barrio and the existing type of uses. The percentage value of type of uses for each barrio is obtained using the formula below:

type of uses in barrio %=(number of type of uses)/(number of population in barrio)×100

We also compared the obtained values to the average percentage of type of uses in the city. The calculation shows that, barrio 09 is 18% better than the city average, which is 0.33 however, barrio 11 was below -81% of the city's average.

type of uses in city %=(average number of type of uses)/(average number of populaion in barrio)×100

Figure 5.8 Type of uses map Barrio 09 (right-above).

Figure 5.9 Type of uses map Barrio 11 (right-bottom).

5.2.4 Transportation

For the overall analysis of transportation, we have used the buses and bikes due to the availability of data. The walking distances range from maximum of 400m (bike) to 1000m (bus) which takes Five- and twelve-minutes' walk, respectively. Moreover, the bus and bike stops are taken as nodes for the catchment area calculation. The sum of both bus and bike factors from the QGIS analysis is used for both barrios to compare it with the average value of links in the city.

Link in barrio % = (sum of bus and bike – average of link in the city)/(Average of link in city)×100

Using the above formula, the values of barrio 09 and 11 are -32% and 28% respectively. Barrio 09, when compared to the average transport links within the walking distance of transport stops, it shows less performance however, barrio 11 is better by 28%.

Figure 5.10 Transportation map barrio 09 (right-above)

Figure 5.11 Transportation map barrio 11

5.3 Vertical Investigation

5.3.1 Porosity

Porosity can be better understanding by considering the amount of volume needed correspondence with the number of people residing in each barrio. By referring the standard area needed per person which is 30 sqm and the following formula is used to calculate the expected volume in the barrios

expected volume fraction in %=(30 m2 ×number of population in barrio)/(shape area of barrio)×100

This gives us the minimum required value which is expected to be achieved and the existing volume area value will be compared to the expected value to see the difference. Based on the calculation, it is found that barrio nine is -51% porous below the expected value whereas barrio eleven is -33% porous below the standard expected value. To calculate the existing volume-fraction the formula below is used:

existing volume fraction in %=(area of buildings in barrio)/(shape area of the barrio)×100

Note: the negative figures are indicating the barrios are not providing enough volumes and can be increased with more storey buildings.
Finally, the above-mentioned percentage values of porosity were calculated using the formula below and the obtained negative values which are indicated above are not providing enough volumes and can be improved by adding more stories to the buildings.
porosity in %=(existing volume fraction-expected volume fraction)/(expected expected volume fraction) ×100
We also used an indicator to reinforce the understanding of porosity, such as volume percentage, buildings per hectare, building distribution factor and floor area ratio (FAR). From the analysis, the volume percentage calculation in both barrios is performing better compared to the indicator less buildings per hectare and less building distribution factor in barrio eleven (see the chart below).

- Building Distribution Factor

One of the indicator is named Distribution Factor, mainly influenced by the mu-tual distances of the buildings in a determined urban context.

- Buildings per Hectare

Residential density is used to measure the intensity of development within a given area. There are two types of density; gross density and net density. Gross density is the number of dwellings per hectare of a given area, including public infrastructure such as roads, open space and in some instances non-residential development (e.g. schools and shops).

- Floor Area Ratio

Floor area ratio (FAR) is the ratio of a building's total floor area (gross floor area) to the size of the piece of land upon which it is built. It is often used as one of the regulations in city planning along with the building-to-land ratio.The terms can also refer to limits imposed on such a ratio through zoning.

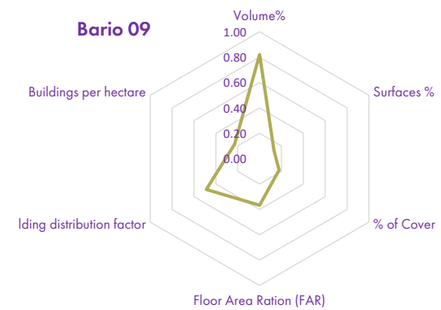


Figure 5.12 Porosity index Barrio 09 (left-above)

Figure 5.13 Porosity Index Barrio 11 (left-bottom)

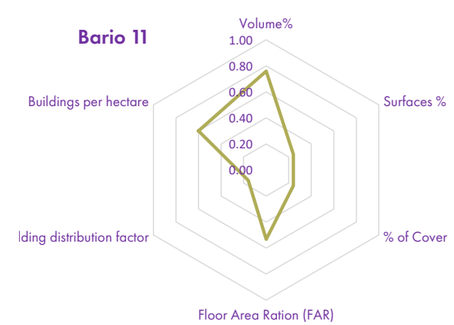


Figure 5.14 Porosity map Barrio 09 (right-above)

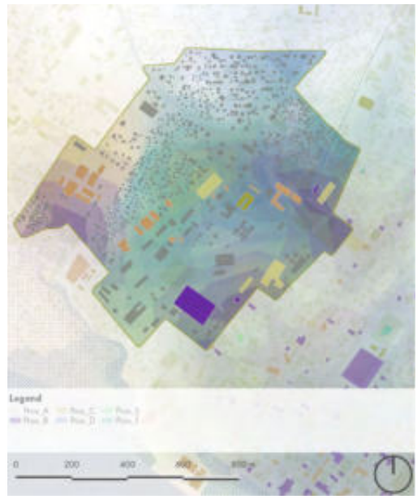
Figure 5.15 Porosity map Barrio 11 (right-bottom)

5.3.2 Proximity

Since proximity is the availability of function within the existing volumes, we analysed the proximity of each barrios in terms of percentage value. This is done using the sum of points given based on the number of activities whose catchment area intersect with the barrio.

For instance, barrio 09 and 11 has a value of -6% and -4% respectively, however, this calculation is limited within the perimeter of each barrios. For this reason, we included the immediate surrounding which can be reached by 10 minutes' walk to make the analysis more realistic. By doing this, the values of barrio 09 and 11 has found to be 122 and 125, respectively. In addition, the values obtained from both barrios were compared to the proximity of the city scale which is 130.5 and the result shows that barrio 11 is 156% better than the average city proximity followed by barrio 09 with 153%.

Note: the higher the number is the more proximity between the type of uses and vice versa.



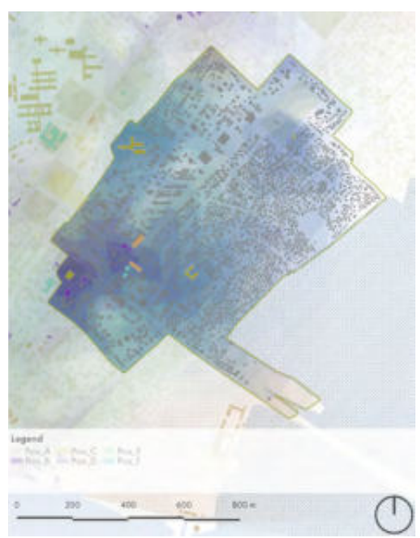


Figure 5.16 Proximity map Barrio 09 (right-above)

Figure 5.17 Diversity map Barrio 11 (Right bottom)

5.3.3 Diversity

In this map, we have considered overlaying the void and function maps to identify the functions categorized under ''necessary regular'', ''necessary optional'', and ''optional activities''. Based on the availability of data, we classified the key functions in relation to the three categories.

NRA: Educational facilities, Health services and food market.

NOA: Bank/ATM, post office, police, park and commercial.

OA: Bar, Restaurants, and sport facilities.

The first step is to identify the existed functions and categorizing them into NRA, NOA, and OA. The Necessary regular activities are the ones which are used daily by the community, such as educational facilities and marketplaces. The Necessary optional activities are the ones used occasionally, for instance, police office and park whereas the Optional activities are the ones that are not necessary but exists for leisure, like sport and bars.

Secondly, we used ORS software to define the walking distance and travel time and at last, we counted the number of activities within the intersection of the catchment area in the barrios using the QGIS. For instance, barrio 09 has 1 NRA, 0 NOR, and 0 OPA on the other hand barrio 11 has 3 NRA, 0 NOR, and 0 OPA.

Figure 5.18 Diversity map Barrio 09 (right-above)

Figure 5.19 Diversity map Barrio 11 (Right-bottom)

5.3.4 Accessibility

Accessibility, which is the distribution of key functions with respect to transportation nodes, is analysed by calculating the percentage of functions over the transport nodes. The team also formulated an assumption that pushing the percentage to near zero would be best practice for successful accessibility of functions and the negative percentages tells the function are not accessible. Based on the analysis, 76% of type of uses residing in barrio 09 are not accessible while all the functions in barrio 11 are easily accessed through the existing transport system. The computed values are compared with the expected value of accessibility which is like barrio 11. The above percentages of accessibility are calculated using the following formula:

Accessibility in %=(number of accessible uses -total number of uses)/(total number of uses) ×100

Figure 5.20 Accessibility map Barrio 09 (right -above)

Figure 5.21 Accessibility map Barrio 11 (right -bottom)

5.3.5 Interface

As interface measures the quality of movement within the street network with reading the efficiency of the urban morphology, we used ''UCL depth map'' and QGIS to understand the mentioned efficiency. For this case we have provided the interface map for both barrio 09 and 11 and find out the quality of movement.

The lines with small figures or with the yellowish colour indicate the better connection. In other words, it is easier to reach points using this route.

On the other hand, the higher number (purple) as 0.25 and 0.26 shows the poor quality of movement. Based on the comparison of both barrios with the average value of the city's interface integration (30.87) the figures show 223% and 156% (barrio 09 and 11 respectively) of better interface compared to the city average.

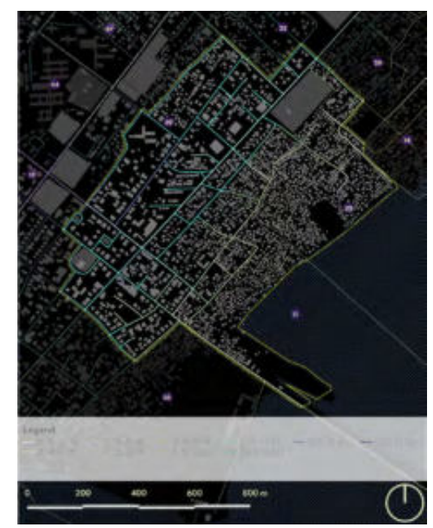


Figure 5.22 Interface map Barrio 09 (right-above))

Figure 5.23 Interface map Barrio 11 (right bottom)

5.3.6 Effectiveness

The effectiveness is to highlight the efficiency of transportation system within the existing volumes. For better understanding of how effective each barrio are we calculated the availability of bike within on hour of tie over the total number of residents within its catchment area. Moreover, we used the value ''1'' as the most effective base line while less than or greater that value is less effective. Bikes were used in the analysis because of the availability of data and there are about 4000 registered bikes throughout the whole city of Quelimane however, we used 2000 of them for our analysis.

We also computed the effectiveness over the 28 barrios except the barrios which lack sufficient data for the calculation. However, our study focuses on barrio 09 and 11 and the result shows -98% (barrio 09) and -89% (barrio 11) deficiency of transport service when compared to the expected transport availability. Barrio 11 has better coverage compared to barrio 09 this is also readable from the map below. The more purple colour in each 25 by 25 grid to show the average coverage of bike transport.

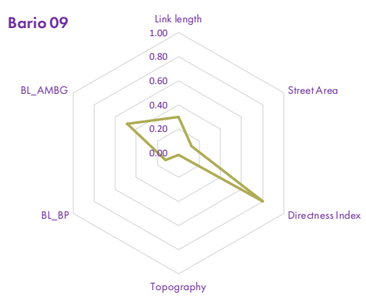
Figure 5.24 Permeability Barrio 11 (left up)

Figure 5.25 Directness Barrio 09 (left bottom)

5.3.7 Permeability

"In Fluid mechanic Permeability is a measure of the ability of a porous material to allow fluids to pass through it. Permeability is related to Porosity but also to the shapes of the porous". The porosity map was provided for both barrios to measure and understand the quality of passing through the volumes. To measure the case, we have provided a directness map for both barrios which is a method show the direct connection or path between one point and the others. The map was letter refined according to the existing road network to get a realistic movement of peoples using the frequent path.

Bario 09



Bario 11

Figure 5.26 Permeability map Barrio 09 (right-above)

Figure 5.27 Permeability map Barrio 11 (right-bottom)

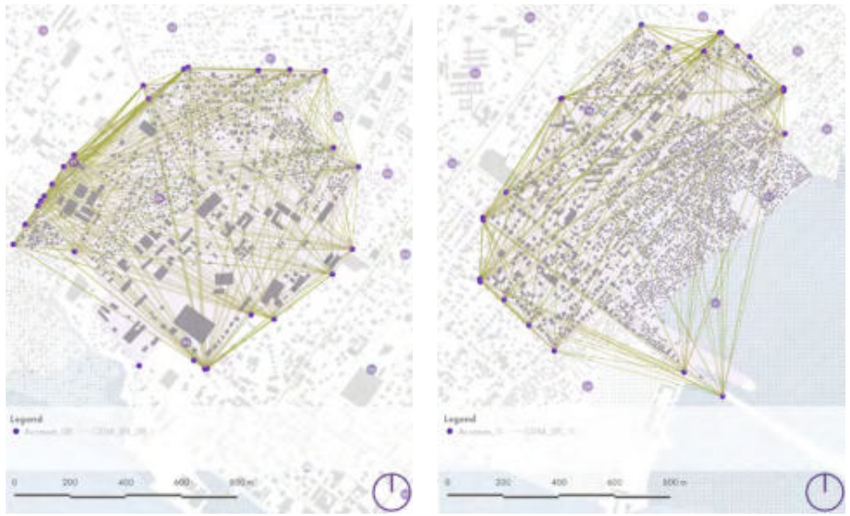


Figure 5.28 Directness map Barrio 09 (left-above and bottom)

Figure 5.29 Directness map Barrio 11 (right -above and bottom)

IMM Phase 2

Formulation and Assumption

Formulation is the next Phase of the IMM after the investigation. At this stage we seek to process the investigations to identify the catalyst and the Define the Design ordering principles. The main goals of the formulation phase are;
First to find the hypothesis of the Catalysts, based on the knowledge obtained in the previous phases, as to explain the CAS configuration, its behavior and performance
Secondly to understand the role of the Catalysts in each Sub-system and Key categories;
Lastly to preliminary control of the local consequences of the design choices ie. Using the DOP.
The focus boundaries of the formulation process was limited to the barrio scales. Bot Barrio's 9 and 11 data were processed to identify their catalyst. Form that point the DOP was arrange. Note that since this mathematical approach was being tested, we analysis ed two areas to serve as a control to identify the potential flaws. After these, intervention with the purpose of optimizing the system should start with improving the weaker subsystem, and only through the catalyst, the scope of the transformation is being defined. In this way, design principals for any project are locally defined according to its very particular situation.

The sections further explores the thematic areas of study. This is manifested as the SMART acronym. A breakdown of what it entails, it connection to the SDGs and the case studies are highlighted. It finally explores state of the various themes in Quelimane.The Living Building Challenge would serve as a guides in the form of certification and standardization to inform the extents and basilines to which the SMART acronym should be applied These when summed up would serve as the formulations to guide the design on the urban and Architectural scales.

6

Presumptions

Findng the catalyst and arranging the DOP.

What to Expect

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6.1 Catalyst Selection

In the investigation stage, numerical values were assigned to the various components and key categories. These numerical values were the first point of interaction. Using the values, the different key categories were suddenly comparable and so was the components.

6.1.1 Weakest components

Volumes and Voids were ranked based on how the existing barrio performance compared to the what is required by standard. The standard volume used was a minimum of 30sqm per person while a 9sqm accessible open space was used for the void. The standard for the open space was obtained form UN suggestions(source). The minimum volume was based on previous studies on minimum square meters of space for groups of countries. Thus different groups of countries had different minimum standards. For Quelimane, we adopted a minimum based on an assumed figure in a the study look for the study for developing African countries.

Links on the other hand was evaluated based on the length of links within the barrio. This was compared with the average of the city itself. This was we were able to determine the whether the barrio was under provided for compared to the main city as a whole. Note that the further understanding of the links is elaborated on in the categories. As such this level of comparison was deemed sufficient for the component level.

Uses and types of uses was evaluated as a ratio of the non-residential uses to the residential uses. These ratios were used to understand the proportions of the uses. The individual values were compared to the average of the city other than the highest since that would mean converting all areas into commercial. However using the average ratios of the city would help to find the balance of uses to reach the need of the city. We however recommend a further study into the standards of uses per people as we find this would be a clearer method of analysis.

From the above assumptions the following table (Table 6.6) were the findings;

Component	Barrio 9	Barrio 11
Voids	-74%	-98%
Vol	-82%	-76%
Links	-32%	28%
Types of Uses	9%	-82%

From the table barrio 9's weakest component is the volume while bario 11's weakest component is the Voids. A visual inspection was carried out to compare the mathematical findings. It revealed that voids was a common weakness for both barrios. When compared, with the table we find that the values are high and show the signs of weakness of the voids as well. Thus although the weakness of the barrios were

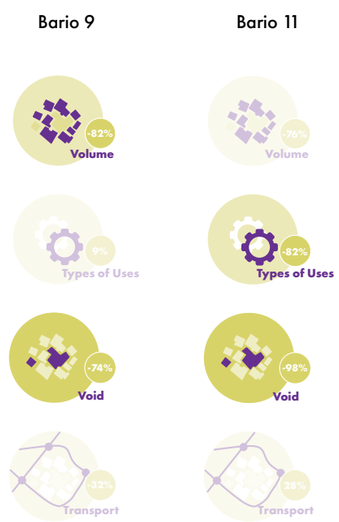


Figure 6.1 Performance of the bario 11 and 9 components

Table 6.6 Performance of the bario 11 and 9 components

mentioned we also kept in mind the voids during the proposals

6.1.2 Key Categories

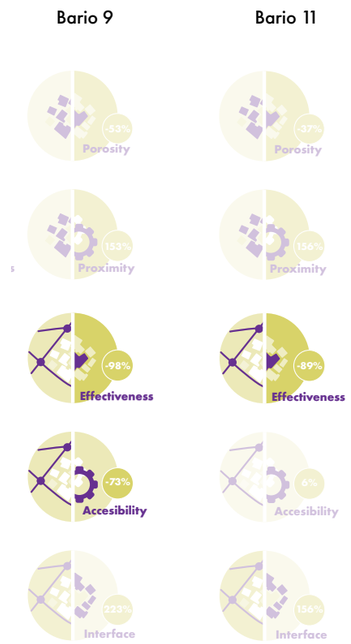
Proximity and interface were compared based on

Key Categories		Barrio 9	Barrio 11
Diversity	NRA	1	3
	NOA	0	0
	OPA	0	0
Effectiveness		-98%	-89%
Interface		223%	156%
Porosity		-53%	-37%
Proximity		153%	156%
Accessibility		-73%	6%

their comparison to the city average. Proximity points indicates the closes of functions in the barrio. Interface on the hand was evaluated based on how connected the links were in the barrio. An inverse evaluation was used due to the out put data of the Syntax map. The final values were benchmark against the city average to find the possibilities to improve.

Accessibility was evaluated based on the functions being served by the available transport. This was compare not to the city but to the barrio itself .Effectiveness adopted a similar comparison. The effectiveness of the area is compared with the barrio's best possible situation. In the case of effectiveness, the aim is to achieve a ratio close to one. Thus each barrio is evaluated to find its closeness to one.

Finally the Porosity evaluates the ability of the barrio to provide the minimum need living space for total number of people currently recorded there. Thus the comparisons l s between the bario's current state and what it should be.Categories as diversity and permeability on the hand were not evaluated in any mathematical approach. Summaries of the find findings



were put together in the following table(Table 6.7). From the table effectiveness was the weakest of the key categories in both barrios. A visual analysis of the maps also inferred the same findings.

Table 6.7 Performance of the bario 11 and 9 Key Categories

Figure 6.2 Performance of the bario 11 and 9 Key Categories

6.2 Design Ordering Principles

The design ordering principles are crucial in the determining the principles needed in high urgency within the specified area. Currently the DOP consists of 12 main families and over 150 indicators. The quality of the use measurement of the various principles is dependent on the indicators and their respective tiers. Two major steps were carried out this step. First was arrange the DOP and to identify the indicators.

Indicators

The selection of the indicators were primarily based on the availability of the information to satisfy the indicator and the applicability in the context. Through this premise the indicators were filtered to the following usable list. (Table 6.8). Thus a total of 32 indicators were selected.

DOP Family	Indicators	
01. GROUND USE	Urban Built density	Street Cover Ratio (SCR)
	Number of buildings per hectare	Solar energy potential
	Number of inhabitants per hectare	Block Density`
03. MULTIPLICITY AND VARIETY	Ratio between numbers of residents and activities	Job/housing ratio
	Housing diversity	Ratio of place dedicated to Innovation and Knowledge
04. URBAN BIODIVERSITY	Proportion of the resident living 300m of a park	
5. GREEN SPACES	Percentage of Residents within Walking Distance of a Recreation Area	
06. CYCLABILITY & WALKABILITY	Length of biking roads	Pedestrian street paths - walkways
	Number of bike parking spots	Number of people that are within walking distance of frequent transit stops
	Number of key function in a walking distance from residential buildings	Shade and shelter
07. URBAN FLOW (people)	Collective taxis per thousand inhabitants	Length of road per urban hectare
08.	Number of public transport operated (boat, train, tram, metro, buses, micro-buses, ...)	Number of "Park-and-Ride" parking places
09. ENERGY MANAGEMENT	Consumption per capita	Renewable electricity production
	Rate of energy coming from renewable sources	
10. FOOD MANAGEMENT	Amount of urban farm production per person	Number of Supermarkets within a given locale/community
	Number of Farmers markets within a given locale/community	
11. WASTE MANAGEMENT	Amount of solid waste produced	Number of Small food stores within a given locale/community
12. WATER MANAGEMENT	Total Annual Water Consumption	Produced urban wastewater

Table 6.8 Selected DOP families and indicators

6.2.1 DOP families

The selected indicators are then used to narrow down the ordering process of the DOP. The 12 families of the DOP each have indicators which are directly linked to the key categories and components. The state of each of the indicators for established in the investigation.

DOP Family	Key Categories	Components	
01. GROUND USE	Porosity	Transport	Volume
	Interface	-	Volume
	Proximity	-	Volume
	Effectiveness	Transport	Volume
03. MULTIPLICITY AND VARIETY	Diversity	Function	Volume
	Accessibility	Function	Volume
	Proximity	Function	Volume
5. GREEN SPACES	Porosity	Void	Function
	Proximity	Void	Function
06. CYCLABILITY & WALKABILITY	Interface	Transport	-
	Diversity	Function	-
	Accessibility	Transport	Function
	Proximity	Transport	Function
07. URBAN FLOW (people)	Porosity	Transport	-
	Interface	Transport	
	Accessibility	Transport	
	Effectiveness	Transport	
08.	Interface		Transport
	Accessibility		Transport
	Proximity		Transport
	Effectiveness		Transport
10. FOOD	Porosity	Void	Function
	Diversity	Function	
	Proximity	Function	

Table 6.9 Relationships between the key categories and the DOP families

Our aim now was to improve each of the component by 150%. Setting this target meant each key category could be evaluated on a point system. The point system thus ranged from 1.5 as the minimum to 2.5 maximum. Next the percentage of the deficiency of the components was used as an adjusting factor applied family and key component cases. Summing the different cases gave the resulting ranking of the DOP for barrios 9 and 11

Key categories	Bario	Fcator	1. Ground Use:	2. Permeability:	3. Multiplicity and Variety:	4. Urban biodiversity:	5.Green spaces:	6a. Cydability & 6b. Walkability	7. Urban flow and mobility		9. Energy management	10. Food management:	11. Waste management:	12. Water management:	13. Governance
Porosity	11	-1.87	0.89	0.00	0.00	0.00	3.36	0.00	-0.53	0.00	0.00	1.52	0.00	0.00	0.00
Interface	11	0.06	-0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00
Diversity	11	-1.50	0.00	0.00	0.72	0.00	0.00	1.22	0.00	0.00	0.00	1.22	0.00	0.00	0.00
Accessibility	11	-1.44	0.00	0.00	0.69	0.00	0.00	0.77	-0.41	-0.41	0.00	0.00	0.00	0.00	0.00
Proximity	11	0.06	-0.05	0.00	-0.03	0.00	-0.11	-0.03	0.00	0.02	0.00	-0.05	0.00	0.00	0.00
Effectiveness	11	-2.39	1.14	0.00	0.00	0.00	0.00	0.00	-0.68	-0.68	0.00	0.00	0.00	0.00	0.00
Totals	-	-	1.94	-5.00	1.37	-5.00	3.25	1.98	-1.59	-1.05	-5.00	2.70	-5.00	-5.00	-5.00
Ranking	-	-	**10**	**1**	**9**	**1**	**13**	**11**	**7**	**8**	**1**	**12**	**1**	**1**	**1**

Table 6.10 Sample DOP arrangement table for the bario 11.

Figure 6.3 Bario 11 DOP arrangement

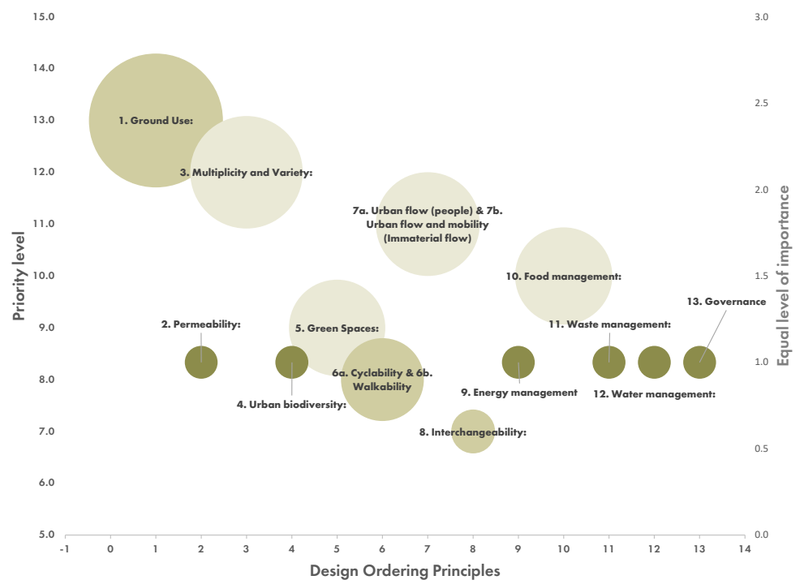
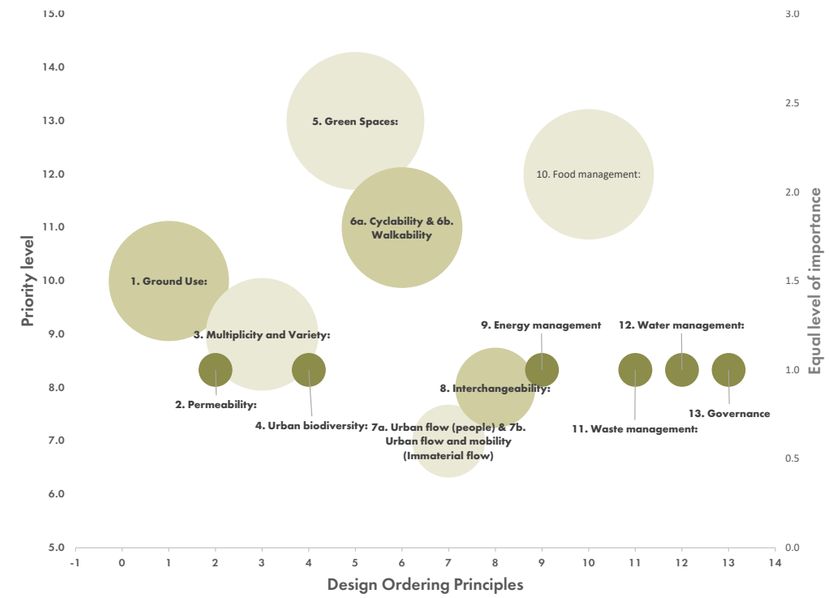


Table 6.11 Selected DOP families and indicators

Key categories	Bario	Factor	1. Ground Use:	2. Permeability:	3. Multiplicity and Variety:	4. Urban biodiversity:	5.Green spaces:	6a. Cyclability & 6b. Walkability	7. Urban flow and mobility		9. Energy management	10. Food management:	11. Waste management:	12. Water management:	13. Governance
Porosity	9.00	-2.03	2.32	0.00	0.00	0.00	1.32	0.00	0.66	0.00	0.00	1.51	0.00	0.00	0.00
Interface	9.00	0.73	-0.60	0.00	0.00	0.00	0.00	-0.24	-0.24	-0.24	0.00	0.00	0.00	0.00	0.00
Diversity	9.00	-1.50	0.00	0.00	1.09	0.00	0.00	-0.14	0.00	-4.50	0.00	-0.14	0.00	0.00	0.00
Accessibility	9.00	-2.23	0.00	0.00	1.62	0.00	0.00	0.52	0.72	0.72	0.00	0.00	0.00	0.00	0.00
Proximity	9.00	0.03	-0.02	0.00	-0.02	0.00	-0.02	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
Effectiveness	9.00	-2.48	2.84	0.00	0.00	0.00	0.00	0.00	0.80	0.80	0.00	0.00	0.00	0.00	0.00
Totals	-	-	4.54	-5.00	2.69	-5.00	1.30	0.13	1.94	-3.22	-5.00	1.37	-5.00	-5.00	-5.00
Ranking	-	-	**13**	**1**	**12**	**1**	**9**	**8**	**11**	**7**	**1**	**10**	**1**	**1**	**1**

Table 6.12 Bario 9 DOP Arrangement



6.3 Connecting the dots

In this section, the team studies the relationship between SMART, DOP and WWMEFH to have a better understanding on fortifying the ideas of smart.

- SMART

The acronym SMART coupled with IMM methodology is used as a tool coupled with the IMM methodology to have a better design intervention for both urban and local scales.

Softness: The Softness term has been used by David Sim to describe the coziness that people of the Scandinavia to make for themselves despite the harshness of their part of the world. Sim explains further a concept of a "Soft city" as being related to the getting closer, connecting people and to all aspects of life around them.

Multilayer: Multilayer considers the introduction of different function to buildings at medium to higher densities. This approach seeks to consecrate people and functions thus promoting walkability.

Agritecture: Most cities have been built without ''food in mind'' concept, however, buildings are now integrating spaces like roof top and facades to grow food. The concept of AgriTecture is to utilize the architecture not only for habitable spaces but also to produce food.

Technology: The term robustness was one of the many new terms coined in the book Responsive Environments (Bentley et al., 1985) where it was also applied to the design of public spaces, that is, spaces should be designed to facilitate a range of activities and allow them to change over time without significant alteration to the fabric.

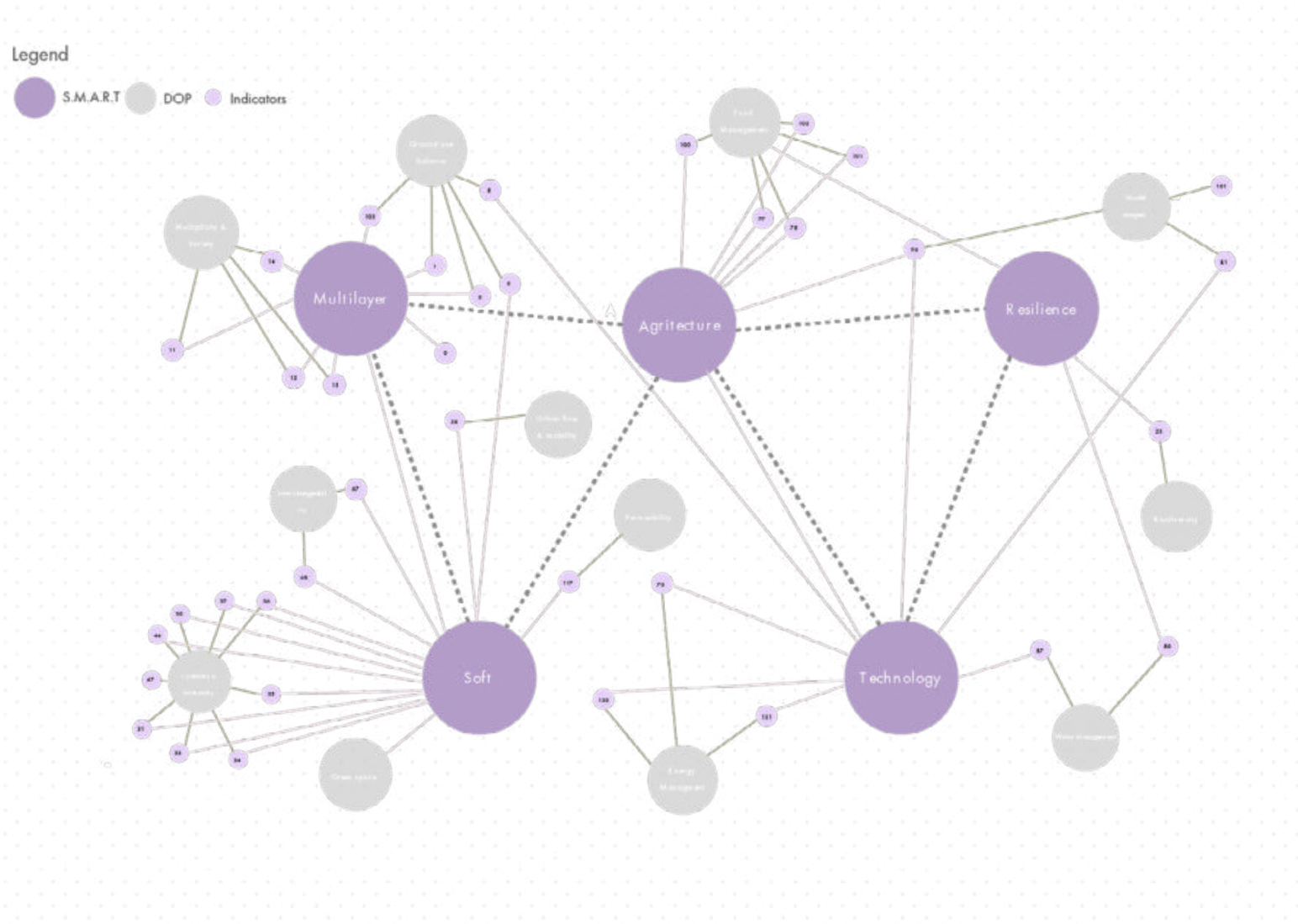


Table 6.13 S M A R T - DOP relationship

- Design Ordering Principles

1. Promote Walkability, Cycling and Reinforce their integration with public transportation.
2. Balance the ground use
3. Fostering the local energy production. Building as component of Smart Energy Comunity
4. Prevent the negative impact of waste
5. Balancing the public transportation potential
6. Makes Biodiversity an important part of urban life
7. Convert the city in a food producer
8. Balance the distribution of functions and developing multifunctional urban spaces.
9. Create connected open space system, activate urban metabolism
10. Change from multimodality to inter-modality concept
11. Implement permeability to facilitate urban flows and adopt an locally based strategy.
12. Implementwater management

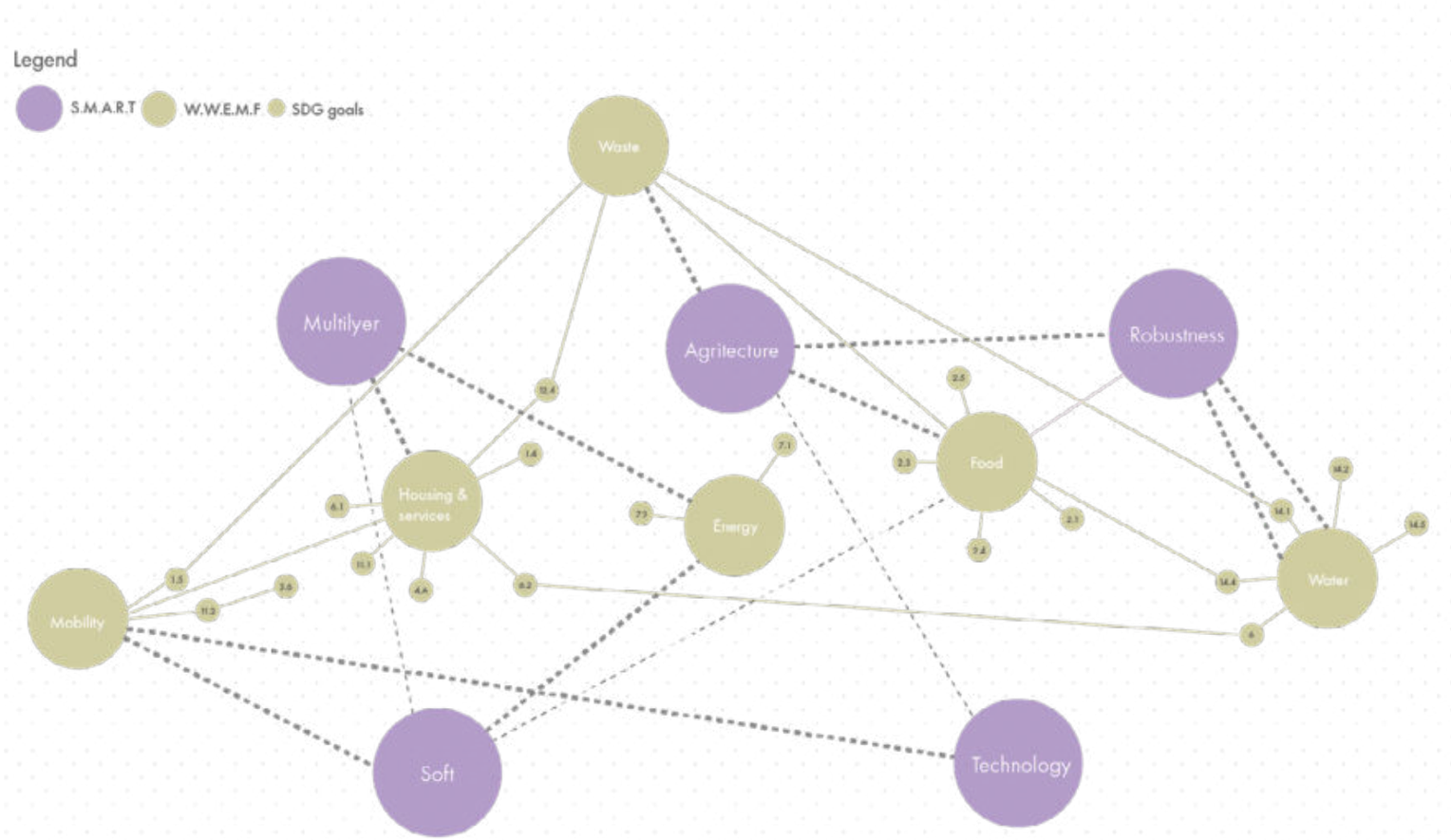


Table 6.14 SMART to WWEMFH relationship

- WWEMFH

Waste management: include the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process.
Water management: Water is essential for our survival. The field of water resources management will have to continue to adapt to the current and future issues facing the allocation of water. With the growing uncertainties of global climate change and the long-term impacts of management actions, the decision-making will be even more difficult.
Energy: is the power we use for transportation, for heat and light in our homes and for the manufacture of all kinds of products. There are two sources of energy: renewable and nonrenewable energy.
Mobility: is the ability to move all people safely and affordably between where they live, work, and spend their leisure time. It includes walking, cycling, vehicle sharing, public transportation, and much more. Mobility is the ability to move or be moved freely.
Food: Availability of food, access to food, and risks related to either availability or access are the essential determinants of food security (von Braun et al. 1992). National foodsecurity implies that within a country the amount of food available, if evenly distributed, is enough to meet people's food needs.
Housing: Housing, or more generally living spaces, refers to the construction and assigned usage of houses or buildings collectively, for the purpose of sheltering people — the planning or provision delivered by an authority, with related meanings.

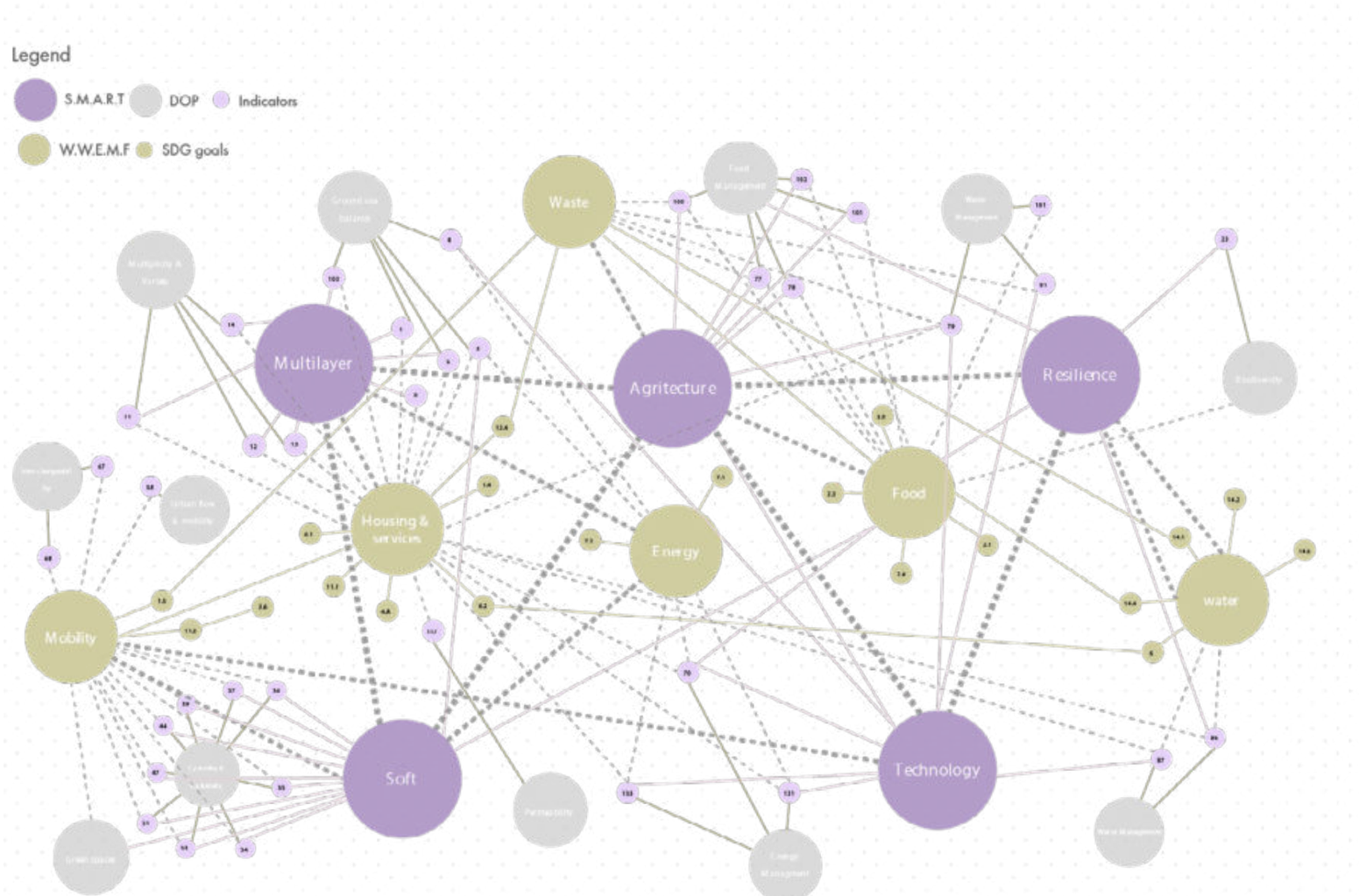
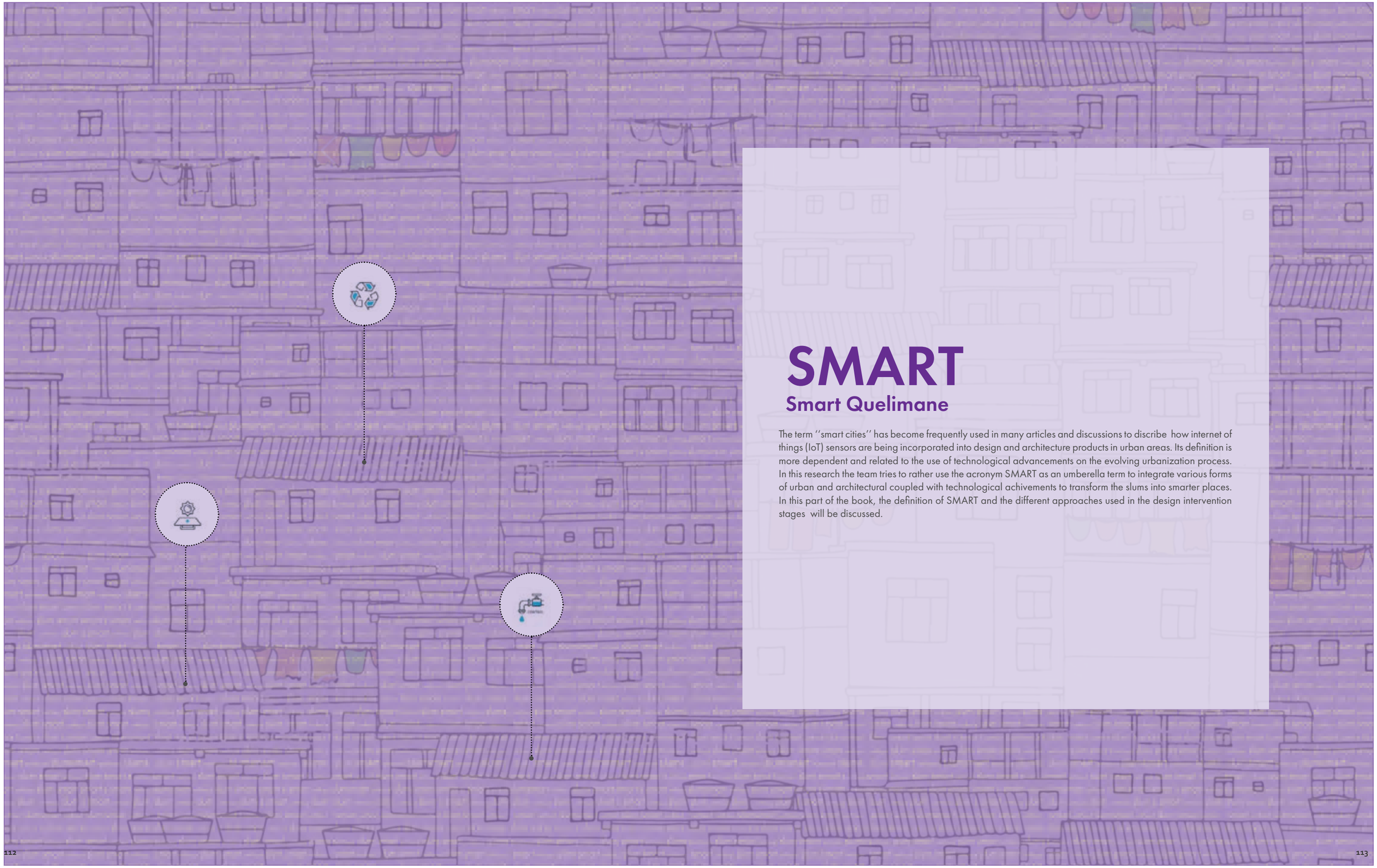


Table 6.15 SMART - DOP- WWEMFH relationships



SMART

Smart Quelimane

The term ''smart cities'' has become frequently used in many articles and discussions to discribe how internet of things (IoT) sensors are being incorporated into design and architecture products in urban areas. Its definition is more dependent and related to the use of technological advancements on the evolving urbanization process. In this research the team tries to rather use the acronym SMART as an umberella term to integrate various forms of urban and architectural coupled with technological achivements to transform the slums into smarter places. In this part of the book, the definition of SMART and the different approaches used in the design intervention stages will be discussed.

7

SMART

Soft/Multilayer/Agritecture/Robust/Technology

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7.1 Soft

The Softness term has been used by David Sim to describe the coziness that people of the Scandinavia to make for themselves despite the harshness of their part of the world. Sim explains further a concept of a "Soft city" as being related to the getting closer, connecting people and to all aspects of life around them. (8) . This relatively new but old idea aims at helping people experience the life that happens between the buildings. Life in between the buildings is highly dependent on the streets that they form. With this in mind, the attention can be given to how to actually tackle the street to allow for the best of coziness, so to say, whether or not you exist in the Scandinavia.(8) This softness then would not be somewhat limited to one section of the life i.e.; movement. It needs to be considered as a system that would seek to enable activities that remind people of what it means to human. It should seek not only to move but also to allow for stops. These stops would enable them to get closer to each other and reconcile with their humanness.

7.1.1 Softness-SDG-DOP

From David Sim's explanation the softness of the city would depend on two main components. First is the street to allow the movement. The other is the place to connect i.e.; the open spaces. The SDG 's 11.2 focusses on the need to improve and expand transport systems in cities. This has been integrated into the DOP's families 6 and 7. Here the indicators seek to help to perceive the existing situation and the effects of the interventions. In all the DOP and the SDG's 11 goal are intertwined with the street which is a component of the Softness. The SDG 11 further expands on the issue of inadequate distribution and access to public spaces in cities. Its reports that about 21% of the surveyed cities have convenient access to public spaces (9). The integration of this important issue is found in the DOP family 5. The second component discussed earlier, open spaces, can be measured using the indicators of the DOP family 5. Achieving Soft city thus helps to address the key issue of mobility, using the street component, and open spaces, using the public space component. These two derived components form the basis for the formulation of the prototypes Green Network.

Figure 7.1 Bike Taxi of Quelimane "Cycling in Quelimane is more than a mode of transport it is a tool for social cohesion; it is our identity."

7.1.2 Situation in Quelimane

A Quelimane currently aims at becoming the spear head in sustainable transportation in Africa. The city leadership has sort to improve the softness of the city with use cylciing. The advantage Quelimane has is the cultural preference of this mode of transportation. According to TUMI initiatives report on Wuelimane, plans have been made to connect the city with dedicated ccyleing routes. It thus fitting to say the city is really seeking to demonstrate how cycling can be implemented in African conxtext.

The population of Quelimane have been living a relatively low carbon lifestyle by the international standard.(Figure 7.2) The distribution of transport modalities can be a first place to look to understand the city's dedication to such low carbon lifestyles. This is a plus and is demonstrated in the modal split of transport in the city.(Figure 7.3)

Tumi reports that over a third if journeys taking place in quelimane are by bicylces. The report attributes this success to the unrelenting efforts of the mayor to improve and maintain the bicyle culture. The mayor is also admits that to Quelimane, Cycling is more than transport, but rather a tool for social cohesion. This realiazation true points that softness in quelimane is on a rather good stance.

Another reason for the popularity of bicycles in the city can be attributed to the nature of the terrain in the city. The city is relatively flat, this was even clear observed during the IMM analysis. Relating to the terrain also is the state and size of streets. The city has a predominant narrow and unpaved street. Access in these areas is highly restricted by nature to bicycles and walking.

Finally the city's admiration and preparation of cycling can also be attributed to the wide range of bicycle related business. Theses business although small in sizes provide a means of supporting the bicycle economy. This economy is reportedly dominated by the Nigerian, Indian and Chinese nationals. The economy has ensure the read availability of spare parts and repair shops across the city.

Despite these positives there exist a number of factors that threaten the longevity of this culture. This was observed in 2016 -2017 when bike ownership reduced by 3%. Foremost of these is the lack of Bicycle lanes. This has lead to cyclist share roads with fast moving

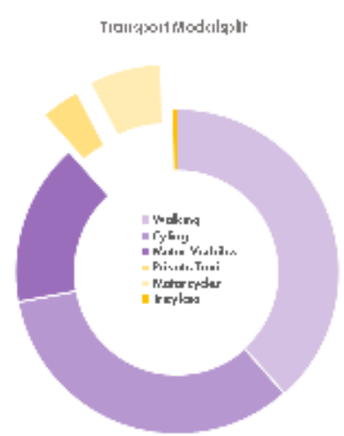


Figure 7.2 The City of Low carbon lifestyle

Figure 7.3 Modal Split of Transportation modes in Quelimane

Figure 7.5 Formalizing the Bike taxies of Quelimane

and dangerous vehicles. The situation is further worsened by the erratic behavior of bicycle taxi operators. Also the unavailability of bike storage whether cover or not leave has increase the rate of theft and thus inconvenience of bicycling.
With all these mentioned, it would be unfair not to point out the city's ambitions and measure being taken. Currently the municipality has taken steps to monitor and regularized the bike taxies. To handle this, the Association of Taxi Drivers and Bikers Zambézia (ATAMOZ) has been engaged in a process to register and license them since 2017(Figure 7.5). The aim to improve the driver behavior by enforcing compliance with road laws. The city also currently has plans to connect the markets and other commercial zones by bicycling routes. Within this plane exists the initiative to install biking equipment's, and services. They also hope to compliment the initiative with tree planting on the sidewalks.

Green Network

As mentioned earlier, the components of the green network are needed to soften the city or the neighborhood. Within the context of the streets and open spaces there are different elements that would help to make them highly efficient in softening the city. The prototype would thus be discussed in terms of its components. Following this discussion, a set case studies would present..

- The street

Streets are formed when groups of enclosures are assembled. [8]. they are the in-between of the groups of enclosures. A good street network encourages movement, communication as well as connection. The street is an important component softness which is key to the establishing a community [7]. But street come in different widths and sizes to accommodate diverse uses. Street would be soft and thus sustainable, if they improve walkability, cyclability and good public transportation [7].
Walkability Jeff Speck mentions that people won't walk unless the walk serves some purpose (5). Walkability is encouraged if activities are within reach. Thus, locating activities within a reachable and comfortable walking distance can go a long way to improving the walkability. However, if there is a purpose but little or poor streets the people would prefer the freedom of the car. Walkability can is dependent of the connection and the quality of the street. In other to be walkable, streets should connect purposes or function within acceptable distances of time. Streets quality depend on the nature of the abutting building setback, heights, frequency to entrances and the presence or absence of windows. (2) The analysis of cities like Venice, los Angeles ad Portland that streets of typically 60m block tend to encourage walkability (5).
Provision of sidewalk should be to accommodate the movement and stops of people in a comfortable way. Although this is required, providing a rather lager and over accommodating sidewalk is not preferable. Speck reports that people enjoy a tight squeeze. And as such Speck suggests 1.5m to 1.8m for sidewalks. A typical urban sidewalk has three major zones: zone one is mainly for walk and talk, zone two is for the tree and perpendicular benches and finally zone 3 is the in transitional area to the shops (5). Each zone's function improves on the quality of the street. The trees of zone one complements walking are by providing a shade. Due to the presence of trees in zone two, a permeable surface is required. The shade provided here by the trees of zone on give the possibility to position benches and other functions in between the trees.
Experience is important in the design of street network. If longer distance may feel shorter when the experience is good (4). As softness requires connection humans, providing an enhanced experience would lead to increasing the perception of walkable distance. This in turn goes to improve the walkability. Experience can be achieved using trees, rhythm, public art and theme (5).
Creating an experience with trees requires consistency. Attention must be given to plant spacing, tree canopy, altering species, alignment and final growth of the trees. A study on trees in Beverly Hills showed that shops within these zones earned about 12% more income (5). This can attest to the fact that the provision of trees most likely increase the shopping experience thus more shoppers. Other studies have been reported to have linked trees to prolonged life, reduction in asthma, obesity, stress and heart diseases (5). (Figure 7.6)

Figure 7.4 Strøget street in 1962

Figure 7.6 Lining streets with trees to increase experience

No two humans would have the same taste of building façade, a variety of facades tired in by a single or multiple rhythm goes a long way to reducing the boredom and increasing the experience of the street. Rhythm of the façade that form the street are important because Humans prefer signs of humanity to be attracted to places (5). Humanity can be expressed in rhythm and limited repetition. Repetition is Limited when vertical layering is considered for the block other than stacking (8).

Figure 7.7 Creating and Improving Cyclability

Cyclability
Cyclability offers the freedom of speed at healthy and lower energy cost. Bicycle infrastructure is essential for the higher cyclability(Figure 7.7). In Copenhagen, identifying and locating the infrastructure has been done considering its ingredients of bike success; city life, comfort, travel time and security (4). This recipe puts cyclist at the forefront of the campaign towards sustainable and softer cities.
City life: The city aims at making cycling a part of city life. To promote this new lifestyle, it invented new cycling trends like Cargo bikes, the bike thru parks and shopping. These new cultural shifts have helped the cycling economy boom. This has led to 17% of families owing a cargo bike and 34% of shopping trips being done by cargo bikes. Furthermore, Multifunctional streets have been introduced to act as bike lanes in the rush hours and as sidewalks in the off-peak hours. These shifts happened due to the efforts made make cycling a part of the culture.
Comfort: is also been improved by very simple and innovative approaches. To make cycles accessible to all, the city can partner with smaller organization to create bike sharing initiatives. Because of the expected increase in cyclist the city can make storage in the form of parking available to all. In Copenhagen,

when citizen was not using the bike racks and parking the city further introduced the bicycle butler project (4). In fact, comfort can also be increase for cyclist when the appropriate roads and made available. On these roads' simple rails and footrest at the stop signs or strategically placed pumps also can help to improve on the comfort (5).

Travel time: Cycling would highly preferred if it offers a short and quicker means of reaching a destination. It is also more preferred if equally give the rider more choice and freedom. Different types of lanes and routes may create to support choice and speed. Copenhagen again is a fine example. The city has the green routes; which move past the green areas and provide more scenic and relaxed cycling experience ;the blue routes which are more fast paced and within vehicular track areas;(4)The city plans to add new modes of bike transport highspeed and families. Such alternatives allow for more alternatives of travel time.

Sense of Security: Security is highly valued as it provides the people a higher incentive to switch the mode of transport.as the saying goes, there is strength in numbers. Concentrating cyclers onto specific routes increases their safety (5). In concentrations protection is easy to provide for cyclist. Cycling Boulevards can be adopted to increase concentration and thus protection.

Public transportation.

Public transportation is key to connect humans from one local area to another. The justification off a public transportation would depend on the population within the spatial limits of the local area. Within a justified local area transportation can be improved by the urban structure and priority. A justified local area for a bus stop is suggested to 100 people per hectare. The urban structure such as a grid, linear can increase the efficiency of the transportation system. However, an efficient transportation system would not be effective if not given priority. Thus, public transport should be given priority and leverages to allow for more reliable and swift services (6).

- Public spaces

Public space consists of the areas designated for public use. They are outdoor living spaces for the people (7). Public spaces can be parks or squares. The quality of the public realm is not just the function of the overall but also the details of the activities(2).This level of detail relates to how the space establishes a direct relationship with the immediate surrounding and the people that would interact with it. A public space provides a web of connections that allow people a range of choices when they decide a local journey.

7.1.3 Case study

- Strogret – Copenhagen

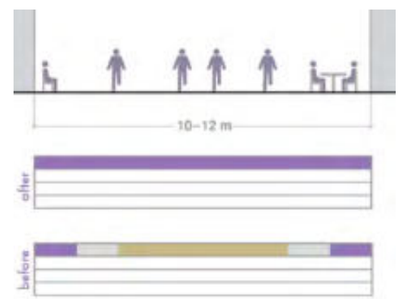
The pedestrianization of Copenhagen began with the city's main street, Strøget, which was converted in 1962 as an experiment. The conversion of the 1.15 km-long main street into a pedestrian street was seen as a pioneering effort, which gave rise to much public debate before the street was converted(Figure 7.16). "Pedestrian streets will never work in Scandinavia" was one theory. "No cars means no customers and no customers means no business," said local business owners.[global designing cities Initiative]

Soon, Strøget proved to be a huge success, with businesses realizing that traffic-free environments provide increased financial revenue. Magasin Torv, the square by Nikolaj Church, and Gråbrødre Torv were the first squares to be renovated.

The pedestrianization of Strøget highlighted the potential for outdoor public life in Denmark, as Danes never before had the room and the opportunity to develop a public life in public spaces. This pedestrianization created peaceful, yet lively, public spaces. Strøget also proved that pedestrian streets can increase revenue for local retailers.

Strøget has been renewed and upgraded several times during its 53 years as a pedestrian street, by using progressively better-quality materials, repurposing public spaces and plazas to increase pedestrian comfort, and adding outdoor uses.(Figure 7.10)

Figure 7.8 Strøget street section and transformation phase and Strøget street after transformed to pedestrian street



7.1.4 Soft-Prototypes

Soft prototypes were extracted from the idea of connected Green spaces. The diagram below also shows the relationship between soft and mobility which can be achived through greennetworks. The soft intervention intended to connect the existing pedestrian streets in more inclusive way for the users. Trees and green areas will be incorporated as they create a defined paths, shades, and also activate the existing biodiversity.

The other important soft intervention is introducing defined transport routes and increase bicycling in the city. The pedestrian routes would be having sitting areas to socialize and enjoy the journy by the peoples. As cycling is a culture in Quelimane, the soft interventions such as sitting areas, bike repair cafes, bikeapp and separated bike lane would help to maintain the character of the city(Figure 7.15).

Figure 7.9 Soft with mobility relationship.

Figure 7.10 The pedestrain street of Strøget

7.2 Multilayer

After the CIAM meeting in Athens of urban planners in 1931, Planners embraced the idea of functional cities. This idea stipulated strict zoning of functions in the urban planning. The result? Cities were gradually focused on buildings rather than around people. It leads to monofunctional and freestanding buildings and neighborhoods. The effects of this idea were noticed and in about 65 years after its implementation a new meeting was held. The 1998 CIAM basically stated that multifunction should be encouraged.

The idea of multilayering goes one step ahead of merely mixing function by planning juxtaposition. Multilayer considers the introduction of different function to buildings at medium to higher densities. This approach seeks to consecrate people and functions thus promoting walkability (5). Multilayering depends on the ideals of density but low height blocks. It seeks to move away from stacking functions to layering, from mono functioning to multifunctioning, widespread to concentrated and walkable and from large scales to smaller scale. It's based on addressing the issue of humanity and scale of the activities.

Cities and Neighborhood

Cities can be considered as either magical machine or an organic metaphor (6). These metaphors are accompanied by urban planning concepts. Greek roman and Egyptian cities viewed the city as a machine. The Nigerian Hausa tribes viewed it in the magical sense. The organic approach has been to look at the structure into communities of self-sustained units for sustainable life (6) the organic view of the city seeks to promote the cooperation rather than competition. The organic metaphor of the city is more in line with the thinking of a multilayered approach.

Neighborhoods comprise a mix of uses and not just houses (7). It is the one area that allows a housewife to walk to shop or the child to walk to school safely without having to cross major traffic (6). The neighborhood can also be within the spatial limits of 800m walking distance to the center. Understanding the neighborhood in this light the very complexity way of human activities. By creating neighborhood in this way, we allow for a social integration (7). With the mixing activities, there comes the need for more people to use them. It is therefore advantageous to increase the densities. By doing so, we also tend to increase the possibility off encounter and bring people closer to useful things and places (8). From the cost per capital point of view also, it is obvious that increasing densities and bring people together also decreases cost. Now people would be closer to their jobs and shared spaces. This whole social integration and interaction bring the sense of belonging, the sense of a community.

Blocks

Blocks make up an essential part of the multilayered approach. Blocks in themselves create clusters of buildings and functions. However, the size of blocks can be a deterrent to softness. Cliff Moughtin suggests blocks of about 70 to 100m as ideal for blocks to give permeability (1). In other studies of existing blocks, it was found that 60m blocks typically encourages softness. (5). These point that walkability can be predicted using block sizes. And since block size predicts walkability, it is fair to say that blocks building communities. As a thumb rule Speck further suggests a maximum of 300m of perimeter for blocks. Blocks can be created either by Enclosures or Joined-up. After their creation, they are layered with activities.

Enclosure: this urban pattern is composed of groups of buildings that are typically built on the edge of the property and form an inner enclosure. (8). This is a rather historic approach that has been utilized to create people centered cities. The inner enclosure can is mainly a private controlled space for the residents. Its uses mainly rest in the hands of the residents. Ancient examples of this planning form are the HUTONG of china. A more recent and rather exaggerated form is the HOF residence of Austria.

Joined-up: This approach is more organic and sympathetic as it rehabilitates and regenerate the city by joining. Use a system where the plots of land a rather divided into smaller pieces of land. These smaller pieces are then inter joined on their sides. This in turn reforms a new form of enclosure. Peculiar to this form is that each building is of different owners and thus there is variety in the design of the individual houses. The key principles to joining these buildings is to have at least one edge to the street and individual entrance as well as firewall. These features would ensure the independence of each building overtime. Identification of the regeneratable homes can be done using a hard and soft classification (6). Where the residents are unwilling to join in, they may be classified as hard. These may become soft when the owner dies or moves out or better still has a change of mind.

Layering of Activities

As mentioned in the earlier, multilayering has to with diversity of activities and density. With the blocks created, activities are now considered for the various spaces that are made available. As a neighborhood has been formed by the blocks, it's possible to consider anchor functions that are basic requirement for neighborhoods. The urban task force suggested that within a population of 2000- 5000 people a primary school, doctor, corner shops, public house and groups of shops are reasonably required (7). In their suggestion they considered a walkable radius of 600m from the core of the neighborhood. Sim also suggests the following possible function within the neighborhood; family house, special needs home, office own door, workshop, childcare, healthcare, showroom, salon, fitness and the specialist shop.

7.2.1 Multilayer-SDG-DOP

Multilayer seeks to provide functions integrated into the residential blocks. This has a direct relation to the SDG goal 11.1. The SDG's 11.1 seeks to ensure adequate, safe and affordable housing, basic services and upgrade slums (9). This goal entails extra relations to SDG goals 4.A,1.46.1 and 6.2. These goals entail services and that the UN aims to address in the coming years. The DOP integrates these goals into the DOP families 1,3 and 12. These families provide detailed indicators that would allow a better understanding of the effects of the implementation of the Multilayered approach. The prototypes selected for the approach Affordable housing, schools and community hubs.

7.2.2 Multilayered Quelimane?

Quelimane has very low number of multistory buildings and thus lower levels of multi layering. The densities are widely spreading horizontally. This dispersal has rather decreased in some areas the available land. The Urban form within the city cannot be limited to a grid. This is the case because different areas show different distributions and morphologies of the built area. Within the study area, two major urban forms where identified.

The grid forms

The grid areas demonstrated to be more formally organized. Street patterns either formed regular block of polygons for the volumes. The land demarcations and distributions where very clear and strict in such area. Distances between buildings of these neighborhoods were within 5 – 10m. The maps also suggested a that these neighborhoods where highly vehicular friendly as well. The observations pointed that it was highly probable that such areas had higher income earners.

A variation of the grid was also noticed. This variation occurred to be larger blocks of relatedly longer lengths and less squarish.

Figure 7.11 The grid forms in Maputo, Mozambique

The spontaneous Urban forms

The spontaneous areas where characterized mainly by houses of smaller sizes and lesser spacings. The distances between buildings were sometimes ass low as 1m. these neighborhoods by their morphology showed little concern for a formalized growth like grid. Rather it easier to noticed that these areas have a gradual organic growth towards available land. These neighborhoods although tightly nit together,

Figure 7.12 Grid Vs Spontaneous urban forms

showed signs of mixed activities within the groups of building.
Major streets break these volumes apart to allow for some form of vehicular access. The in-betweens of the buildings are believed to be passageways. This was a conclusion made based on similar examples in the spontaneous neighborhoods of Maputo. Residents use the allies created by the closely-knit buildings as passageways

7.2.3 Case study

- Adabraka-Accra, Ghana

Adabraka is one of the bussiest areas in Accra due to its proximity to the central business district. It is famous for its virbrant markerts and livily streets. Adabraka is charactereised by very formal and strict Square and linear grid street networks. The Kwame Nkrumah Ave is the widest street within this area. It is three lanes one way Avenue that connects directly to the Central business district. On the flanks of this major avenue are a series of one-way streets with on street parking that make up majority of the blocks.
Residential blocks of this area vary largely in levels. However, the single level structures. (see figure 7.8 below) These are multifunction buildings. On the street level within a block, function is integrated onto the sides of the street. The functions range from small scale tailors, boutiques, food vendors to grocery shops. This wide array and mix of functions enable a continues interaction of people within the neighborhood. The proximity of functions within the area is very high. Because of the rather high price of land in this area, spaces for rent are reduced to the essentials. With this reduction in space to let ahs lead to rather

Figure 7.13 Ariel view of Adabraka- Accra, Ghana

denser neighborhood capable of utilizing the various functions.
Blocks within the profiled area of were typically 60m wide and 130m long. Within the 60 m width two buildings should ideally be positioned. This would have created an open space between both plots of land. On the contrary within the block it is noticed that residents have improvised by adding up newer smaller structures for accommodation. This thus has reduced the size of open spaces within the blocks. However, this approach has enabled the increase in densities. Also, with the introduction of the inner building's residents have created smaller pedestrian inner allies. With this innovation, vehicles can access the main property from the main street while highly pedestrian friendly route is created for easy movement. (see figure below)
Due to the reduced internal open spaces, the streets have become a form of urban room that is used during off peak hours for extra activities. Typical of these activities are: Closing off streets for funerals and occupying parklets for domestic activities.

7.2.4 Multilayer-Prototypes

From the above mentioned ideas, it was possible to formulate major prototype which activates the concept of multilayer. In this case, affordable housing is selected as a prototype to facilitate the solution to be given for the slum areas. The smart housing prototype is not only limited itself as dewelling but also contained commercial activities when it faces the streets which helps the area to be multilayred.

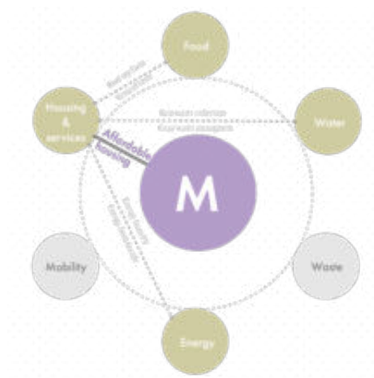


Figure 7.14 Multilayer to housing and services relationship

Figure 7.15 Street axis in Adabraka, Accra

7.3 Agritecture

As cities grow and urbanized, the amount of food consumption increases dramatically. Many cities in our world import food from different places while others produce food near the destination places. This fact clearly shows that transportation is the bridge between food and our mouth. ''For instance, in 1989, over 57% of Cuba's caloric intake was imported from the Soviet Union. When it collapsed, Cuba became, virtually overnight, solely responsible for feeding its population – including the 2.2 million in the city of Havana.'' [1] The story of Cuba offers us the knowledge that becoming dependent on transport to receive food can get into a serious of problem for a city, which gives as a glimpse for the idea cities produce their own food, moreover, in many cities the urban dwellers have no idea on the process of food production or distribution. In her TED Talk, Carolyn Steel, author of Hungry City, explains this situation "The typical Urban Dweller today has no understanding of where or how food is produced/distributed. We have become dependent on huge, powerful, profit-minded corporations to bring huge quantities of food from industrial farms into our supermarkets – but the entire process is hidden, massively complex, and, ultimately, unsustainable." [2]

Based on the above-mentioned ideas, the coined word AGRITECTURE, comes to play its relevant role in our cities today. Most cities have been built without ''food in mind'' concept, however, buildings are now integrating spaces like roof top and facades to grow food. The concept of AgriTecture is to utilize the architecture not only for habitable spaces but also to produce food. By designing our buildings, cities, public spaces, schools and any civic functions with food in mind, we can make our cities food producers and make food part of urban life process by eliminating the physical barrier between food and us.

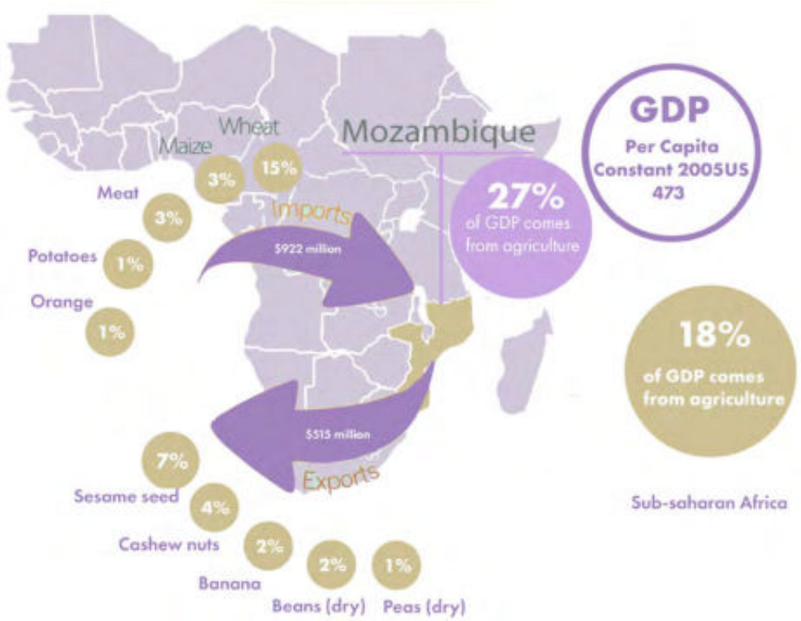


Figure 7.16 Economic relevance of agriculture in Mozambique.

7.3.1 Agritecture -SDG -DOP

An estimated 821 million people – approximately 1 in 9 people in the world – were undernourished in 2017, up from 784 million in 2015. This represents a worrying rise in world hunger for a third consecutive year after a prolonged decline. Africa remains the continent with the highest prevalence of undernourishment, affecting one fifth of its population (more than 256 million people). Consistent with the continued growth in undernourishment, 770 million people faced severe food insecurity in 2017 [3]. As mentioned earlier, cities should have the capability to produce food and attain the idea of food security for the citizens. This can be accomplished through different strategies such as utilizing the architecture and community open spaces to produce food. The UN SDG also states the fact that ending hunger and promoting sustainable agriculture together with food security as its second goal to be achieved by 2030. Moreover, the target 2.3 states that doubling the volume and the incomes of small-scale food producers and target number 2.4 explains about sustainable food production systems and implementation of resilient agricultural practices to adapt with climate change, drought, flooding, extreme weather conditions and other disasters. On the other hand, DOP 11 (Food management) is strongly connected with SDG 2 which again fostered by the idea of Agritecture as a tool of intervention for different study areas.

7.3.2 Climate-Smart

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address trade-offs and synergies between these three pillars: productivity, adaptation, and mitigation [4].

- Economic relevance of agriculture

The agriculture sector is a mainstay of the country's economy, accounting for approximately 79% of total employment and contributing an annual average of 18% to the Gross Domestic Product (GDP) (5). The sector also plays an essential role for women's livelihoods, as 90% of the economically active female population earn a living from agriculture. Moreover, women constitute 61% of the agricultural labour force. Over 80% of the cultivated land is used for production of staple crops [6]. A limited number of commercial farmers invest in export-oriented crops including tobacco, cotton, cashew nuts, prawns, sugar, and timber. Commodity price volatility and global market fluctuations have a significant impact on Mozambique's commercial agriculture and economy.pillars: productivity, adaptation, and mitigation [4]

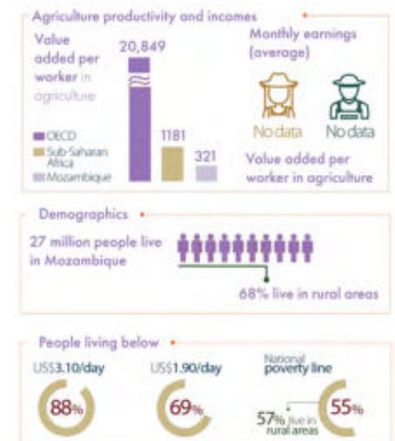


Figure 7.17 People,agriculture and livelihoods in Mozambique

- Agricultural production systems

Agriculture is mainly rain-fed and small-scale, with average farm size estimated at 1.2 hectares (ha). Roughly 72% of the farmers in the country work on farms that do not exceed 2 ha, using limited amounts of purchased inputs and practicing slash-and-burn

extensively. Small-scale farms are concentrated in the province of Zambezia in the central region, which also has the largest land area under agriculture (approximately 1 million ha). [7] Livestock production is also small scale and plays an important role in their livelihoods, food security and nutrition. The most common livestock types include cattle and goats, reared largely in Tete and Gaza provinces. Approximately 2.3 million households raise poultry. In the northern parts of the country, livestock production is challenged by animal disease incidence, such as African Animal Tripanosomiasis (AAT), which causes anaemia, weight loss, emaciation and sometimes death of cattle.
The fisheries sub-sector plays a crucial role in Mozambique's economy, supporting the livelihoods of about 380,000 small-scale, artisanal fishers. Only 2-3% of the 39,550 boats (39,550) owned by artisanal fishermen are motorized [8].

- Food security and nutrition

Mozambique was one of seven to achieve the MDG 1c target of halving the proportion of people suffering from hunger and undernourishment by 2015 [9].
High levels of rural poverty, low household purchasing power, limited access to markets, high post-harvest losses and weather-related hazards (droughts and cyclone-induced floods) continue to put significant pressure on food and nutrition security and of the population.
Access to clean energy for cooking is limited to only 4.4% of the population. Despite the associated health and environmental impacts, 78% of households use wood fuel as a main energy source, with average consumption estimated at 70 kilograms per week [10].

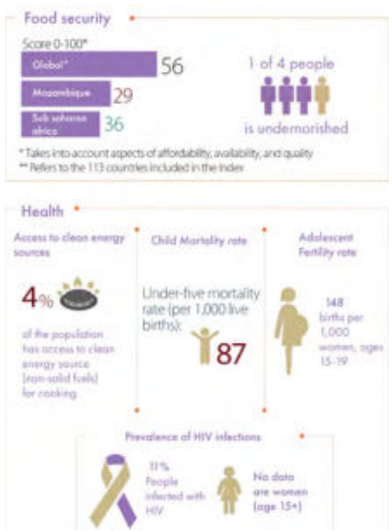


Figure 7.18 Food security, nutrition and health in Mozambique. source Climate-Smart Agriculture Mozambique

- Challenges for the agricultural sector

Limited mechanization and the use of traditional tools for agriculture also hinder production and productivity. Most farmers still use hand hoes or ox-drawn implements in their daily farm activities.
Another major challenge is the underutilization of available irrigation infrastructure as well as of the irrigable land (estimated at 3 million ha).
Arguably, the greatest challenge to the agriculture sector is the country's exposure, vulnerability, and susceptibility to highly variable weather, as well as climate-related hazards, particularly droughts and cyclone-induced floods.[11]

- Agriculture and climate change

Mozambique is among the most vulnerable and least prepared countries about natural disasters, ranking 153 out of 178 nations on the Global Adaptation Index (ND-GAIN), with a score of 38.67[12].
Over the period 1996-2015, climatic hazards such as droughts, floods, and cyclones generated economic losses of approximately US$ 790 million. Mozambique's coastline, which extends over 2,700 km and where half of the country's population live, is affected by tropical cyclones which occur at varying intensity at least once a year. In 2000, Cyclone Eline brought about record levels of precipitation, resulting in floods which, cost the economy an estimated 20% of the GDP. A 2009 estimate of drought and flood costs indicated average annual losses of maize and sorghum of 9% and 7% respectively [13].

7.3.3 Urban agriculture in Quelimane

As population grows into the rural and peri-urban areas surrounding the city, environmental impacts from increased food production include devastation of mangrove areas and an in-crease in food waste in markets. At the municipal level the priority is to build the resilience of the city and at the same time support food production for food security. Therefore, as a member of ICLEI-RU-AF CITYFOOD project and as a signatory of the Milan Urban Food Policy Pact, the Municipality of Quelimane launched an initiative in support of intensive food production in small fields owned by family households using only organic fertilizers. Institution of organic pro-duction practices laid the foundation to produce compost from food waste. Waste management and reuse has the potential to reduce the spread of diseases among the population and to curb malnutrition, increasing household food production [14].

Within the project "Quelimane Limpa" food waste is collected from 11 markets within the municipality and taken to a compost-making facility. Here, four Community Associations, composed of about 32 members each, are provided with training and involved in the com-post-making process. Compost is then distributed to 140 gardens, where different types of vegetables and food crops are grown and then sold in the markets. Thanks to the use of compost, the farm-ers obtain high quality yields and at the same time preserve the soil structure. This process enhances the development of micro to small-medium scale entrepreneurs, leading to processing, packag-ing and selling of different food products. With 128 people involved with their gardens and considering that each household has about 5 family members, the number of people directly involved can be esti-mated to 700. Furthermore, the initiative fosters the production of food consumed within the city, comprised of about 450 000 people [14].

Figure 7.19 Agriculture input use in Mozambique. Source Climate-Smart Agriculture Mozambique

- Community garden

A community garden is a single piece of land gardened collectively by a group of people. Community gardens utilize either individual or shared plots on private or public land while producing fruit, vegetables, and/or plants grown for their attractive appearance. Around the world the community gardens can fulfil variety of purposes such as aesthetic and community improvement, physical or mental well-being, or land conservation. (15)
Community gardens may help alleviate one effect of climate change, which is expected to cause a global decline in agricultural output, making fresh produce increasingly unaffordable. Community gardens are also an increasingly popular method of changing the built environment in order to promote health and wellness in the face of urbanization. Advocates say locally grown food decreases a community's reliance on fossil fuels for transport of food from large agricultural areas and reduces a society's overall use of fossil fuels to drive in agricultural machinery. (15)
Community gardens improve users' health through increased fresh vegetable consumption and providing a venue for exercise. A fundamental part of good health is a diet rich in fresh fruits, vegetables, and oth-

er plant-based foods. Community gardens provide access to such foods for the communities in which they are located. Community gardens are especially important in communities with large concentrations of low socioeconomic populations, as a lack fresh fruit and vegetable availability plagues these communities at disproportionate rates. (15)

Neighbourhood gardens are the most common type that is normally defined as a garden where a group of people come together to grow fruits, vegetables and ornamentals. They are identifiable as a parcel of private or public land where individual plots are rented by gardeners at a nominal annual fee.

- Urban Farming

Urban gardens can occupy a multitude of places and have varied scales - window sills and balconies, slabs and vacant lots, courtyards of schools, public parks and even unlikely places, such as subway tunnels. They can also be communitarian or private. Whatever the case, it is important to consider some variables:

Area: When designing a garden, reserve space not only for planting, but also for storing materials and tools - and maybe even for a compost.

Sun: Vegetables require a lot of light to grow healthy. It is recommended that you get at least 7 hours of sunshine a day - ideally 11. Some plants survive in less sunny places, so do a search and see which ones fit the best location available.

Water: Vegetables also need a lot of water to grow healthy. Make sure the place has access to quality water and in good quantity.

Drainage: Soaked grounds can delay the growth of plants or favor the emergence of diseases.

Winds: Even plants adapted to the cold do not accept strong and cold winds. If the site does not have a wind barrier, try to introduce windbreaks - such as through planting of shrub plants.

Species: Cultivating plants requires dedication. Some species require greater care in pest control and maintenance - such as pruning and frequent watering. Others, like some species, adapt easily to any environment. It is also necessary to consider the size of the plant: the branch of a potato would spread through a whole balcony if left unattended. (16)

- Spaces for food

Figure 7.20 Women on farming in community garen in Zambezia, Source celim.com

Land/public areas Urban community agriculture often occurs on empty land - private or public - or in areas such as squares, parks, schools. Some municipalities offer fiscal and legal incentives for the use of public, private and rural urban land for agriculture. Increasingly, city halls have been adopting this practice to meet a demand from the communities and offer a differential to improve the quality of life in the city, contributing to the urban requalification, the environment and health. (16)

Roofing of buildings Roof farming allows the use of spaces that would otherwise be underutilized. Green ceilings reduce urban heat by absorbing solar radiation and reducing rainwater pressure in sewage systems by absorbing rainfall. Plants can benefit from greater sunlight. Roofing can be done in raised beds or in pots. (16)

Intensive and Extensive Green roofs (Roof gardens) "Intensive green" roofs have a higher weight and require a minimum soil thickness of at least 30 cm compared to the 5-12 cm of the latter. For roof gardens, an extra load of 400-750 kg/m2 on the structure of the building must be accounted for, compared to the 60-250 kg/m2 of the "extensive green roof". In "intensive green roofs" an accessible garden is created, which requires suitable irrigation and maintenance. In "extensive green roofs" small plants are grown, which withhold the soil, they are not accessible, but the amount of maintenance required is lower and the irrigation system simpler [17].

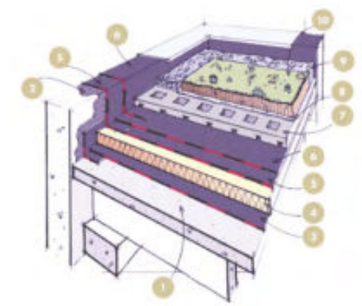


Figure 7.21 Intensive Green roof (left). (1) support (2) Ecover (3) polyster (4) Defend polyster (5) draining layer (6) filtering layer (7) soil

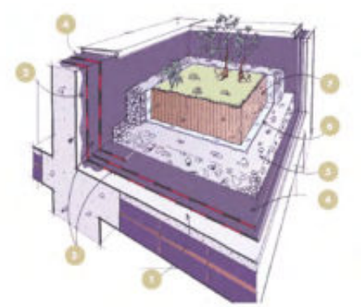


Figure 7.22 Extensive Green roof (right). (1) support (2) Indever (3) Vapour barrior (4) thermal insulation (5) Polyester (6) defend antiradice polyester (7) draining elements with water reserve (8) filtering layer (9) perimeter drainage (10) soil for cultivation

Hydroponics is the technique of growing plants without soil, where the roots receive a balanced nutrient solution that contains water and all the nutrients essential to the development of the plant. the popularity and mass integration of hydroponics is new. Many consider the mass use of hydroponics as the future of agriculture. This is because recent studies on hydroponic agriculture have shown that it has many benefits, such as producing high quality plants, occupying less space and consuming fewer resources. In addition, hydroponic cultivation methods, in combination with vertical gardening, have helped expand the possibilities of urban gardening and indoor gardening - such as vertical farms, where plants are grown inside buildings and skyscrapers, called farmscrapers. The diagram below shows the operation of hydroponic cultivation. (16)

7.3.4 Case studies

- Fish farming and Beekeeping

The main objective of the project is to alleviate the problems of malnutrition and increase the income of farming families by introducing local processing and sale of products.

The poverty and food insecurity of Zambezia originate from scarce and little diversified agricultural products, poor crop management and unsustainable rural development. The backwardness of agricultural practices, combined with extreme climatic events such as floods and droughts, result in very poor and inad-

Table 7.16 Comparison of extensive and intensive systems

Option	Extensive system	Intensive system
Weight	Lighter system owing to the shallower soil	More weight on the roof which requires a high structural capacity.
Building	Can be used on existing roofs, may require a few additional supports or not	Might call for new structural supports
Costs	Cheaper because of no or few additional load bearing supports	More expensive due to load bearing demands
Plants	Crop selection limited to species with more shallow roots (leafy greens and herbs)	Higher variety of species possible. More efficient plants growth and health because of larger soil depth

Table 7.17 Weight of rooftop agriculture systems

Roof system	Weight range (kg/m²)
Extensive system	50 - 200
Intensive system	200 - 1000
Rooftop containers	50 - 1000
Hydroponic system	20 +

equate crop yields. The "cut and burn" practice, used to fertilize a plot of land, is a very common practice that eventually leads to land impoverishment and desertification [18].
Agricultural production is based almost exclusively on rice, corn and cassava. The nutritional power of the latter is very low. Moreover, the post-production processes of crops are not adequate, and this prevents the development of on-site trade and export: production is only just enough for subsistence.
Fish farming and beekeeping are present, yet little developed. As far as the first one is concerned, the supply of feed is greatly hindered by transport difficulties and high costs. On top of this, the knowledge on conservation and processing techniques is limited. As for beekeeping, honey is produced using archaic techniques and rudimentary equipment and the resulting low-quality product is therefore difficult to sell.
Lastly, the new generations, representing more than 50% of the population, do not possess the skills needed to cope with an emergency situation and do not know how to secure houses and fields nor how the available natural resources should be managed [18].
To address these issues, the intervention focuses on an increase in and a greater diversification of agricultural production. Post-production processes will also be

Figure 7.23 Beekeeping in Queliman. source Celim.com

Figure 7.24 Fish farming in quelimane, source celim.com

Figure 7.25 Greenhouse, Nayón, Ecuador

Figure 7.26 e The construction process using bamboo, wood and plastic

optimized and the ability to adapt crops to extreme climate changes will be improved. The project's key point will therefore be the creation of 300 more resistant plantations, characterised by a better yield and the smallest possible impact on the environment.
The project also envisages the consolidation of fish farming and beekeeping. To this end, 100 breeding tanks for tilapia will be installed and fish-processing ovens and driers will be built. 600 beehives will also be put in place for beekeeping and two honey processing centres will be created, which will be linked to the local Cizenda Tae Cooperative.

- Low-Budget Urban community Garden

The social design from Natura Futura Arquitectura for a greenhouse in the warm subtropical climate of Nayón, Ecuador, the proposal approaches the use of local material resources in the construction of low-budget productive structures for the development of the collective.
The project, materialized with bamboo, wood and greenhouse plastic, is based on the basic geometrical figure of the triangle, proposing sectors with different levels of illumination for different types of farming. Located in Nayón, a parish of 15,000 inhabitants, which has the particularity to have a warm subtropical climate that favors the crops; this takes advantage of the population with the help of greenhouses work with various species of both consumption and decorative, making the sale of one of the characteristics of the population, which is also known as the Garden of Quito.
The triangle of the vegetables can be seen in the distance as a ghost in the middle of the mountain;

Figure 7.27 Site plan of Grow Dat sustainable farm (top right)

lightweight, compact, transparent. Built with local materials, bamboo, wood, plastic greenhouse, taking as reference a basic geometric figure (triangle), its shape allows for multiple layers of light and shade during the day, categorizing by sector and levels different types of crops of seedlings that will feed after the orchards of the organization. (19)

- The Grow Dat Sustainable Farm

Located on a seven-acre (28328m2) site in New Orleans' City Park which operate a two-acre sustainable farm. Each year, the farm grows and harvest an average of 25,000 pounds of fresh produce. Seventy percent is sold at the farm stand and at farmers' markets (run by our youth employees). 30% is distributed through the Shared Harvest program, to low-income residents who otherwise have little or no access to fresh food. (20)

The Grow Dat Youth Farm use sustainable methods to build a resilient agricultural system. The means of producing food is by supporting natural ecological systems and stewarding natural and human resources for the future. It does not use chemical-based pesticides or fertilizers. Instead, it utilizes techniques such as cover cropping, composting, companion planting, farmscaping and crop rotation to stimulate micro-biological activity and soil health. (20)

At the Grow Dat Youth Farm, youth from across the city of New Orleans come to learn, work, earn money, and grow food that goes back out to the city; the teens themselves sell about 60% of the produce to markets, restaurants, and corner stores, the other

Figure 7.28 Integration of containers as building material (right -bottom)

Figure 7.29 Vegitable garden cultivated by the teens

40% they then donate via Shared Harvest. But it's not just the youth that make this farm come alive – it's the people of all stripes, shapes, sizes, and disciplines (architects included) that have come together for this common cause. (20)

Architecture students worked with community-members to design various structures: an outdoor classroom, teaching kitchen, locker rooms, administrative offices, a large post-harvest area.

7.3.5 Agritecture-Prototypes

After analysing the existing situation in Mozambique and Quelimane, we are able to formulate the cycle of food from production to consumption and to recycling of the waste. Food can be produced in smaller scale (rooftop farms, backyards or in school yards) or in larger scale (community gardens, community parks and farmlands) and it will be transported by Bike-food system to the food markets. The organic waste from the market and households will be collected and transported to the compost plant and will be used as fertilizer for farmlands. Rainwater collection system will also be integrated to the houses and public buildings to utilize it for farmlands and rooftop farms.

On the other hand, the team identified the relationship between Agritecture and the WWMFEH (waste,water,mobility,food,energy and housing) and the prototypes which fosters the idea of Agritecture intervention both in urban and local scale. By doing this, community gardens/farms are used as a prototypes throughout the intervention areas together with rooftop gardens. The picture below shows the primary relation ship between Food and Agritecture and the secondary connection between food with water, housing, waste and mobility respectively.

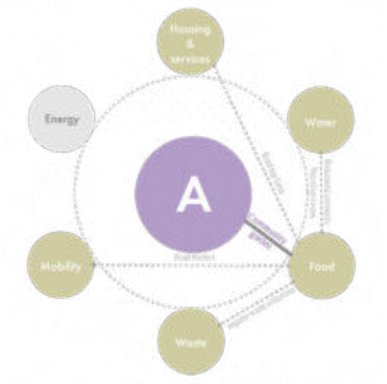


Figure 7.30 Agritecture to food relationship

Figure 7.31 Food cycle in the city of Quelimane

7.4 Robustness

• Introduction

The term robustness was one of the many new terms coined in the book Responsive Environments (Bentley et al., 1985) where it was also applied to the design of public spaces, that is, spaces should be designed to facilitate a range of activities and allow them to change over time without significant alteration to the fabric. (In this book, the term has been extended to cover the design of the city as a whole.) The concept has a close relation to the concept of the extendibility of buildings, particularly family houses. Whereas this is not appropriate for all buildings, the idea is that it is advantageous if their design allows scope for extending their size with minimal impact on both the original structure and surrounding buildings and spaces [21].

The argument on the book ''Robust city'' is that the settlement of cities regarding settlement or pattern of settlement should be responsive for the upcoming changes, in other words, there is always alteration of use, increase intensity of use, and expansion of size both horizontally and vertically. Moreover, buildings are designed to endure from 60 to hundred years also they might be refurbished or replaced however the outline of streets remain the same.

The other important idea, in the book Robust City, to be noticed is that the persistence of form. In most European countries, buildings are functioning more than 60 years which is one of the implications derived from refurbishment, repair and extension. This phenomenon reached to the point that when the buildings sustained more than the intended functionality period, it is most likely to be conserved rather than demolishing.

The problem in many developing cities is that less consideration for future expansion of urban areas which leads to the emerging of informal settlement and slums. Where there is also an increase in population or immigration from rural to urban areas the expansion of cities even become faster. The need for new buildings is also true for the developed world where the population trend may be stable or falling.

Tony Hall, the Author of the book Robust cities, on the fourth chapter of his book explains about a goal-driven approach in which it is possible to establish patterns of form by a goal-driven process. It takes to agreeing on goals without trivial matters to generate urban form patterns.

7.4.1 Urban Resilience

Cities face a growing range of adversities and challenges in the 21st century. From the effects of climate change to growing migrant populations to inadequate infrastructure to pandemics to cyber-attacks. Resilience is what helps cities adapt and transform in the face of these challenges, helping them to prepare for both the expected and the unexpected. (22)

100RC defines urban resilience as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience." (22)

Building urban resilience requires looking at a city holistically: understanding the systems that make up the city and the interdependencies and risks they may face. By strengthening the underlying fabric of a city and better understanding the potential shocks and stresses it may face, a city can improve its development trajectory and the well-being of its citizens. (22)

• Resilient Systems

In order to build a city's resilience, the systems must be designed and functioning in a way that they can withstand, respond to, and adapt more readily to shocks and stresses. The CRF builds on decades of research on resilient systems and identifies 7 characteristics that various city systems need. (22)

Reflectiveness and **Resourcefulness** are about the ability to learn from the past and act in times of crisis.Individuals and institutions that are reflective use past experience to inform future decisions and will modify standards and behaviours accordingly. For example, planning processes that are reflective are better able to respond to changing circumstances. (22)

Inclusive and **Integrated** relate to the processes of good governance and effective leadership that ensure investments and actions are appropriate, address the needs of the most vulnerable and collectively create a resilient city – for everyone. (22)

Robustness, **Redundancy**, and **Flexibility** are qualities that help to conceive systems and assets that can withstand shocks and stresses as well as the willingness to use alternative strategies to facilitate rapid recovery. (22)

7.4.2 Sponge city

"Basically, 'sponge city' is a phrase that was invented in China," says Austin Williams, an urban studies professor at Jiaotong-Liverpool University in Suzhou. "Nobody used this phrase until Xi Jinping announced it."

''The concept of a water-sensitive built environment is already established in many urban areas around the world on various scales through approaches such as sustainable drainage systems (SuDS) and low impact development (LID). China has embraced what it terms the 'Sponge City' concept because, combined with the facts of rapidly growing urban populations, poor water management and climate change, half of China's 657 cities are reported to be water scarce. Of these cities 230 were affected by flooding in 2013 alone.'' (23)

The traditional idea of managing surface water runoff in an urban environment is to funnel that water away from cities as fast as possible. Recently, however, city planners and governments are realizing that this design concept is flawed as it means that they are, to all intents and purposes, throwing away a highly valuable resource: water. (23)

The new mode of thinking is to design a city in such a way that it retains all the surface water runoff that occurs within the confines of the city and that it can be reused at a later date, thereby creating an urban environment that absorbs the water then releases that water when required—in a similar manner to a sponge. (23)

7.4.3 Case study

• water square

Benthemplein, the world's first full-scale water square, opened in Rotterdam (Netherlands). The square can retain nearly 2 million liters (528,344 gallons) of water. During dry weather, the square can host several sports, theater and relaxation activities. (24)

The city and district water board included input from local residents, including students of the adjoining Zadkine school. The URBANISTEN architects facilitated this participation process, which served as a valuable form of local cooperation. As a result, the square now hosts greener infrastructure as well as facilities for skateboarding and basketball. The Zadkine school can program outdoor activities as well. (24)

When it's dry, the concrete basin can be used as a basketball court or a soccer field. The stadium-like stairs act as seating for plays by theatre students in the school next to the park, or for churchgoers from the church on the other side. If it suddenly rains, the basin fills up with water, and then slowly releases it into the ground, giving the city's overloaded sewers a break. (24)

The park is part of a larger district that the city is making climate-proof, tearing up asphalt and concrete and replacing it with new paving that can hold water. A nearby building, surrounded by skyscrapers, is topped with Europe's largest rooftop farm—part of the city's push to cover roofs in greenery that can absorb water in storms. Already, more than 200,000 square meters of roofs have been greened. The city's network of trams winds through tracks surrounded by grass and flowers, not pavement. An underground parking garage, like the concrete park, doubles as water storage when it's needed. Ultimately, infrastructure may be redesigned so stormwater is all stored and no longer flows into the sewer system at all. (24)

Rotterdam's abundant impervious surfaces guide rainwater to surface waters and sewers. Increasingly intense rain events have overwhelmed the city's stormwater infrastructure, resulting in flooded streets and basements. The Benthemplein area was in a high-flood risk zone. However, the water square is helping to prevent floods. It is one among a host of smart solutions applied in Rotterdam, such as green rooftops, water storage facilities, and the Bellamyplein, a smaller version of the Benthemplein. (24)

"The Rotterdam approach to climate change has grown into a movement of change over the last five years. It spans everything from city improvement in the social sense and in water safety, to economic growth," said Vice-Mayor Alexandra van Huffelen. "Smart combinations and actual experimentation have rendered us successful, inside our city and all over the world." (24)

Figure 7.32 Benthemplein, water square, Rotterdam (Netherlands)

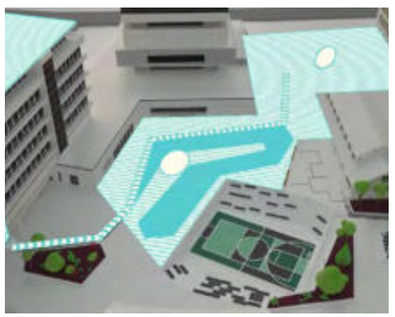


Figure 7.33 Benthemplein, water square, Rotterdam (Netherlands)

- The BIG U

BIG's proposal, The BIG U, is rooted in the firm's signature concepts of social infrastructure and hedonistic sustainability. It envisions a 10-mile protective system that encircles Manhattan, protecting the city from floods and storm water while simultaneously providing public realms specific to the needs of the city's diverse communities. Bjarke Ingels states: "We asked ourselves: What if we could envision the resilience infrastructure for Lower Manhattan in a way that wouldn't be like a wall between the city and the water, but rather a string of pearls of social and environmental amenities tailored to their specific neighbourhoods, that also happens to shield their various communities from flooding. Social infrastructure understood as a big overall strategy rooted in the local-communities." (25)

The team's approach is rooted in the two concepts of social infrastructure and hedonistic sustainability. The Big U not only shields the city against floods and storm water; it provides social and environmental benefits to the community and fosters an improved public realm. The team envisions three compartments that function independently to provide flood protection. Each compartment comprises a physically discrete flood-protection zone that can be isolated from flooding in adjacent zones. At the same time, each presents opportunity for integrated social and community planning. The compartments work in unison to protect and enhance the city, yet each compartment's proposal is designed to stand on its own. (25)

The proposal consists of separate but coordinated plans for three contiguous regions of the waterfront and associated communities, regions dubbed compartments. Each compartment comprises a physically separate flood-protection zone, isolated from flooding in the other zones, but each equally a field for integrated social and community planning. The compartments work in concert to protect and enhance the city, but each compartment's proposal is designed to stand on its own. Each compartment was designed in close consultation with the associated communities and many local, municipal, state and federal stakeholders; each has a benefit-cost ratio greater than one; and each is flexible, easily phasable, and can be integrated

with in-progress developments along the City's waterfront.

Figure 7.34 Concepts of social infrastructure and hedonistic sustainability, Manhattan, BIG Architects. (Bottom-right)

Figure 7.35 Flood protection zone integrated with public activities along the BIG U.

7.4.4 Robustness-prototypes

Understanding the concept of robustness and resillience helped the team to approach the Urban and local scale problems interms of systematic and wholistic approach.

The city of Quelimane has been facing frequent flooding and Cyclones for the past decades and will also experiance similar climate change hazardes in the upcoming events. One of the solution to adapt with the changing environment is that building the infrastracture and the way of life in a robust and resilient manner. For example, from the above given examples the city of Quelimane can learn how to manage the flood incidents by soft interventions instead of trying to resist the event.

In case of the water square project in Rotterdam, the proposal shows how to collect water to be utilized without flooding the city. On the other hand, the project in Manhattan, incoporated series of activities also being the protective shield from flooding. In this project the idea of hedonistic sustainblity is also presented which focuses on the contineous adaptation of upcoming changes with resilient solution.

In case of this research, the primary relationship between robustness and WMF (water, food & mobility) is studied. Moreover, the prototypes which will be used to achive robust Quelimane are identified. These are sponge parks, gardens including rooftop gardens and an integrated drainage systems can be mentioned.

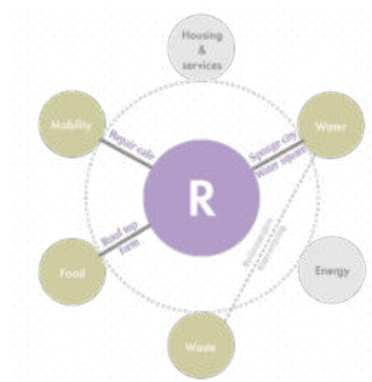


Figure 7.36 Technology to food, Mobility and water relationship

7.5 Technology

- Introduction

Waste management is a crucial process for the development of any country. The exponential growth in the urbanization and industrialization has brought the waste management issue into prime focus. The practices adopted for waste management vary across the nations as well as regions and sectors. Solid waste management encompasses some activities ranging from waste collection to waste recycling and waste reuse. These activities can make use of the technology for enhancing the throughput at each level.

Technology can play a significant role in improving this situation, by providing efficient, economical and easy-to-implement solutions for the garbage crisis. Given our large population and the enormity of waste that we generate, technological solutions are almost mandatory.

7.5.1 Technology-SDG-DOP

fight, Clay changed his name to Cassius X, and then later to Muhammad Ali upon converting to Islam and affiliating with the Nation of Islam. Ali then faced a rematch with Liston scheduled for May 1965 in Lewiston, Maine. It had been scheduled for Boston the previous November, but was postponed for six months due to Ali's emergency surgery for a hernia three days before.[61] The fight was controversial. Midway through the first round, Liston was knocked down by a difficult-to-see blow the press dubbed a "phantom punch". Referee Jersey Joe Walcott did not begin the count immediately after the knockdown, as Ali refused to retreat to a neutral corner. Liston rose after he had been down for about 20 seconds, and the fight momentarily continued. However a few seconds later Walcott, having been informed by the timekeepers that Liston had been down for a count of 10, stopped the match and declared Ali the winner by knockout. [62] The entire fight lasted less than two minutes.[63]

7.5.2 Waste management in Mozambique

In Mozambique the solid waste management sector is underperforming, a situation common to other developing countries. Rough estimates show that around 60% of the waste is not collected, as municipalities do not have the financial, human and material resources to deal with urban growth and increased production. Worsening this situation is the disorderly occupation of space, which makes access difficult and in the suburban and peri-urban neighbourhoods, the problems of urban management are at their most significant[1]. The production of urban solid waste is increasing from year to year. This phenomenon results from factors such as increase in population, market liberalisation, and appearance of products with a short life span. This situation, linked to the defects in the USW management system, has as its consequences including reduction in the useful space available direct threats to health from pathogens and indirect damage to health from pollution of the air and of ground water[1].

- Waste characterisation and generation

The government of Mozambique in partnership with Mozambican Recycling Association (AMOR) initiated a waste characterisation and generation campaign (2015-2018), funded by Denmark, Ireland, Sweden and Switzerland cooperation agencies (Dias and Socre 2014) The campaign was conducted in selected cities in Mozambique including Quelimane [1].

Waste characterization included sorting 25 categories from collection points in 4 cities, out of which the main 7 categories are presented below:

Biodegradable, Fines, Glass, Paper/Card, Metal, Plastics, Others

Waste generation rates surveys covered 96 (Nampula) and 91 (Quelimane) households, from urban to peri-urban and rural areas. 41 local assistants were supervised in their daily measures of "dry" and "wet" weight fraction segregated into marked buckets given to each household. A total of 71 samples and 18,229 kg of Municipal Solid Waste (MSW) were characterized in the 4 surveys. On overall, 43% of the MSW collected by the municipalities is Fines (< 20 mm), followed by 24% as Biodegradables and 19% as Others. The daily solid waste generation per inhabitant per day is estimated as 0.31kg (out of which 0.06 kg are dry and 0.25kg are wet) (United Nations 2017)

Municipality	Population		Annual Growth rate	Population 2013	Estimated daily MSW generation [t.day^{-1}]
	Census 1997	Census 2007			
Beira	405.040	431.583	0,7%	499.520	287,2
Cuambai	58.594	79.013	3,5%	99.758	45,9
Dondo	71.664	70.817	-0,1%	81.965	37,7
Ilha de Moçambique	43.188	48.063	1,1%	56.097	16,3
Marrromeu	18.827	39.409	10,9%	45.611	15,7
Metangula	6.852	12.772	8,6%	16.125	5,6
Mocimboa da Praia	26.132	39.010	4,9%	43.689	15,1
Mocuba	58.594	87.889	6,0%	113.308	67,9
Montepuez	54.802	76.139	3,0%	85.270	39,2
Nacala	161.460	206.449	2,8%	240.960	116,0
Nampula	310.955	471.717	5,2%	564.472	324,6
Pemba	87.662	138.716	5,8%	155.350	81,0
Quelimane	150.116	193.343	2,9%	226.768	112,7
Total	1.453.886	1.894.920	3,03%	2.228.893	1.165,0

Table 7.18 Population and solid waste generated 2013 : Source: (Dias and Socre 2014)

Although official estimates point to a variation in the annual production of USW in the country's main urban areas, waste recycling potential is around 34,700 ton/year and composting 45,500 ton/year. These figures exclude informal recycling, which needs additional research to be quantified. Dias et al, 2008 reports that households seem to be open to waste segregation and willing to collaborate in improved waste collection systems.

It is worth noting that these wastes originate from domestic activities, trade, agricultural and livestock activities, hospitals, workshops, the transport and communication sector, the building industry, tourism and recreational practices, industry and informal activities. As reported in table 1, Quelimane is the 4th largest waste generator in Mozambique. [1].

- Urban solid waste

The management of Urban Solid Waste involves various stages from production, treatment, transport, and collection to deposit. At each of these stages, the reuse of waste may occur, as a source of generating income, and in other cases of energy. In past decades, it was thought that solid wastes were materials that were no longer useful, and that it was urgent to eliminate them through various methods, such as dumping them on rubbish tips, incinerating them, or burying them, among other practices. The current behaviour of society towards solid waste, as well as the work of some authors, show that, unlike what was believed in the past, they are still a valuable resource.

- Collection

Wastes are collected in containers of 1 m3, 6 m3, 10 m3, and 16 m 3, depending on the area and number of inhabitants. The city suffers from inadequacies in the collection, deposit and treatment of USW and like most Mozambican cities, USW is not collected in the suburban areas. On the contrary, they are deliberately deposited in inhabited suburban areas, or used to fill in holes, particularly those caused by rainwater erosion. (Tas and Belon 2014b)
One common scenario seen in most of the municipalities is the lack of storage systems which causes waste scattering in streets and public spaces. Elevated community bunkers were introduced in some designated parts of the city for the temporal deposition of waste, a solution already implemented in the South of the country in 2010 (Dias and Socre 2014). One of its advantages is the confinement of waste, and the flexibility to use different kinds of collection vehicles (tractor, small or big trucks, etc) due to associated elevated deposition This implied higher collection efficiencies from the bunkers. Associated problems include the improper cleaning of the bunker site

Figure 7.37 Elevated community bunker in Quelimane

Figure 7.38 Managing the garbage container with machines

- Treatment

Mixing different kinds of solid waste in the same recipient makes recycling difficult, although it is recognised that some people do informal recycling of recipients, selecting plastic, glass and metal, often for their own use or for informal sale (United Nations 2017)
Suburban communities adopt an "informal" Urban Solid Waste management system (recycling, burying and burning rubbish). However, this system is not ideal, given that the neighbourhoods are growing, and there is no space, inside or outside the yards, for this type of treatment. Apart from this, the system does not envisage special treatment for the toxic and non-biodegradable components including hospital and laboratory waste, which can cause other environmental problems considering that USW are potential vectors for the transmission of infectious and parasitic diseases (Dias and Socre 2014)

- Transport

The vehicles used to collect USW include open tippers, compacting vehicles, to load and unload large volume containers, and tractors in the municipal districts. Observing this fact on the ground, it may be concluded that the use of compacting trucks with a hydraulic system as a means to collect and transport USW does not seem technically appropriate for certain areas of our cities due to the different perceptions and socio-economic capacities of city residents who mix together all kinds of waste in the same container, including glass, paper, organic material, and waste of varying density (Tas and Belon 2014b)

- Final deposit

The destination of USW in Mozambique consists of simple open-air rubbish dumps and the controlled landfill. In these places, waste is burnt, buried and compacted, causing a certain concern in society because:

a) The rubbish dumps are in the centre of residential areas, and the USW is transported there along public roads, used by large amounts of traffic;
b) There are no studies on the types of soil under these rubbish dumps, which may sometimes be susceptible to leaching and to pollution of ground water;
c) At the same time, air pollution may occur, caused by the fumes, bad smells, and potentially toxic particles, since the USW is not subject to prior sorting, and is burnt from time to time;
d) They are not easily accessible to the USW workers, which means that the waste may be deposited at the entrance and beside the roads;
e) Although no conclusive studies have been made into the impact of these rubbish dumps on public health, one cannot ignore the potential danger they pose, because no specific treatment is given to the USW. (Dias and Socre 2014)

- Recycling of urban solid waste

In Mozambique Recycling is the result of a series of activities through which material that would otherwise become useless waste is used again. This material is collected, separated and processed so that it may be re-used as raw material. Mixing different types of solid waste in the same recipient makes recycling or re-use difficult, although it is recognised that some people do informal recycling of recipients, selecting plastic, glass and metal. This occurs mainly at the rubbish dumps and in some areas where solid waste is concentrated in the main urban centre. Recycling is slowly gaining popularity because of the amount of waste produced and the ease of finding a market for recycled produce, either through export to neighbouring South Africa, or through sale to interested companies. The value of materials that can be recycled is unquestionable, but the capacity of Mozambican industry to absorb these materials means that this is still a limited market, where few can really make a profit. Currently in Mozambique, there are no organised forms of making use of materials that can be recycled from USW. The re-use of glass bottles, plastic, metal and other materials occurs above all at individual level or in the informal sector. There are some industries with a recycling capacity which are paralysed, such as Vidreira (glass) and Fapacar (paper). There are also companies that wish to be involved in recycling activities such as MOZA WASTEPAPER (paper) and NEOQUIMICA (glass). The National Integrated Urban Solid Waste Management Strategy, drawn up by MICOA, advocates as one of its activities the recycling of solid wastes and encourages the development of markets in recycled materials, as well as promoting the recycling industry itself (United Nations 2017)

7.5.3 Waste management in Quelimane

The municipality has the full responsibility for the current waste management through its associated Municipal Sanitation Company (EMUSA) in collaboration with the Municipal Sanitation Department, hence the only active stakeholder in the waste management. Before 5:30 every morning a team of three superiors from EMUSA goes by car through the city to determine the state at the waste collecting points and identify critical disposal sites. Then, based on their observations, the collecting routes are determined for each vehicle to cover the most critical parts first. This results in different routes every day.
There are containers placed on strategic sites in the city where residents should dispose their waste between 5 pm and 8 pm every day. However, the residents do not respect the time interval for disposal and throw their waste in the containers at any time, which contributes to bad smell and health issues. Also, there are problems associated with residents throwing the

Figure 7.39 A disposal site in Quelimane where the waste is disposed outside the container

Figure 7.40 Relationship between the Waste and the SMART

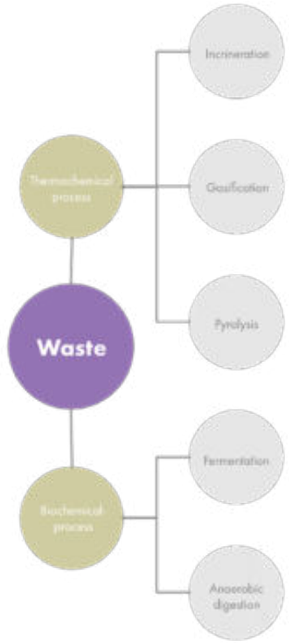
waste on the nearby ground when the containers are full, which is visualized in Figure below. When the waste is disposed on the ground rather than in the containers the waste collection becomes more difficult and time consuming. [3]
Depending on the used vehicle the method for collection and disposal of the waste varies:
A] Truck tippers: the waste removers need to use shovels to get the waste into the flatbed at the collecting points while at the dumpsite the waste is tipped out.
B] Tractors with a trailer: the waste needs to be shoved both in and out of the trailer.
C] Lifter: the truck can lift one container up on the trailer and then empty it at the dumpsite. In collaboration with the lifter a forklift is used which operates at the collecting point to put the waste from the ground into the containers. The waste removers only need to use the shovel to get the surplus waste not collected by the forklift into the containers.

7.5.4 Waste to Energy technologies

Waste-to-energy (WtE) or energy-from-waste (EfW) is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste, or the processing of waste into a fuel source. WtE is a form of energy recovery. Most WtE processes generate electricity and/or heat directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels. [4]

- Incineration

Incineration, the combustion of organic material such as waste with energy recovery, is the most common WtE implementation.
The method of incineration to convert municipal solid waste (MSW) is a relatively old method of WtE generation. Incineration generally entails burning waste (residual MSW, commercial, industrial and RDF) to boil water which powers steam generators that generate electric energy and heat to be used in homes, businesses, institutions and industries. One problem associated is the potential for pollutants to enter the atmosphere with the flue gases from the boiler. These



pollutants can be acidic and in the 1980s were reported to cause environmental degradation by turning rain into acid rain. Modern incinerators incorporate carefully engineered primary and secondary burn chambers, and controlled burners designed to burn completely with the lowest possible emissions. [5]

- Anaerobic digestion

It is a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste or to produce fuels. Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses anaerobic digestion.
Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide, and traces of

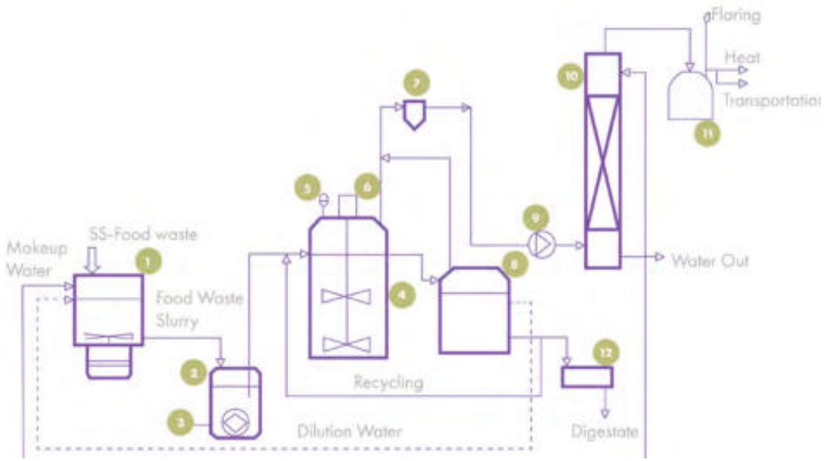


Figure 7.41 Schematic diagram of pilot scale anaerobic digestion plant.(1) Shredder; (2) Buffer tank; (3) Submerged pump; (4) Anaerobic digester; (5) Pressure gauge; (6) Pressure relief valve; (7) Moisture trap; (8) Sedimentation tank; (9) Compressor; (10).Scrubber; (11) Gas collection; (12) Final digestate collection tank Water contains in the sludge is further removed and following aerobic composting, digestate is used as fertilizer.

other 'contaminant' gases. This biogas can be used directly as fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane. The nutrient-rich digestate also produced can be used as fertilizer. [6]

- Landfill Gas to Energy

Landfill gas is a complex mix of different gases created by the action of microorganisms within a landfill. Landfill gas is approximately forty to sixty percent methane, with the remainder being mostly carbon dioxide.
The gases produced within a landfill can be collected and used in various ways. The landfill gas can be utilized directly on site by a boiler or any type of combustion system, providing heat. Electricity can also be generated on site through the use of microturbines, steam turbines, or fuel cells.[7] The landfill gas can also be sold off site and sent into natural gas pipelines. This approach requires the gas to be processed into pipeline quality, e.g., by removing various contaminants and components.[8] The efficiency of gas collection at landfills directly impacts the amount of energy that can be recovered - closed landfills (those no longer accepting waste) collect gas more efficiently than open landfills (those that are still accepting waste).[7]

- Refused Derived fuel

RDF consists largely of combustible components of such waste, as non-recyclable plastics (not including PVC), paper cardboard, labels, and other corrugated materials. These fractions are separated by different processing steps, such as screening, air classification, ballistic separation, separation of ferrous and nonferrous materials, glass, stones and other foreign materials and shredding into a uniform grain size, or also pelletized in order to produce a homogeneous material which can be used as substitute for fossil fuels in e.g. cement plants, lime plants, coal fired power plants or as reduction agent in steel furnaces.[8]

- Gasification

Gasification is a process that converts organic- or fossil fuel-based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas) or producer gas and is itself a fuel. The power derived from gasification and combustion of the resultant gas

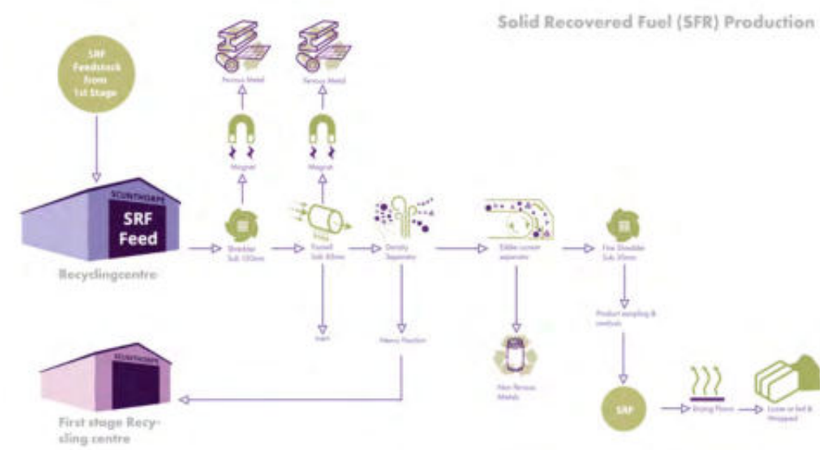


Figure 7.42 Solid recovered fuel production: source www.ellgia.co.uk

is a source of renewable energy if the gasified compounds were obtained from biomass. [9]

7.5.5 Water and Sanitation

The World Health Organization (WHO) estimates that 17 percent of under-five deaths in Mozambique (10,700 children per year) are the result of diarrheal diseases, resulting in very high child mortality (108 per 1,000 live births). Approximately 90 percent of these are caused by poor water, sanitation and hygiene (WASH) services and the provinces with the highest disease risk values are Cabo Delgado, Tete and Zambezia. [10]

Poor sanitation is also one of the key factors limiting school attendance and retention of female students. According to the World Health Organization one in ten schoolgirls in Africa miss classes or drop out completely due to menstruation.

Half of the population has access to improved water supply, and in rural areas, most people (63 percent) still rely on unimproved sources and practice open defecation (52 percent). Though significant progress has been made in improving water supply services in the larger cities, the poorest people still face several challenges in accessing sanitation and water supply services. In some of the capital cities, such as Quelimane and Tete, more than 20 percent of the population rely on open defecation. These cities are also among the most affected by recurrent cholera outbreaks. [10]

• Proposed Development by World Bank

Priority sewerage works for Quelimane, including the (i) rehabilitation and expansion of 29km of sewers, (ii) construction of a Wastewater Treatment Plant (WWTP), (iii) upgrading of approximately 2,000 existing connections, (iv) construction of three pilot condominial sewer systems to serve about 600 new connections, and (v) rehabilitation of about 10 km of small to medium scale drains to channel excess storm water and water-logged areas, and reduce the risk of urban floods.

On-site Sanitation investments in Quelimane, including the (i) sanitation marketing and hygiene promotion to influence sanitation behaviours; (ii) support to the construction and upgrade of 11,000 household on-site sanitation systems, (iii) construction of 65 public sanitation systems in schools and markets, including dedicated facilities for menstrual hygiene management; (iv) construction of two Fecal Sludge Treatment Plants (FSTPs), and (v) support to private sector on FSM business development [10].

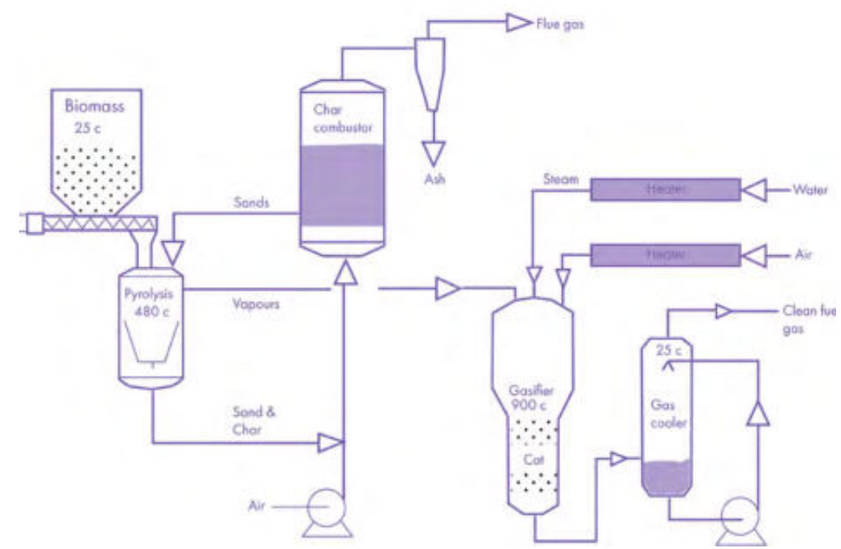


Figure 7.43 Gasification process: source www.btgworld.com

7.5.6 Case studies

• Landfill gas to energy in Thailand

The Kamphaeng Saen West and East projects ("Thailand MWE Projects") are two 8.0 MW power generation and abatement schemes located in Kamphaeng Saen district, Nakhon Pathom, Thailand. The projects involve the production of clean energy from the use of landfill gas ("LFG") emitted from the Bangkok's largest waste landfill, which is also one of the largest landfills in Asia. Approximately 50 – 60% of LFG is methane, which is a highly combustible gas that can be utilised in spark ignition engines to produce electricity. Methane that cannot be used for power generation is destroyed in enclosed flares. The two projects were registered with the UNFCCC in January 2011, and combined are expected to generate 5.2 million CERs over their lifetimes [11].

A] Landfill gas collection: High-density polyethylene (HDPE) horizontal collection pipes are connected via main carrier pipes to the LFG extraction plant. The LFG, comprising approximately 50% methane and 50% carbon dioxide is used for power generation with any surplus gas flared. [11]

B] Pre-treatment: Recovered LFG passes through the pre-treatment plant where moisture and particulates are removed prior to the power generating engines. [11]

C] Power generation units/LFG generator sets: After the LFG has passed through the pre-treatment plant the gas is sent to spark ignition power generation units. The electricity produced is distributed to the Thailand Electric Grid. Currently the project activity consists of 8 generator sets. [11]

D] Flare system: Surplus gas is destroyed by a flare system. (Visvanathan 2014). The combination of power generation and flare optimizes the destruction of landfill gas. The flare system is equipped with a monitoring system to measure flow, pressure, methane concentration and the temperature in order to comply with the tool. [11]

- Small scale Anaerobic Digester plant in Quelimane

''In order to successfully implement a small-scale AD plant in Quelimane, it is essential that the technology is inexpensive, easy to construct and maintain as well as insensitive to variation in substrates and hot climate. These factors were identified through observations on site. The plant type that was considered best for the local conditions was a balloon plant since it was the technology that met the desired criteria the most compared to other technologies. The balloon plant consists of a rubber or plastic bag that includes both the digester and the gas holder since the gas is naturally stored in the upper part of the bag. Since the bag needs to be UV-resistant, tolerant to weather and stabile, special material is required and synthetic caoutchouc or reinforced plastic is recommended. The outlet and inlet tubes are attached on the skin of the bag and to increase the gas pressure weights can be added on top of the bag as shown in Figure below. To prevent damage on the skin due to high gas pressure safety valves are required in the design. The useful lifespan of the balloon plant is between 2 and 5 years.'' [12]

For the balloon plant functioning as the small scale AD plant in Quelimane, the chosen design for the model is a Low-Cost Polyethylene Tube Digester, a design that have been successfully used in a number of countries in Central and South America.

Figure 7.44 Ballon plant consists of the digester and gas holder

- The biogas production

In order to determine the produced quantity of biogas in the balloon digester another AD plant technology was required for the calculations. This technology is developed by ARTI (Appropriate Rural Technology Institute) and is a successful small-scale AD plant which uses waste food as feedstock. For the balloon AD plant technology, there is only available data for animal manure as feedstock and not waste food. Due to this, calculation has been performed for the ARTI technology due to its similarity in the feedstock, rather than performance of technology. Therefore, data for the ARTI technology further on is assumed to represent the suggested balloon technology. The presented ratio of the input and output in the ARTI Biogas system is shown in Table below.

Table 7.19 The ratio for the fedstock for the AD digester

	Waste foodinput [Kg]	Water input [m³]	Digestate Output [m³]	Biogas output [Kg]
AD Digester	1	0.01	0.01	0.25

7.5.7 Technology-prototypes

Technology is the back bone of smart cities and it has astrong relationship with all SMART tools that has been discussed in the perivious sections.

The team focused on the use of technology for managing the waste and generating energy from it. One of the prototype in this case would be biogas digester plant in local scale.

Solar panels in rooftops and in bus stop shelters would be integrated to harvest solar power. In addition, to facilitate the transport activites Bikeapps would be suggested to the registered public transport providers.

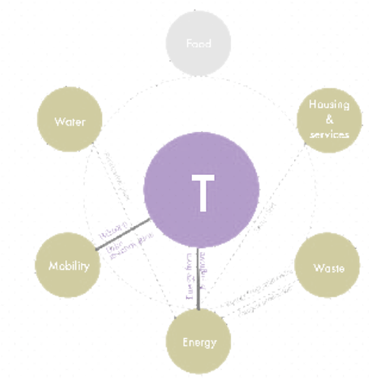


Figure 7.45 Technology to Mobility and Energy relationship.

7.6 Living Building Challenge

The Living Building Challenge is an attempt to dramatically raise the bar from a paradigm of doing less harm to one in which we view our role as steward and co-creator of a true Living Future. It aims at transforming the the act of designing and construction to an opportunity of positively impacting the community. The challenge acts as an advocacy tool and a certification program. The Living Building challenge philosophy is not limited to merely creating less negatively impacting buildings but to aims higher as positive regeneration Impacts(Figure 7.10). Living Building challenge has been impactful since its inception. Its impact on the built industry lead to its receiving the Buckminster Fuller Prize in 2012 for the world top socially responsible design award. The direction of the challenge fits with the philosophy of the project. As such some imperative can viewed on scales larger than the project. It must be noted that although the living building challenge is only administered to buildings monitored over 12 months , the project uses the challenge as a guideline and target.

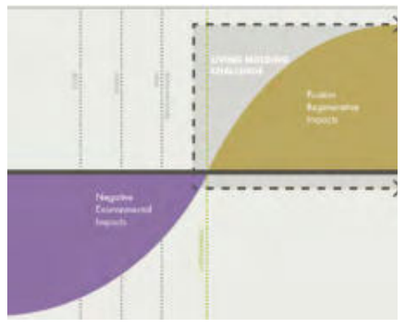


Figure 7.46 Living Building Chalellenge's aims at regenration Impacts not merely less negatively impacting buildings

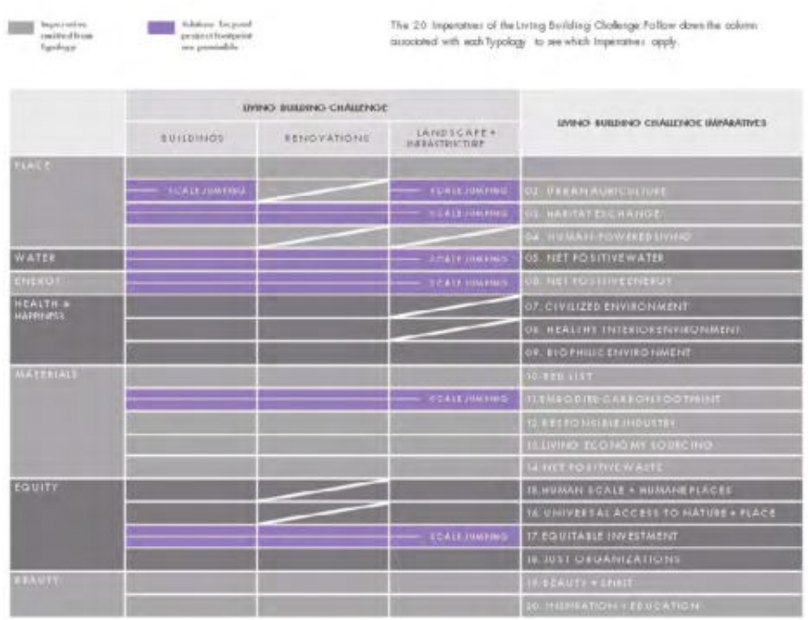


Figure 7.47 Scale Jumping table

7.6.1 The petals and Imperatives

The Living building challenge is comprised of seven performance categories or Petals comprised of twenty imperative. Achieving all the imperatives would ensure a Living certification. While the Living certification is the highest standard and may not be fully recognized, there is exists a next level of recognition for partial achievements. Meeting at least seven imperatives of the petals of which one must be either Water, Energy or Material, would secure the design a petal certification. Net zero energy certification is also recognized by the building living challenge. Its defines Net zero energy buildings whose energy needs are supplied onsite for are 100% form renewables. This certification is coupled with achieving 4 selected imperatives. The Living building challenge allow the concept of scale jumping(Figure 7.47).

7.6.2 Place Petal

The Place petal is intended to realign how people think of our impact on the environment. It articulates through the imperatives where to build, how to protect and restore a once developed area and finally to encourage the creation of communities based of people power (pedestrianize) rather than automotive. To compliment these communities, the petal promotes the local and regional agriculture for the said project.

- Imperative 01; Limits to Growth

Projects related landscape is required to either be indigenous based or imitate the indigenous. Project locations can be only greyfields or brownfields within the following sensitive ecological habitats;

- Wetlands: maintain at least 15 meters, and up to 70 meters of separation
- Primary dunes: maintain at least 40 meters of separation
- Old-growth forest: maintain at least 60 meters of separation
- Virgin prairie: maintain at least 30 meters of separation
- Prime farmland
- Within the 100-year flood plain

- Imperative 2; Urban Agriculture

The project is require to have a minimum food lot area dedicated to food production. This is taken with respect to the FAR. The potential edible strategies recognized by this imperative include live stock, hydroponics or aquaponics, aquaculture, raised beds, in-ground cultivation, vertical gardens and rooftop gardens. Below are the minimum and recommended requirements(Figure 7.48).

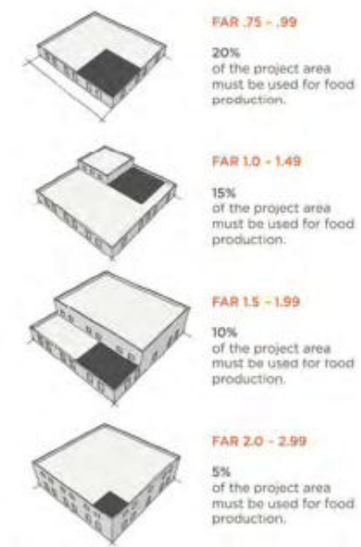


Figure 7.48 Minimum urban agriculture as per floor Area ratio. (Extracted from the Living building challenge)

- Imperative 3; Habitat Exchange

This imperative is intended to protect thriving habitats from the building developments. This is achieved through the reservation of a minimum of 0.4 hectares offset offsite for every hectare of development. This imperative automatically falls into the jump scale, since the requirements are not entirely onsite related. The image below further explains the concept().

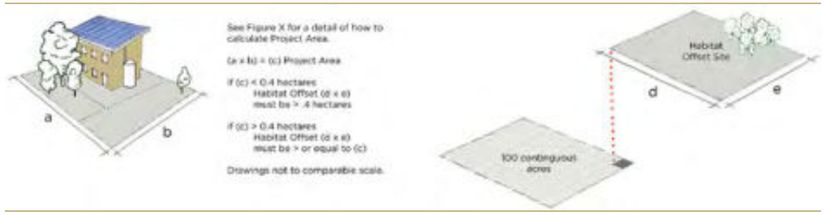


Figure 7.49 Imperative 03 It must be noted that is was not considered for the project due to unavailability of information

- Imperative 04;human powered living

It is intended to promote the creation of walkable and pedestrian centered communities. It requires the proposed project increase or maintain the density of the area. Thus the FAR of the site area before a the project should be either less or equal after the project. This enforces the enhancement of the community support for human powered lifestyle through the mobility plans both on site and local area. Projects are required to demonstrate the on the minimum the following;

- Secure, weather protected storage for human-powered vehicles that provide facilities to encourage biking. (recommended 15% bike storage for occupants of the project but increased for residential)
- Consideration and enhancement of pedestrian routes, including weather protection on street frontages.
- Promotion of the use of stairs over elevators through interior layout and quality of stairways.
- Advocacy in the community to facilitate the uptake of human-powered transportation.

7.6.3 Water Petal

With the increase in water shortages and reduced access to fresh worldwide, there has come a great need for the realignment of our understanding towards water usage. The water petal promotes the this realignment by envisioning an ideal situation of circular water. This comprises of harvesting sufficient water for the population while respecting the hydrological ecosystem and reusing water.

- Imperative 05; Net positive water

By net positive water , the imperative implies the developed land area should at least have the pre-developed hydrology. Thus water then flows within and through the site as a function of the larger watershed, thereby healing wounded wetlands and natural waterways, as well as replenishing depleted aquifers. The imperative requires that 100% of water use on the site be captured from precipitation or naturally closed loop water systems. Recycling of water is also required. Stormwater and water discharge management are required to be within a closed loop system and may released on treatment onsite. The imperative recognizes the following onsite water resources ; Rainwater, groundwater and Recycled water.

Energy Petal

The energy petal aims at signaling the new age of design, wherein the built environment relies solely on renewable forms of energy and operates year round in a safe, pollution-free manner. It further envisions a utopic future of decentralized power grid powered by renewable energy. Within this utopia, the buildings are envisioned to be highly energy efficient without the negative externalities associated with combustion or fission.

- Imperative 06; Net positive Energy

The requirement is to have the building produce and satisfy 105% of the building's annual energy needs by the on-site renewables. Projects must demonstrate that sufficient backup battery power be installed for emergency lighting (at least 10 percent of lighting load) and refrigeration use for up to one week for greater resiliency.

7.6.4 Health and Happiness Petal

The intent of the Health and Happiness Petal is to focus on the most important environmental conditions that must be present to create robust and healthy spaces. These environmental conditions include air quality, thermal control and visual comfort.

- Imperative 07; Civilized Environment;

This imperative requires every regularly occupied space must have operable windows that provide access to fresh air and daylight.

Imperative 08;Healthy Interior Environment

An exemplary interior environment is required to have quality air . this is achieved by adhering to the ventilation requirements of Ashrae 62 or equivalent international standards. The entry approach to the building and the through shoes are also monitored. Finally a dedicated exhaust systems are required for the bathrooms and kitchen spaces.

- Imperative 09; Biophilic environment

The imperative is aimed at including elements that promotes human nature connection. It require therefore an exploration of a biophilic framework and plan for the project that would tackle the following:

- How the project will be transformed by deliberately incorporating nature through Environmental Features, Light and Space, and Natural Shapes and Forms
- How the project will be transformed by deliberately incorporating nature's patterns through Natural Patterns and Processes and Evolved Human-Nature Relationships
- How the project will be uniquely connected to the place, climate and culture through Place-Based Relationships
- The provision of sufficient and frequent human-nature interactions in both the interior and exterior of the project to connect the majority of occupants with nature directly.

7.6.5 Materials Petal

Materials Petal is intended to create a non-toxic, ecologically regenerative ,transparent and social equitable material economy. The imperative of this petal red list worst known offending materials and urges for a more responsible material economy. This is achievable if knowledge of materials and company claims are available. This has been made possible by Declare.(Declareproducts.com)

- Imperative 10; Red List

The use of the following material are not allowed to satisfy this imperative as they are considered red List;

- Alkylphenols
- Asbestos
- Bisphenol A (BPA)
- Cadmium
- Chlorinated Polyethylene and Chlorosulfonated Polyethlene
- Chlorobenzenes
- Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs)
- Chloroprene (Neoprene)
- Chromium VI
- Chlorinated Polyvinyl Chloride (CPVC)
- Formaldehyde (added)
- Halogenated Flame Retardants (HFRs)
- Lead (added)
- Mercury
- Polychlorinated Biphenyls (PCBs)
- Perfluorinated Compounds (PFCs)
- Phthalates
- Polyvinyl Chloride (PVC)
- Polyvinylidene Chloride (PVDC)
- Short Chain Chlorinated Paraffins
- Wood treatments containing Creosote, Arsenic or Pentachlorophenol
- Volatile Organic Compounds (VOCs)in wet-applied products22

- Imperative 11: embodied Carbon Footprint

The project must account for the total embodied carbon (tCO2e) impact from its construction through a one-time carbon offset in the Institute's new Living Future Carbon Exchange or an approved carbon offset provider.

- Imperative 12: Responsible Industry

The project must advocate for the creation and adoption of third-party certified standards for sustainable

resource extraction and fair labor practices. Applicable raw materials include stone and rock, metal, minerals, and timber. The requirements in this imperative were not considered since the current Declare list does not cover the project location.

Imperative 13: Living economy Sourcing

It is intended to improve the local economies rooted in sustainable practices, products and services. This imperative applies the following restriction to material manufacturer locations;

- 20% or more of materials construction budget must come from within 500 km of construction site.
- An additional 30% of materials construction budget must come from within 1000 km of the construction site or closer.
- An additional 25% of materials construction budget must come from within 5000 km of the construction site.
- 25% of materials may be sourced from any location.
- Consultants must come from within 2500 km of the project location.

- Imperative 14; Net Positive waste

Net positive waste here refers to creating an elimination or reduction in the waste during design, construction, and operation of the project. It idealizes a industrial loop that integrates waste. The imperative requires a material conservation management Plan on how materials would be optimized, during design, construction, operation and end of life phases.

7.6.6 Equity Petal

Equity Petal intend to transform developments to foster a true, inclusive sense of community that is just and equitable. It challenges the notion that property ownership somehow implies that we can do whatever we like, even externalize the negative environmental impacts of our actions onto others. Thus the equity of the project is not only local but can be jumped in scale.

- Imperative 15: Human scale + Humane Places

This strives to encourage the human scaled environment over the automotive scaled place. This in turn brings humanity in the experience of the context. The following guidelines are required;

Table 7.20

- Imperative 16; Universal access to nature +/& place

The project is required not to restrict or diminish access to quality fresh air, sunlight and natural waterways for any member of society or adjacent developments. With regards to sunlight , the project should not shade the roof of a development with which it shares a party wall, unless the adjoining development was built to a lesser density than acceptable

- Imperative 17; Equitable Investment.

This requires an investment into the development of renewable infrastructure. The imperative outline here is was found to be impractical for the project and it location. The team thus ignored the requirement.

- Imperative 18; Just Organization.

The requirement is to have at least on JUST Label organization on the project. For this requirement the team ignored due to its inapplicability.

7.6.7 Beauty Petal

The intent here is not to define beauty but to know the effort the designer has consciously made towards achieving preservation, conservation humane environments. The thus sets no limitations but leave an open and wild are for the designer. The imperative rather consider the teams willingness to either educate on the positive impacts of the project.

Imperative 19; Beaty and spirit

It requires the project contain feature that are delightful to humans and invoke the spirit of culture and the place.

- Imperative 20; Inspiration and Education

The project must be made available for public share on the success in operation and performance. The main provision outlined to achieve this intent do not apply since the project is academic. However the same intent can be achieved by educating the mayor and the people of Quelimane on the potential they have.

Table 7.20 The Transcet leels that outline ways of achieving humane scale.

TRANSECT		T1	T2	T3	T4	T5	T6
Surface Cover	Maximum dimension of surface parking lot before separation is required on all four sides e.g. building, wall, or 3 m wide (minimum) planted median or bioswale	20 mx 30 m					
	Total area of surface parking lot allowed. All other parking requirements must be handled in structured or underground parking.	20%	20%	20%	15%	5%	0%

TRANSECT	T1	T2	T3	T4	T5	T6
Maximum street width, measured either shoulder-to-shoulder or lip-of-curb-to-curb	5 m		7.5 m	10 m	15 m	22.5 m
Maximum street width before driving lanes must be separated by speed-reduction strip and planting median. Additional lanes may be added on the other side of median to a maximum of 22.5 m total width of driving area	Not applicable		15 m			
Maximum street width before tree plantings and sidewalks are required on both sides	Development of this land is not permitted in a Natural Habitat Preserve or Rural Agricultural Zone		7.5 m			
Minimum overall width of sidewalks and planted median			1/3 street width			
Maximum distance between trees in furnishing zone and planted median			9 m			
Maximum distance between circulation routes. Access way must be 3 m wide minimum to qualify			45 m		60 m	
Maximum street block size			60 m x 120 m		120 m x 120 m	

TRANSECT	T1	T2	T3	T4	T5	T6
Number of freestanding signs per development	1					
Maximum dimensions of freestanding sign(s)	2 mx 2.5 m		2.5 mx 3 m		3.5 mx 6 m	
Maximum elevation of sign's bottom edge above ground	2 m	3 m	6 m	9 m	12 m	12 m and wall

TRANSECT	T1	T2	T3	T4	T5	T6
Maximum single family residence size	N/A		425 m²			
Maximum distance between façade openings	N/A		30 m			
Maximum footprint for any building with a single use, single owner or single tenant. Acceptable to provide additional floor area for tenant on upper/lower level(s)			3750 m² each floor area of atriums, courtyards and daylight shafts			
Provision of places for people to gather and connect internally and/or with the neighborhood	1	1	One every 1000 m² (10,760sf)			
Provision of elements along the project edge that support the human scale of the larger neighborhood, such as seat walls, art, displays, or pocket parks. Single Family residences are excluded	1	1	One every 4000 m² (43,000sf)			

IMM Phase 3

Intervention and Design

The Urban intervention considered for this project is disguised in the form of major prototype projects working towards a SMART city without SLUMS. The protypes conceived for Quelimane resulted from a discussion and synthesis of the SMART acronym and investigations the city. These prototype projects are focused on improving the entire SMARTness of Quelimane. The scope of the project starts from the city scale and then narrows down towards the selected barrio of study.

At this level the discussion is based on major intervention that can be carried out towards the improvement of the selected barrio of study. The Prototype project a selected and discussed base on the how they improve the smartness of the barrio as a whole.

Within the selected barrio a detailed architectural project has been conceived. Here we explore what could be done to help the individual homes. This project stands as model home that would seek to exhibit the possibilities of improving slum dwellings to be SMART.

8

SMART draink

Draining and linking the city Quelimane towards an improved SMARTness.

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8.1 Draink the city

Investigations form the IMM revealed the city as a complex adaptive system had areas that could be improved. The study of the accessibility and transportation revealed the disconnect between the supply and demand for transportation. In addition to this, the major effects of climate change on Quelimane has been the rising sea levels and cyclones.

Through further study of SMART themes in relation to the city hinted at major prototypes projects that could enhance the city as whole. These enhancements while improving on the SMARTnes of the city would seek to address the major identified problems of the city. A synthesis of the prototype projects lead to a conceptual proposal that is centered around building SMARTly Draining and linking City.

The concept diagram explores the lives of diverse individual in Quelimane as seen in Figure 8.1. All these lives would benefit from the SMART draining and linking of the city. The prototype take into account the Historical values and bicycling culture of the city. With these as back bones of the concept master plan, the lives of our individuals are intertwined and nourished. Notice their responses from the at the end of this section. For now lets explore how the city has been SMARTly Draink.

Figure 8.1 The Concept Map

8.2 Draining the city

The city has over the years been a subject of the effects of climate change by virtue of the rising sea levels. Climate change has also impacted heavily on the seasonal rains and cyclones. The city has continuously had deal with the fast changes as well as with its own growth. As this issue has been a yearly battle for the city, the team considered ways of SMARTly draining the city. Two major prototypes have been considered for this problem.

8.2.1 City Belt

Initial search showed that the mangroves surrounding the city has in the past been the first line of defense against nature. However, as the city started growing, residents of poorer neighborhoods have resorted to cutting them for fuel. The knowledge of this past ecosystem service of the Mangrove brought the initial thought of considering a nature based solution for the flooding issues of Quelimane.The Idea of a city belt stems from the synthesis of the Quelimane's past as well as observations of the city and its periphery. The city belt has been envisioned as a form of buffer between the water lodged mangroves and the city. This would inherently define the edges of the city of Quelimane. A 25m wide buffer from the edges of the mangrove and water lodged areas has been proposed. This is aimed to restoring the city edge and mangroves.

Figure 8.2 Green cityBelt

Although a buffer would allow nature to stay uninterrupted by the growing city size, we considered additional measures to the belt. These additional measures were based on the consideration of a SMART. The 25m buffer provided the opportunity to implement four of the five themes to this is prototype.

- Soft City Belt

We considered a bike track since the buffer connects to the edge of the city. This bike track is integrated along the city belt to allow for an experience of nature while biking. Leisure biking and would be encouraged on this bikeway.

- Multilayered City Belt

The city belt is not limited to its main function. It integrates a host of functions. Close to the densely populated areas, public spaces were created. The belt also serves as a pathway and for such neighborhoods.

While this prototype seeks to help the city as a whole, it would negatively affect about find percentage of homes affected . To cater for these mishappening, relocation of affect families have been factored into the design.

New home would be inserted into the existing urban fabric(figure). The analysis of the city's porosity showed the potential for increasing the story heights. This is taken advantage of by looking out for expandable houses. The criteria for identifying them was based on the minimum area needed per person in the context of developing countries. Thus house below the 30m2 were identified. The next step was to enter into a negotiation to help the own expand his house while accommodating a resettled person.

This process would be carried out maintaining that relocated people are placed neighborhood close to their former. This careful consideration is necessary as to maintain the society.

- Agritectural City Belt

Community gardens are planed to be incorporated into the green belt. This would be used by volunteer families living in proximity to the belt. The bed are oriented towards the city centre. The community gardens would house close to 0.57ha (1445 of four square meter beds). These gardens would be distributed to 200 individuals evicted from their previous homes due to the intervention.

This number represents roughly 10% of the evicted residents. Also the selection would be based on the residents interest and willingness to join the program. The program would entitle them as the care takers and users of 9-10 beds each in close proximity to their homes. The intervention is expected to produce enough food to feed families of three for 15 days a year. This scenario was simulated using four common crops. The crop planting dates were obtained from the food and agriculture organisation data for mozambique. The data is adjusted for Quelimane area.

Farmers would be advise on crop rotation measures that could increase their yield and thus increase the feed days. Interested farmers would be granted the opportunity to add a vertical farm capable of tripling their produce for at least 2 beds used for vegetable farming.

- Robust City Belt

The city belt has a crucial responsibility to create a buffer between the flood zones and the city. While a buffer can in itself complete the job, an extra layer of protection was considered. Swales were dug on the flooding side of the green belt. These serve as a factor to decrease the amount of overflow the wetlands. These swales are expected to increase the travel time of the flood waters. Thus residents have a double layer protection. The protection is further improved by the mix mangroves palm trees to strengthen and drain flood water. Palm trees were selected as well to improve on the wind breaking effect of the city belt against cyclones.

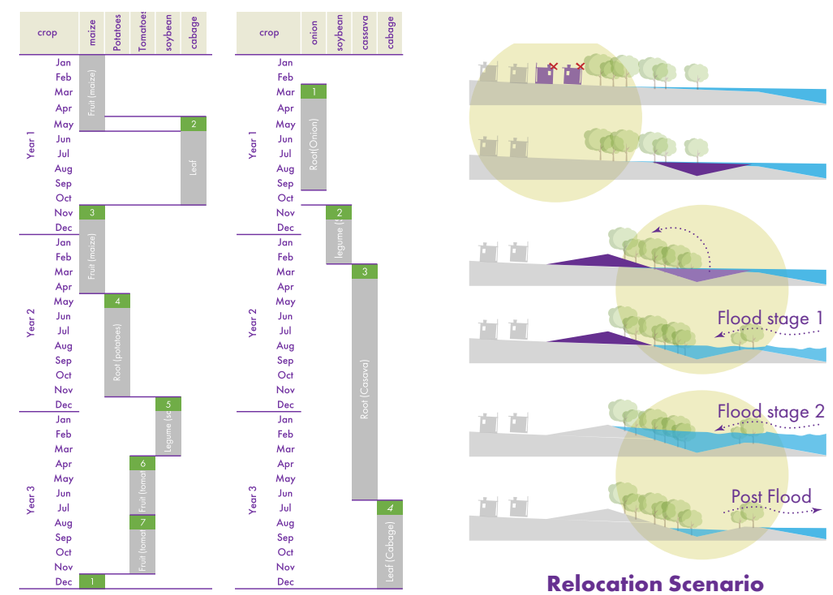


Table 8.21 Crop rotation over a three year plan based on planting schedules of FAO

Figure 8.3 Flood prevention swale of the green belt

8.2.2 Linear City Park

City Parks are essential as they have a great role in carving out the city. From the horizontal investigation of the voids of Quelimane, it was observed that the open space and covered green spaces existed in isolation. These voids are important in alleviating the effects of heavy rains and cyclones in the city. Cities such as Jakarta and Bangkok , come to mind when one thinks of flooding cities. Common to both cities is their reduced number of permeable land. Bangkok om realizing this problem has built a city part capable of holding up to 1 million gallons of rainwater. This has been done to reintroduce sustainable measures to reduce flood risk.

In the City of Quelimane, we sort to follow in this direction, to introduce more permeability, to reduce the city's flood risks. The city parks have been envisioned as water storage . A water storage in that, it is composed of series of permeable spaces to soak up storm water. They are scattered around the city but thoughtfully interconnected by a system of green streets. The crown jewel of the parks is the main central city park. This park covers about 34.9 hectares(86.2 acres). The positioning of the park tends to mark the beginning of the City center. Due to its positioning, it would serve as an indirect educational tool to the public. This is achieved because people tend to move towards the central business district on daily basis. During such daily activities they are able to observe the how the city parks contribute to the reduction of floods and drains the city as a whole. They would thus realize the to a greater degree through daily observation the importance of their mangroves and permeable areas.

While achieving this main goal of draining the city, we adopted further measures to ensure the SMARTness of the city parks.

Figure 8.5 The Green Belt connects financial divide of Quelimane physically

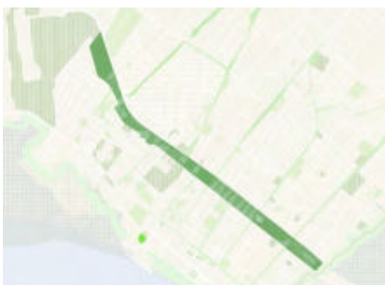


Figure 8.4 Green Belt

- Soft City Park;

The Central City park is located in close proximity to major services that attract higher volumes of people. These include the bus terminal, the Training school and on axis towards the airport. The softness of the park is further experienced as one moves through the axis of the park. It gradually connects the expensive neighborhoods close to the airport to the rather poorer impoverished informal settlements. Such a connection would ingeniously be building on the SDG 11 goal of bringing adequate access to public spaces

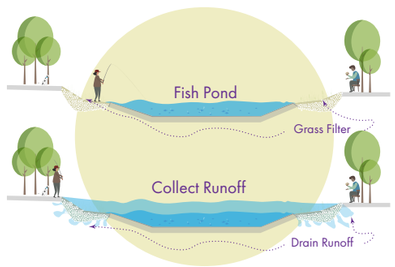
to all. Also, by designing the park as a symbolic bridge between these two divides, we provide hope of more inclusion and connections.

- Multilayered City Park;

The is in itself a main single function. But to achieve a multilayered park, the team considered its relationship with the neighboring communities and functions. This initial consideration pointed towards major functions as the bus terminal, the markets , formal and informal settlements. With these in mind, the team contemplated on layers of activities that would relate to the environment around. These include diversity of community farms, outdoor exercise, community living rooms, festival plazas to advocate the city's culture and sponge parks. These layers of activities are overlapped and juxtaposed over the city park as three themes; sponge spaces, farming spaces and recreational spaces. The overlap of activities provides the opportunity to maximize the land use within the city center through underlying similarities.

Fish(or rice) farms were layered over sponge recreational spaces. This layering is made possible due to the common factor, water. As a fish farm a minimum amount of water is required. As a sponge, a level of permeability is required, and this has been wrapped around the boundaries of the farm activity. This thus allows the fish pond (rice fam) to maintain required level of water year round through growth and draining of the sponge. Finally, as a recreational area it tends to provide the localized climate needed for relaxation.

Over 30% of land within the city park has been dedicated to community farms. These community farms



within the city parks are also juxtaposed with retention ponds. The juxtaposition allows the water in the retention ponds to be reused for the city farming activities.

Such layering gives maximum use to the land area.

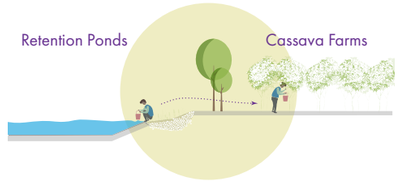


Figure 8.7 Schematic of farm juxtapose with ponds. . this allows the uses of ponds as water source for farms and in the city centre park

- Agritecture City Park;

The 30% of city park dedicated to community farms is significant. These farms are estimated to have the capacity to provide for about 2000 people lunch for 3 months.(Table 8.22) . The total expected revenue from this farm around $34,000 a year. Tand reduce poverty within Quelimane. By this the DOP 11 and SDG

crop	maize	cassava	soya beans	potato	Totals
Yield [tn/ha]	0.9	8.9	2.3	15.0	-
Selling price [$/tn]	261.0	267.0	592.0	648.0	-
1/4 land area	2.5	2.5	2.5	2.5	10.0
Area available [ha]	10.0	10.0	10.0	10.0	-
Yield [tons]	2.3	22.3	5.8	37.5	-
Value [$]	601.0	5940.8	3404.0	24300.0	34245.7
Calories per 100g	177.0	159.0	446.0	77.0	-
Calories per ton	0.0018	0.0159	0.0446	0.0077	-
Calories made	4075425	35377500	25645000	28875000	93972925
No. of lunch [Mel]	5094	44222	32056	36094	117466
Calories per meal	800	800	800	800	**2400**
No.3 Course meal [ppl]	1698	14741	10685	12031	39155

Table 8.22 Estimating the food production and its worth in the Mozambican economy

Figure 8.6 Schematic of the fish and sponge area.

This revenue is equivalent to 50 new jobs or increasing around 190 people yearly earning by $180 a year each. Proposals for the integration of livestock farming have been added. They have a rather special purpose in the maintenance of the city parks.

Figure 8.8 The Green Belt connects financial divide of Quelimane physically

Maintenance; The creation of the community farms would require maintenance. For this we decide to build on the existing groups that have been created in Quelimane. Student groups and youth groups would be establish and allotted portions of t he city park to maintain. Portions of the city farm may be allotted to the relocated residents form the green belts. The groups may sell the produce from the farm . Maintenance of the open green areas would be carried out using city livestock.

Farm days; Along the city park also exists a green corridor for street market. Stalls have been pre-designed and installed. As such farmers only have occupy the space for the Farm days. The suggestion is to create a day in the week to allow farmers from to display and sell produce. Such a day would complement the existing market day.

Extend Market Day venues to Include city Park

These initiative would help to increase the food security and reduce poverty within Quelimane. By this the DOP 11 and SDG 2.3, 2.4 (increase small scale food production and its systems) is achieved to a level better than before.

- Robust City Park;

The city park plays an important role display very robust properties due to its major features. The Sponge parks incorporated into the park cover about 10ha of the park area. The overall average depth through these sponge park is about 1.5 m deep. With such a depth the sponges gain a capacity 32million gallons of water. Using the highest average rainfall month, the maximum average direct runoff water from the roads on the study area of the city was computed as roughly 28millon gallons.

From the general data on the natural (unregulated) lands in the Zambize basin some base variables were established. It is estimated that these natural lands a an evaporation potential of about 1060 mm annually, a mean runoff efficiency of 0.10.Also basic and general information on infiltration capacities of soils were sort to help establish a fair scenario of the performance of the proposed sponge spaces.

In a possible 24 hour long rain at the 250mm per day. In this scenario, the runoff expected from all the roads is 28million gallons, the capacity of the sponge parks is 32million gallons, and finally the measure of rain pouring directly onto the sponge parks being 5million gallons. However during the 24 hr rain period it must be noted that the infiltration rate of the soil , in this case loamy, would contribute to about 2 – 5.3million gallon during the 24 hours. Thus after a 24hour rainfall measuring 250mm the sponge park would have retained about 28million with close to 4million gallons of space available.

The success of this system would also depend on the linking of runoff water from the streets to the sponge parks. This was considered . On the highways swales have been proposed integrated into the roads. Within the city center, the rain garden are employed. These are aligned towards the central park.

Technology City Park; The city park would be host to two major technologies, solar and composting. This is to indirectly inform and educate the public of their importance.

A Composting facility has been designed within the park. This facility would serve the management of organic waste in the city park. The compost produced would then be reused on the city park. Such a circular approach would imprint in the minds of locals the importance of waste sorting.

Solar panels have also been incorporated to power the street lamps within the park. The incorporation of solar panels on the stall of the food market would also supply surplus energy to the street lights in its vicinity.

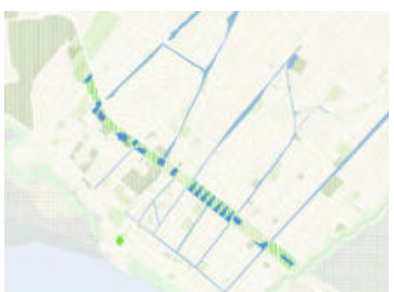


Figure 8.9 Retention ponds have the road runoff directed into it.

Figure 8.10 Multi-layred activities in the city park

The farm land which mingled with the ponds also helps the biodiversity to be regenerated. All the elements are connected through a meandering path way in which the inhabitants can jog and walk on it. The triangulated farm lands are suitable for the farmers to use it based on crop type or property type and also able to be watered from the immediate ponds in the dry seasons.

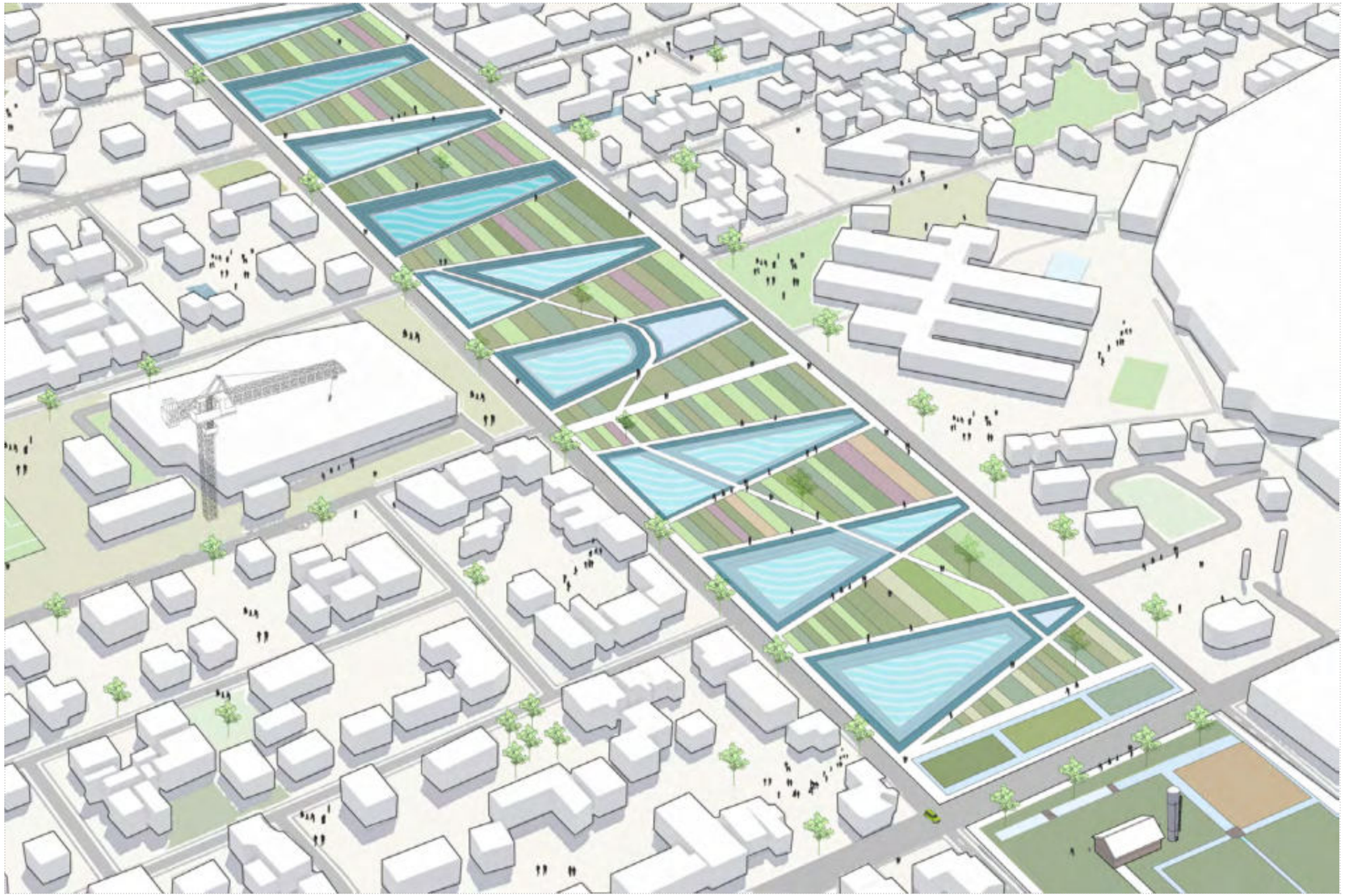
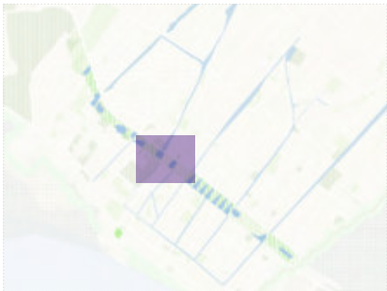


Figure 8.11 The city park with the triangulated water ponds and farmland



Since Quelimane hosts different carnivals and events, the city park design included carival plaza in the city center. This makes it accessiable by most of the residents and adds a flavour to the character of the city.

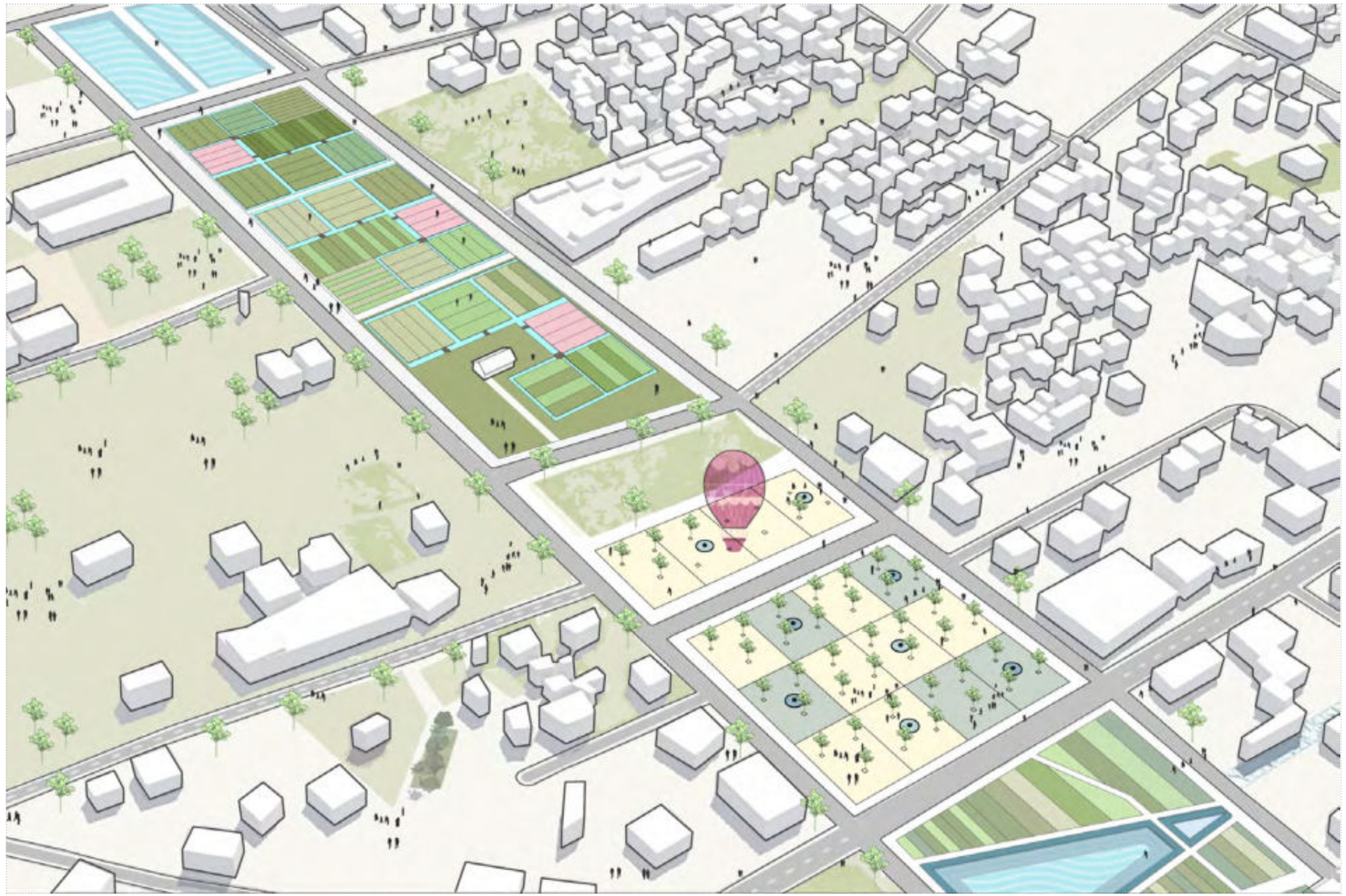


Figure 8.12 The city park having Carnival plaza

8.3 Linking the City

Linking the city is highly connected to the issues found in the IMM analysis relating to accessibility. The distribution of transport to functions was highly imbalanced. Although the city is known for cycling, there existed other modes of transport ie; the Chapa (mini Bus). Realizing that limitations of the current system of connection, we sort to build on the strengths of the existing. We thus implemented two major Prototype projects, the Chapa and Cycling Rapid transit (CCRT) and the Green corridors.

8.3.1 CCRT

The CCRT is stands for the Chapa and Cycling Rapid Transit .Quelimane has constant interaction with its main land areas. Although such areas do not form part of the city center, they play important roles. For instance the, about ten kilometers from the center of the city is the New Hopital of Quelimane. Realizing the importance of connecting to these outskirts, we introduced a CRT.

Cycling is also very important to this society. People in this city find cycling as a cheaper alternative transport. Cycling is highly patronized in this city that is referred to as the cycling city of Africa. Although the city has held such an accolade for years, the culture has been seeing decline. The decline has been attributed to the increase accidents, ignorance of rules and increasing spare part (4). On the city scale we incorporated the use cycling priority initiative.

By creating the Chapa routes we have reduced the conflicts between the Chapas (mini Buses) and the cycling. This move also allowed the creation of interchangeable transport systems. Thus for longer distances towards city out skirts the Chapa is used. The cycling network rather now acts as feeders for the centrally located Chapa route. Thus the system is able complement each other.

Cycling infrastructure is integrated into major street networks . This infrastructure include the creation of cycling routes within the city center.

- Soft CCRT;

The CCRT takes advantage of the existing Mini buses in the city. The aim was to channel them into a routine system where they would use specific routes through the city. This thus allows employment to be maintained while improving the effectiveness of the transport system. With this system dedicated routes have stops assigned at 800m intervals. The connection of the CCRT system is from the city center towards the Airport, Milato, Tivire and Inhangule. Within the city, the CCRT connects to the various neighborhoods by the bike taxis. Using the bike taxis would also allow the easy access to rather difficult to access areas. They further also allow for a better experience of the environment through their rather slower pace.

Figure 8.13 Proposed City Network connected by the Chappa and Bike routes

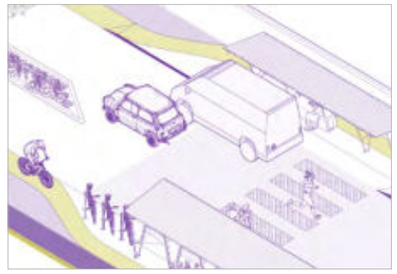


Figure 8.14 Chapa allowed to stop directly on the roads while the roads adjusts for passers-by.

On the major routes for the CCRT priority is given to the transport system. For example, in the above image the Chapa may stop to on the road at the Chapa stop.

To deal with on traffic behind, there is a buffer zone to allow overtaking. Although this was a constraint of the existing street width, it came with the added advantage of speed. The Chapa system is able to reduce the travel time by stopping directly on the roads.

- Multilayered CCRT;

Shared Streets for either traffic and Chapa or traffic, Chapa and bikes were introduced is special zones. Within these zones domestic and commercial traffic are allowed within the rush hours only (ie; 7pm - 9am). This initiative would allow homes and business to use this route during these rush hours.

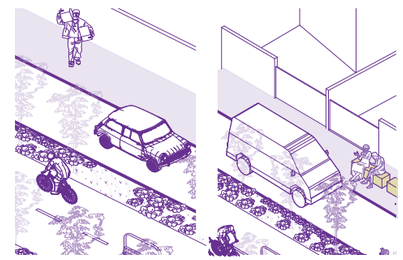
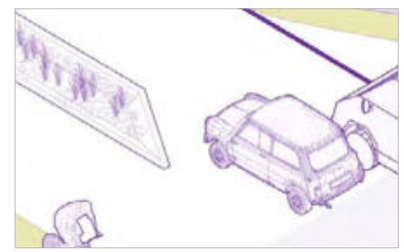


Figure 8.15 Street is multilayered with one way vehicular traffic and bike traffic at specific times of the day.

- Robust CCRT;

To ensure the robustness of the CCRT system, we introduced swales within the roads. The introduction of central swales was considered since flanking the drainage system would result in reduced to no pedestrian areas. Where crossings were needed the swales were connected by underground pipes to ensure continued flow towards the city park.(Figure 8.14) Further more the use of swales not only improves the drainage but helps to improve on the biodiversity of the city.



- Using Technology in the CCRT;

With the increase in usage of smart phones around in developing countries, there arises the opportunity to implement transportation application. For Quelimane, the proposal was an application for both bike sharing and CCRT. The integration of these major features into a single application increase the convenience of use for the people. Also the city of Quelimane may consider adopting it at the at it administrative level. This would increase the chances of biker registering the bike taxis as this has been an issue for the city.

8.3.2 Green corridors

Green Corridors were introduced within the city centre. This location was considered best as it has high possible volumes of people congregating on regular basis. The green corridors would be a system on on-way traffics that give higher importance to pedestrains and also foster the introduction of store fronts. the system is illustrated below in Figure 8.17.

Figure 8.17 Locations of the Green corridors and the directions of traffic

Figure 8.16 Introduction of the swales in the middle of the road to direct runoff water while maintaining biodiversity.

- Soft Green Corridors;

While the CCRT looks at linking humans using transport, the green corridors seeks to look at the alternative, walking. This option is explored in the vicinities of the city center. The green corridors are brought alive due to the introduction of store fronts. This is complemented by the seating and tree canopies. These provide points of encounter and interaction(Figure 8.19).

- Multilayered Green Corridors;

The green corridors combine multiple uses layered and juxtaposed. Side by side, resting spaces in the form of seats and tree canopies complement the busy active streets. The busy streets are further juxtaposed by the store fronts that provide the reason for stops. The introduction of shops within these sections of the city also give the streets a secondary life when actual neighborhood residents are away.

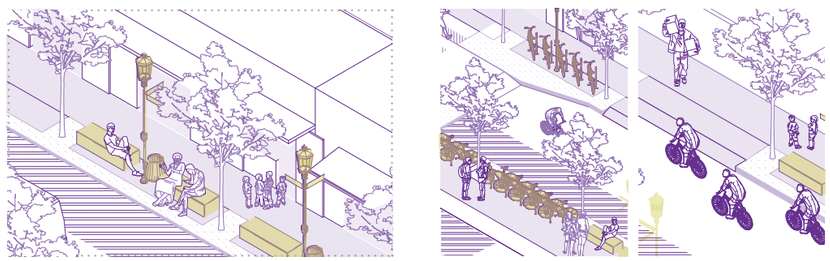


Figure 8.19 Store Fronts and settings would bring life to the street.

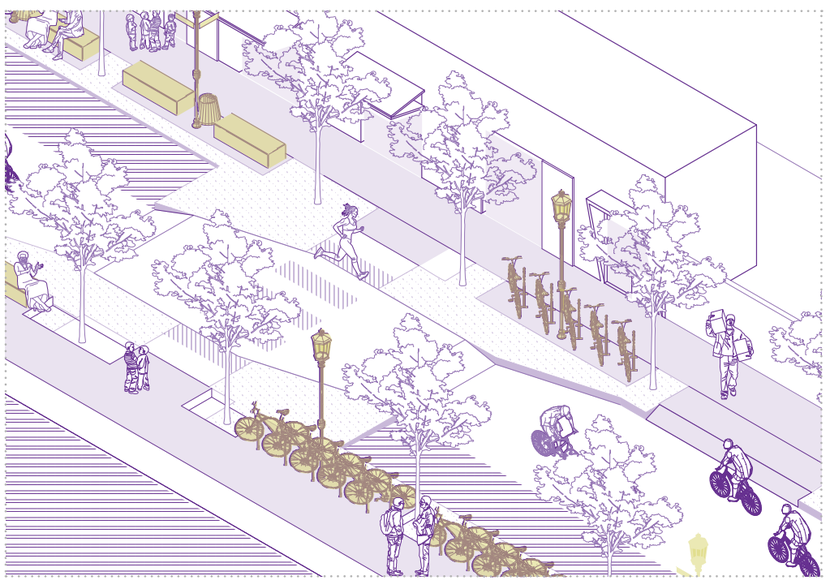


Figure 8.18 Green Belt

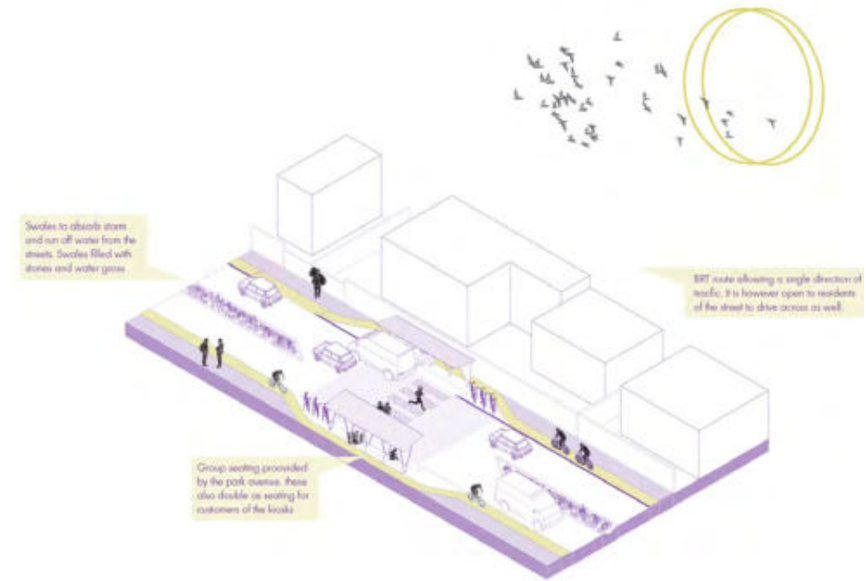


Figure 8.20 Green network on highway

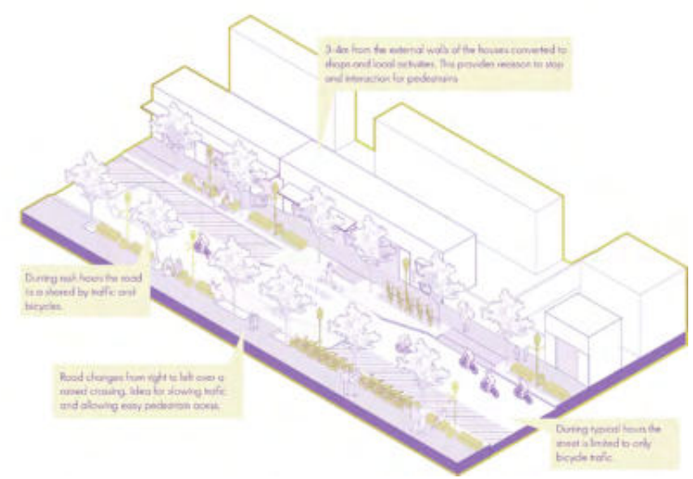


Figure 8.21 Green network on highway

Finally, the streets accommodate vehicular and bike activities. This creates a so-called shared road. This decision is to allow shops and the local resident the chance to move goods and people during the rush hours. Traffic is also further slowed due to the mix of transport modes.

- Robust Green corridors;

The green corridors within the city strength the biodiversity, pedestrian flow, and the sustainability of bike usage through the following approaches.

First the introduction of rain gardens on the side of the streets are used to drain the run off water from the streets. Planting of trees within them also helps in the maintenance of biodiversity within the city context. Furthermore, the Trees tend to provide shade and also reduce the urban heat island effect characterized by city centers. With this pedestrian activity would by encouraged and increase.

The conversion of intermittent parking spots into bike parking would serve as an incentive for the use of bikes within the city. This would in the long run maintain and boost the cycling culture of the city of Quelimane

Figure 8.23 Store Fronts and settings would bring life to the street.

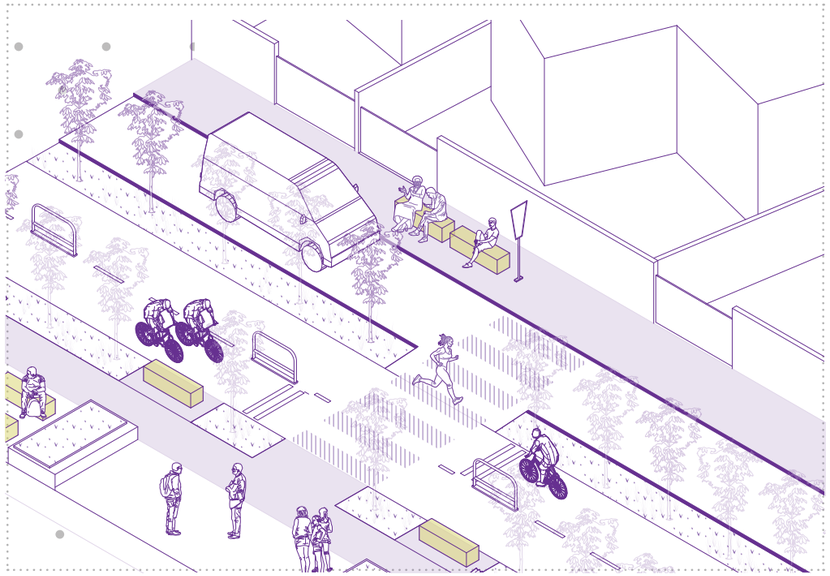


Figure 8.22 Part of the Green Belt

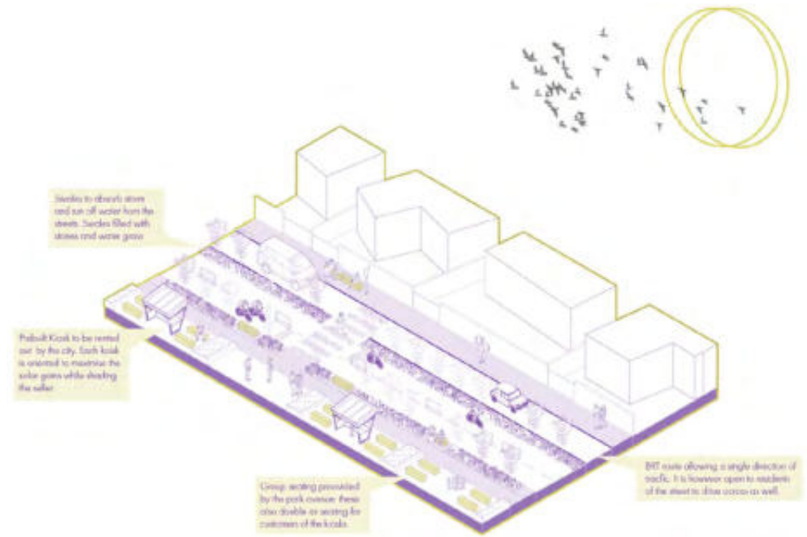


Figure 8.24 Green network and street parking

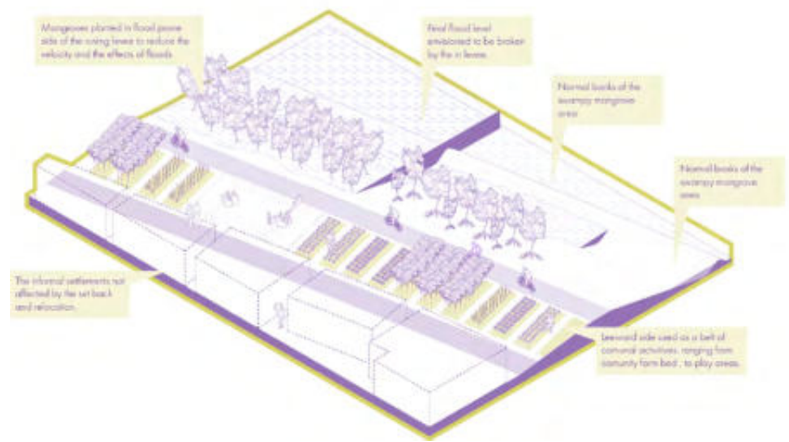


Figure 8.25 Green belt

8.4 Barrio scale

Bario 11 was chosen for further development as it fit the profile of our discussion. Major prototypes from the city scale interventions affect the Bario. However, from the IMM analysis there were other crucial priorities identified (DOPs 5, 6 and 10). Also, through observation and further analysis of the barrio housing was identified as an issue to be tackled. The above mentioned priorities guided our approach towards the master plan.

8.4.1 Soften

To achieve a degree of softness within the proposed green spaces, we considered interconnected parks. Thus, the green spaces do not exist in isolation but have been linked by pathways and cycle routes. The public green spaces within the barrio were below the typical minimum required per person. The current public green space can be counted in the form of the two cemeteries. Knowing the Green space are beneficial to inhabitants, we opted to improve on this situation. We also considered that DOP arrangement leads us to start the intervention with a clear vision (see the DOP arrangment below).

Bario - 11

DOP

5 Green Space
10 Food Management
6 Cyclability and Walkability
1 Ground Use
3 Multiplicity
8 Interchangeability
7 Urban Flow

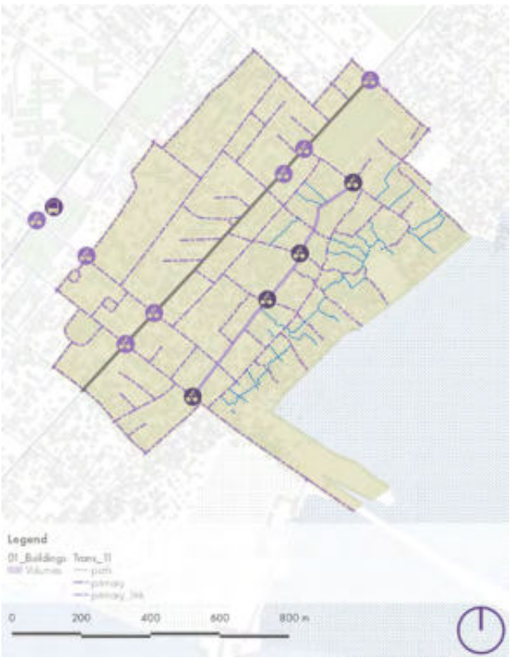
As a starting point, the newly proposed city park and the green belt both run through the barrio. The required green space is thus reduced from the minimum 9.8 ha. While, this number represents the minimum, other opportunities to create green spaces also existing within the barrio. This was in the form of existing wetland channels and streets.

The identified foot paths were chosen to maximize directness of passages. The footpath also leads to the focal point of interest and makes it open space or activity space So, when one walk through them s/he can be transitioned from point to point with rest points. The experience and memorability of the green space is also enhanced by giving the green spaces identities and character. Themes mark each green space. Whether it's a street or the rest point a theme has been considered.

From the analysis of directness, we noticed now purely strong street with strong character. However, where there is existed street that had a potential to become a crucial spine of the barrio. This street was adopted to link up the barrio with its northern and southwestern neighbors.

This route is further enhanced as it directs pedestrian traffic towards existing points of attraction such as the school and it would be lined with pedestrian routes and a shared route for bikes and vehicles.

Figure 8.26 Proposd streets with 4 biketaxi stops and foot path(blue dotted lines)



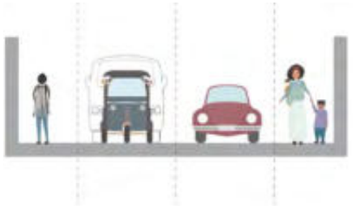


Figure 8.27 Street section on the new added street, Active vehicular street by morning and evening rush hours and active pedestrian street by night and midday

8.4.2 Multilayering

While studying the concept of multilayering, topics such as neighborhoods and block came up. This informal settlement ass it stands appears to have interrelations. However the absence of clear block reduce their accessibility to soley pedestrian. Also the break down of activities within this Bario seem to be limited to residential.

The Main city green belt from the city plan had affected considerable number of homes. Since these people have lived most of their lives and have built bonds with people in the vicinity, we opted to relocate them within the barrio.

To further strengthen the bonds of the people while relocating, we selected homes that were in close proximity to the unaffected homes but of lower quality. The quality of the homes were establish using the size of the home's footprint and the satellite imagery of their roof conditions. Homes of lower quality would

Figure 8.28 The buildings with red color are going to be relocated to the barrio itself (Left-bottom).

Figure 8.29 Maintain neighbourhoods by scheduling the relocations to allow movement of formal neighbours.

Figure 8.30 The street with some .local businesses and the selected site

fall into a program that allowed that to expand their homes while accommodating relocated people. Thus, the ownership becomes share and construction is subsided by the city. Furthermore, volunteering families from these groups are given a further incentive in the form of private sections of the city park and green belt for food production.

Furthermore, we considered ways of improving the accessibility of these neighborhoods and internal activities. This was achieved by establishing firstly a perpendicular link between the main spine and the green belt. With such short cut established, make homes have clearer and easier access to the spine of the barrio. The links were designed within distances of 800m apart. This approach was employed as it allows to continue have the sense of community between the people.

With connection to the spine established, we further consider introducing a host commercial activity on the main spine. Commercializing the spine would seek to increase the on the spine. While homes may be empty or have fewer occupants during the day, the curated links would provide a sense of oversight.

The site to do a detailed architectural project was also selected from barrio 11. While selecting the project site, the team considered Impertive 01limits to growth (chapter 07 pg.138) and also the potential location of the site for future development regarding an activation of the overall barrio due to the IMM application (Figure 8.160).

8.4.3 Agritecture

One standing theme of the green spaces was related to agritecture. Agritecture is integrated into the green space to help curb the food management and poverty of the informal settlements. Under this theme, major distinct sub themes were established. These include the Mango avenue, Papaya and Avocado avenue(-Figure 8.161). Fruits trees were chosen since they require little regular maintenance. These fruit avenues should be able to provide fruits to the public at no cost. Alternatively, the local groups set up at the city level in the form of student clubs and community gardeners may mange and sell produce at lower rates. Parks space also have a range of localized community gardens. These gardens would be managed by the residents groups.

Bee keeping at the barrio level has also been introduced. The benefits envisioned would be that of a circular one. Firstly, the presence of bees would speed up pollination of the fruits avenues , soybean and maize farms proposed for the city. Furthermore, the main produce honey , would improve on the health

Figure 8.31 The Integration of Agritecture to the existing Green areas in barrio 11

off individuals in the society. The integration of the bee hives would be territorial. This would ensure a fair distribution of pollinators without a concentration in an area . in the immediate surrounding of the beehives , flowering plants were incorporated. Also, the rooftop and vertical gardens will be integrated to the housing project which will be discussed in the next chapter.

Figure 8.32 Locations of beehives in barrio 11

Figure 8.33 Wetlands and integration of water channels

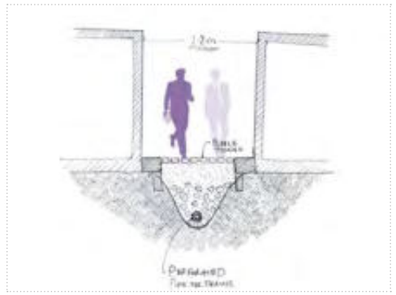
Note; bees fly up to 4km from the hive

Finally to serve as an indirect education, a specialized custom built frame was conceived. It is designed to direct the bees above eye level. This design would make the structure and the hives more urban friendly. With these modifications passersby may enjoy the sights, smell and sounds of bees. This would create a special sense of place for the locations.

8.4.4 Robust

The barrio has increased robustness due to the green belt. However, within the barrio further local consideration have been made to ensure the neighborhood survives. The next level of robustness was assured through reclamation of wetlands around water channels ()and introduction of sponge spaces.

Within the parks and public spaces, natural water management systems have been employed. Standing out are the sponge spaces. These have been designed to serve both a functional use as well as a social one. Functionally, they serve as natural stops to hold portions of runoff water and reduce the urban heat island effect. On the social side, they provide outdoor open spaces for interaction.



This city is prone to frequent rainfalls, while on the other hand they experience longer dry periods. Such a phenomenon affects the barrio's ability to provide for its inhabitant water. This issue is addressed the introduction of communal water storage wells. These well like sponge space would collect runoff water. Unlike the sponge spaces they are waterproofed on the interior to store the water. The intervention at this barrio is to provide these storage point at groups of buildings. At this level of distribution, we can reduce travel distances for water collection (Figure 8.33).

Coastal cities around from developing countries have fallen prey to the lure of water from aquifers. Although a good a quicker way of water supply, it has negative effects for them. Cities like Jakarta, Central Valley California and Mexico City are prime examples of the effects of extracting too much water from aquifers. With this precedence in mind, the designers located bore holes in proximity to the sponge space or water collectors.

This provision ensures that extraction from aquifers is regulated since the its group based. Furthermore, the aquifers can be replenished by the sponge spaces provided.

Figure 8.34 Borewells and communal sponges in barrio 11

Figure 8.35 Footpaths and interconnected by the sponge garderns. Underneath these streets are gravels and perforated pipes to direct the street runoff . Thus streets can be maintain dry .

8.4.5 Technology

Technology cover many aspects of techniques, skills and methods used to achieve objects. In the barrio level, various objects have been established. These are namely, the sponge parks, improvement of groups of houses, improving on biking and community farming. These objectives are indirectly tried to technological solution that can quickly improve on their animation.

- Communal Hotspots

Biker Café is vital in maintaining the bike culture. The idea is to provide a workshop responsible for the repairs and training of bikers. This workshop would also be supported with subsidized bike goods for sale.

Figure 8.36 Bikecafe and farm house to exchange knowledge within the community

Figure 8.37 Typical bikerepair shop in Africa

Also, through the Biker café the city would be able to regulate and train either commercial or domestic bikers. Through this café, the designers hope to improve on social connections and improve on the cycling within the barrio.

- Community Farmers Inn

The sustenance of the farming initiative provided in the masterplan would depend on quality out. This output can be achieved through education and group sup-

Figure 8.38 Biogas plant in Essom,Senegal

port. The Community farmers Inn seeks to provide this support. This facility would be the information hub of the community farmers. Furthermore, it would house the production of the compost. With a localized composting site and group, subsistence farmer in the barrio can get the needed support.

- Biogas

Increased use of firewood in the city has led to high usage of the mangrove tree. This has sped up the loss of mangrove tree in Quelimane. Biogas technology can be employed to curb this problem. The Proposal is to construct the system in sized per her group of buildings. This approach has been successful in Senegal (Figure 8.168). The system would use household organic waste. It would be sized to hold a maximum of 600 liters of gas. This is estimated to be enough to produce up to 4 meals a day or up to 2 hours of cooking time. Below is a schematic of the envision approach for the barrio.

Through individual participation this could be used to reduce the need for LPG or firewood in the community.

Figure 8.39 The city scale proposal for waste collection routes, biogas plant points, landfill area location, public toilets, recycling plant location and barrio scale waste collection points

Figure 8.40 SMART Masterplan for Barrio 11

IMM Phase 3

Intervention and Design

The Urban intervention considered for this project is disguised in the form of major prototype projects working towards a SMART city without SLUMS. The protypes conceived for Quelimane resulted from a discussion and synthesis of the SMART acronym and investigations the city. These prototype projects are focused on improving the entire SMARTness of Quelimane. The scope of the project starts from the city scale and then narrows down towards the selected barrio of study.

At this level the discussion is based on major intervention that can be carried out towards the improvement of the selected barrio of study. The Prototype project a selected and discussed base on the how they improve the smartness of the barrio as a whole.

Within the selected barrio a detailed architectural project has been conceived. Here we explore what could be done to help the individual homes. This project stands as model home that would seek to exhibit the possibilities of improving slum dwellings to be SMART.

9

SMART house

Slum housing problem with a SMART design

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9.1 Housing Thoughts

From the investigations of the IMM within the barrio, It was established that the volumes of houses within the study context could use an improvement. On the urban scale the decision was made to add by infilling and upgrading. This section elaborates on the design of a Housing in the African context, Low Cost housing and important inspirations that guided the design process.

9.1.1 Low Cost

To achieve the a low cost design , the team focused on the use of local material ,local skills and the use provision of quality expandable housing. The implementation of these three thoughts highly ensure the provision of housing that would be within the means of the people.

- Expandability;

It is undoubtable that slums in them serves are a manifestation of expandability and incrementally in housing. Slum dwellers have demonstrated around the world that one would always find a place to lay their heads first then expand. Chilean Architect, Alejandro Aravena has demonstrated that formalizing this process in a way can be useful to a move organized urban development. He provides a three pillars needed to satisfied in a low cost housing scheme. He advices that when one cant provide all that is needed for the housing scheme at the available budget, the following ABC(Figure 9.2) should be observed;

A. Focus on what is more difficult

B. Focus on what cannot be done individually

C. Focus on what will guarantee the common good in the future.

He further defines the design conditions needed to satisfy the ABC as follows;

1.Good location
2. Harmonious growth in time
3. Urban layout
4. Provide Structure for the final scenario of growth
5. Have a middle class DNA

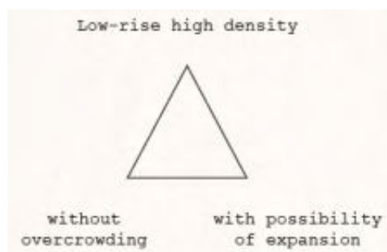


Figure 9.2 The ABC of housing by Elmental

- Local Material;

As established in chapter 3, Quelimane is a port city and as such the availability of used shipping containers stands of a possible high. In order to form a part of a bigger circular economy, the design incorporates the use of containers as the main structure of the building(Figure 9.3). This is expected to reduce the total cost of an equivalent the structure while benefiting the City of Quelimane. Local skills such as welding and carpentry in the city also informed the use of materials easily available in Quelimane. The effect of this was the choice of using local wood and steel sizes common to the region.

Furthermore, local traditional crafts mainly the production of straw roofs and bamboo waffles were highly considered in the design of the structure(Figure 9.4). Further details on the use of the mentioned materials and their applications in the project are elaborated through design process.

Figure 9.1 Expandable Low cost hose by Elemental

Figure 9.3 Containers at the Port of Quelimane

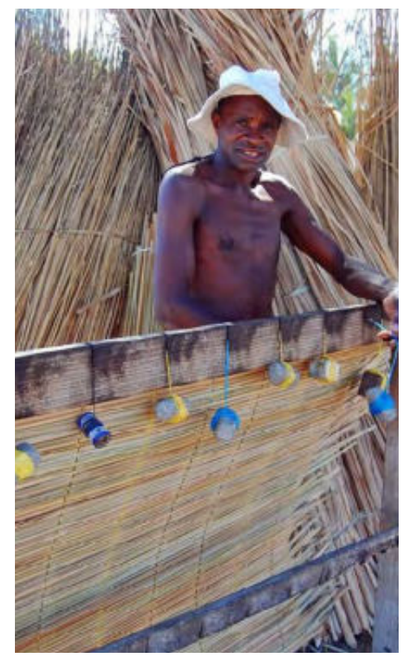


Figure 9.4 Local Artisan builds out dried straw.

9.1.2 Quality Life

Achieving quality of life in a slum area can seem daunting. This is due to the abundance of poor living standards. The main characteristic slums have in co mmon to the formal dense urban settlements is density. This key thought lead to the case study of Donnybrook Quarter. Completed in 2006, Donnybrook Quarter has been said to have redefine the terms of urban terraced housing. The design focusses on achieving a medium density while providing quality of life. The design explores the use of material selection and design techniques.

Material choices of the DonnyBrook Quaarter , is based on cultural preferences and the familiarity of the local. Brick was the choice, and further render white. Finishing a building in white in the British industry was no unfamiliar occurrence. However the architects preference for white in this occasion was to foster the reflection of quality sunlight into the courts spaces. This inevitably have contributed to the high quality of out spaces. It further affects the interior spaces as it allows over 80% of the ground floor spaces to enjoy sunlight on march 21st

Figure 9.5 Donny-Brook Quarter , medium density with good quality life

Design techniques chosen at donnybrook to improve the privacy and the quality of induvial time is seen in the use of windows. The design was guided by the regulation restricting the opposite windows within 22meter distances. The design technique was to rotate the floor plans on the levels by 90 degrees to force their views either into the main street or the external courtyard. This approach not only satisfied the regulation but also reduce the possibility of unwelcomed over looking(Figure 9.7).

Furthermore, The architect sought to improve the comfort and reduce over reliance on mechanical lighting through the design techniques. The design focuses communal spaces towards the south. This was meant to gain quality natural light through out most of the usage period. Also the design takes advantage of the white rendered walls to reflect and improve the daylight in less lit spaces(Figure 9.6). While the design targeted a daylight factor of 5% the real test showed 9%. This meant the design had achieved the and stayed between the comfort limit.

Figure 9.7 Compact urabn plan with ensured privacy.

Figure 9.6 Donny-Brook Quarter : Daylight admission and reflection from white rendered walls.

Finally the design also provides the individual feel of ownership , by creating individual entrances to the apartments. While this would was bent to reduce communal encounter, the design employed a counter space to avoid the problem. The communal courtyard forces the encounter while the individuality is enjoyed at the most intimate level, the home.

9.1.3 Modularity

The team also looks through the idea of modularity in terms of construction system and materials. We tried to use advanced construction technologies however making it more local and contextual. Most of the building materials are prefabricated and are coming as modules to the construction site. In this case, we can reduce the period of construction time and the labour cost. The modular timber frames and compressed straw panels will be produced by a local business and can be easily mantled by the users. This kind of housing concepts were also implemented in different part of the world but we choose to inspired by a project applied in Ethiopia.

The project address the expected population growth and to help lay the foundations for a sustainable urban and social development, students from the Institute of Experimental Architecture at Bauhaus-Universität Weimar and EiABC (Ethiopian Institute of Architecture Building Construction and City Development) worked together to build three residential prototypes at a 1:1 scale for Addis Ababa: the capital of Ethiopia and the heart of hyper-urbanization.

The construction took Two weeks to complete on the area of 86.00 m² with extension space of 30.00 m². Pre-fab elements out of concrete foundations and column, Eucalyptus rips with plywood sheets, Eucalyptus frame, prefabricated, highly compressed straw panels, Light timber frames and claddings (prefab), rubber, metal sheets and compressed wood were used with the budget of 7,000 USD (first floor finished, ground floor incremental).

Developing countries have to find their own modes of urbanization rather than relying on outdated or inappropriate models from the so-called 'developed world'. It must re-invent its indigenous building methods, construction technologies, and material use.

Figure 9.8 Experimental house in Addis ababa, Ethiopia.

9.2 Design concept

The team proposed a concept which integrates low cost, expandable and modular housing. The abundant of containers in Quelimane and the availability of natural materials such as bamboo, timber and straw makes the design to be rely on those materials.

Containers in the port of Quelimane are easily available to the users interms of transportation and affordability. It is also possible to observe container shelters, shops and small businesses built out of container in Quelimane.

On the other hand, bamboo and tached roof made of straw are very common way of the local architecture and construction. These elements gives the team to think mingling of the local architecture with the contemporary one. The design will have two types of façades and spaces made of bamboo and container, the former is the representative of the folk architecture whereas the later stands for the modern tiny houses around the world. By doing this, the building appears as the harmonious intervention between two types of idea in the middle of the slums.

These would give the slum dwellers a sense of confidence and the know how on using traditional knowledge and materials to create a comfortable, durable and aesthetically pleasing architecture.

We also applied basic principles such as modularity in construction system, use of local materials, expandability for future needs and low cost in the early design stage.

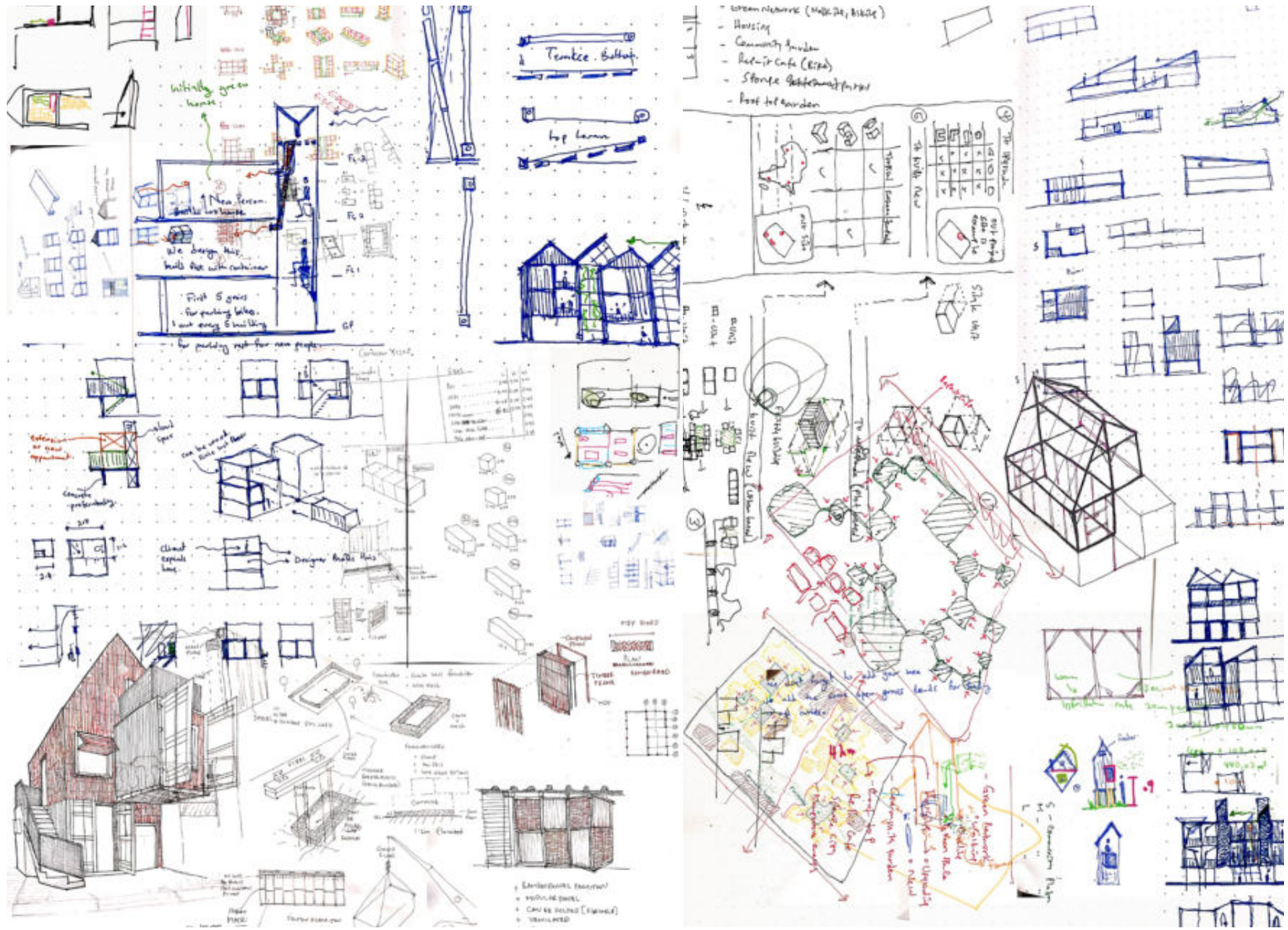


Figure 9.9 Original concept sketches throughout the whole process

9.3 Early holistic design

9.3.1 Envelope Form

Upon deliberating and establishing the concept, two main forms manifested. Both forms incorporated the use shipping containers. Under this subheading the advantages of the forms are discussed considering their expansion approaches, their effects on energy needs and SV factor. The selected form is then used to analyse the effects on energy needs of basic passive strategies in the locality.

- Form A

This incorporated the use two shipping containers as the basic structure. It allows expansion both vertical and horizontal expansions. The shipping containers are stacked in an asymmetrically in elevation view. This provides sheltered space for the future development on the lower section. While the upper section is also granted the equal benefit of expansion using the top of the lower container. This form envisions the use of cranes only during the initial container stacking. From there users are given the freedom of expansion using local techniques available such as wood.

- Starts with two containers providing 30sqm for two families.
- Expansion by use of local materials and controlled at personal pace.
- Form A promises a total of 75sqm for two families in the final scenario.

- Form B

This form uses an approach were the homes are built of containers stacked and arranged on the site over a period. The construction process is thus not limited to the first period. Rather the construction would use a collective effort to grow in over the years. The expansion process here is also both vertical and horizontal. There is also the added advantage that homes are provided with larger living spaces compared to Form A.

- Starts with two containers providing 36sqm of space for a single family
- Expansion using by stacking newer two containers on the existing ones
- This form brings the up 75sqm of to a single family.

- Energy Needs and SV

The SV factors of both forms were compared along with their expected energy consumptions. For a clearer understanding of the forms, the base material was considered as metal with a conductivity of 42 W/mk. This selection was based on the knowledge that shipping container typical come in weathered steel(-Corten). Using the thermal conductivity of actual containers without insulation for the start situation allowed an understanding of the dominant needs of the location.

It was found that although the Form A had a lower SV (0.99), exhibited higher energy needs compared to the Form B(1.07). The energy needs from this initial sketch simulation also revealed that the location is highly cooling dominated. Considering the benefits that can bee gained from the Form A architecturally, we ignored the Form B.

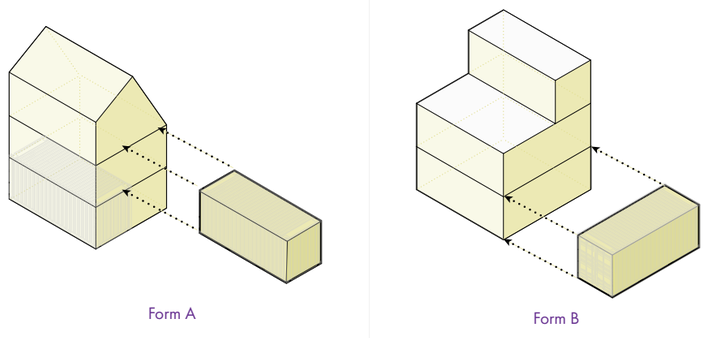


Figure 9.10 Forms A and B used for the SV analysis

Form	Surface Area [m2]	Volume [m³]	SV factor	Cooling Demand [kWh/m²]	Heating Demand [kWh/m²]
Form A	226.4	226	0.99	249.79	2.59
Form B	241.2	226	1.06	221.09	2.29

Figure 9.11 SV factor comparison of Forms A and B

9.3.2 Orientation Analysis

Orientation of a building has to do with how the building is positioned in relation to the elements of nature. These elements include sun's position and the wind direction. Positioning the build can be based on wither of the two. This in turn would affect both the comfort and the energy consumption of the house. Since the project aims a providing a passive design intervention with no reliance on mechanical cooling systems, the team analysed at the early stage the selected form. Three main factors were considered in relation to the analysis. While three of the factors relied on natural elements , the other in contrast relied on the urban morphology of the site. Aim therefore, was to find a middle ground between the factors .To understand this better, the selected form was oriented with the larger faced roof in the four main cardinal directions and also similar to the urban morphology. This way the study was able to understand the best middle ground to select. The two factors are explained below using the said orientations;

- Radiation impact

The location of the site lies within the southern hemisphere. It a regular occurrence to have the moving within the north within this climatic area. However the sun path diagram reveal that due to the location of the site latitudinally, the sun path is not limited to the north. It make its way down south as well. The study of radiation would be on the effects on energy demand and the power generation.

– Power generation;

Two main factors influence the power generation. These were the orientation and the angle of the PV panels. For the angle selection , the Photovoltaic Geographical information system website was used. The website has a model for the radiation received around the earth . This model is based on over 40 station worldwide (as of 2011). Based on their web estimation service the following Chart was developed(Figure 9.12).

From the chart, radiation level were expected to be relatively similar year during the summer using a 60 degree angle. However the angle of 60degres is expected to receive about 21% less irradiation compare to the 22 degrees. Although 22 degrees would have been optimum, the team chose to work with 60 degrees. The choice was influenced by the fact that more radiation on the roof would be translated into

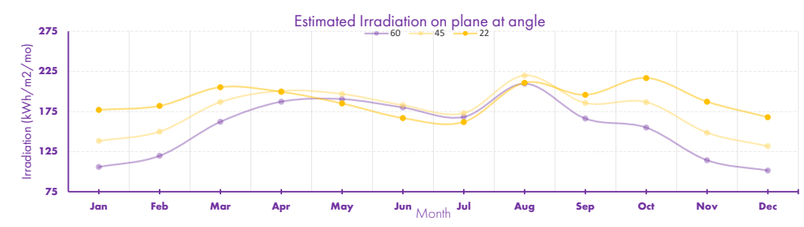


Figure 9.12 Averaged Monthly Estimated radiance levels (Source : Photovoltaic Geographical information system)

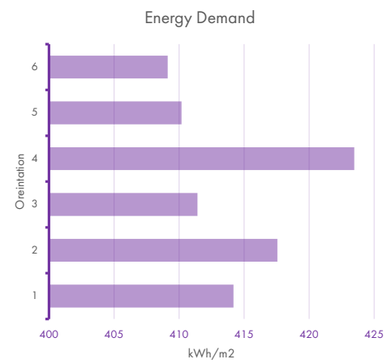
Figure 9.13 Energy demand for the selected study orientations

more cooling needs. It must be noted that the actual figures from the web system were based on a 2005 model for the Quelimane. Thus for clear analysis of the irradiance on site at the specified orientations, Ladybug analysis tools was used.
In Ladybug the total radiation falling on to the larger roof area was estimated using a 2013 climate file(the most recent at the time of study). Here the aim was to find the orientation with the highest solar gains and the best roof angle for the site. This is crucial in determining the theoretical power of the PV systems. The theoretical power Is estimated using the peak power of the solar panels and the solar irradiance. (P= Pnorm*G/1000). Since the full area of solar panels and power demand had not been decided at this level, the formula was used a guide towards evaluating the irradiance's importance. Assuming a PV panel of peak power 50W/m2 the following energy can be forecasted per orientation at an angle of 60 degrees inclination(Figure 9.13).

Table 9.23 Irradiation levels per orientation based on the 2013 weather file

Large Roof	Radiation	Rad/m2 (Kwh/m2)	Power
South	23,140	845	42.26
North	39,863	1,456	72.80
East	32,248	1,178	58.89
West	37,313	1,363	68.14
North-East	36,744	1,342	67.10
South-West	29,081	1,062	53.10

The estimated Power production per square meter of panel is highest in when the large roof area is oriented towards the North. The North-eastern typical urban orientation in the context also performs just about 7 % less. Also the flip version ie; south-western orientation was found to be 21% lower.



– Energy demand;
Following the analysis, it was clear that orienting the larger faced roof area towards the North-East or the South-west gave the least effect on energy. This was also in line with the orientation of buildings within the urban morphology. Although there were improvement in energy demand due to the orientation, its effective reduction was less (3%) with respect to the extreme cases(Figure 9.13)
This could be attributed to the fact that the study model at this stage had no window openings. The effect would thus be amplified if there were windows. Although the reduction was 3% , it was still taken into account for design decisions.

– Wind Analysis
The predominant wind direction from the climate study was from the South east direction while the north east was predominant in a single quarter of the year. Knowing the predominate direction, the team conducted an analysis of the different orientations and effective the wind pressures around the form. The utilizing the predominate wind direction and a speed of 20m/s the different pressure effect on the building form was observed. A series of averaged negative and positive pressures were computed(Figure 9.14).
It was observed that both pressures were lowest in the South-west and north east oriented forms. This was observed to be about lower the worst case.

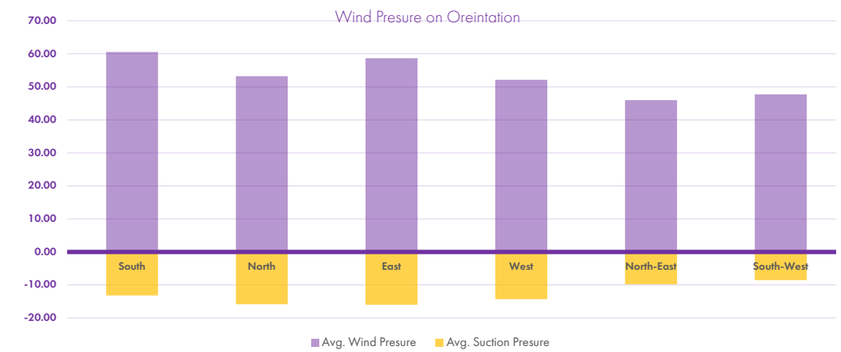


Figure 9.14 Averaged Wind Pressures around the different orientations

The wind pressure diagrams further give a visual representation of the areas affected. The south and east oriented forms are exposed to more effects of wind actions preface area. On other hand the better performing North-Eastern and South-Western oriented forms had less exposed surface to the wind effects(-Figure 9.184).

- Conclusions

Based on the above findings the team finalized the form and orientation study by choosing the North-Eastern and South – Western oriented form. The North-eastern was chosen over it flip version It was preferred due to the following reason;

1. Adheres to the urban form of the area
2. It had second lowest energy demands
3. Its effective wind pressures were lowest recorded.
4. It had 21% percentage high energy production potential to the South – Western form.

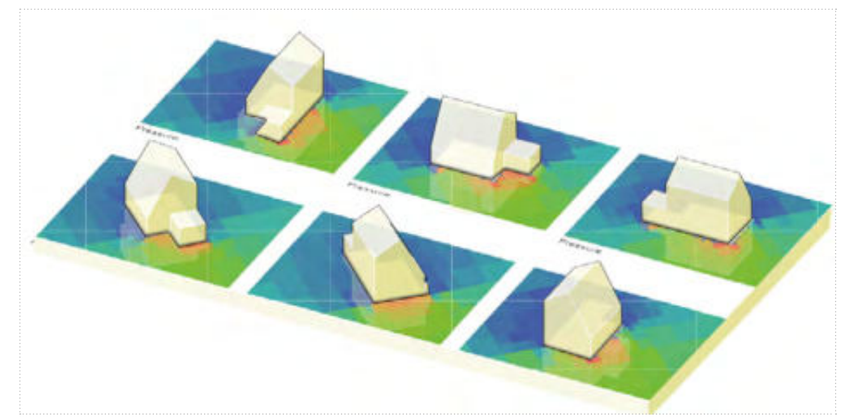


Figure 9.15 Wind presures around the different form .

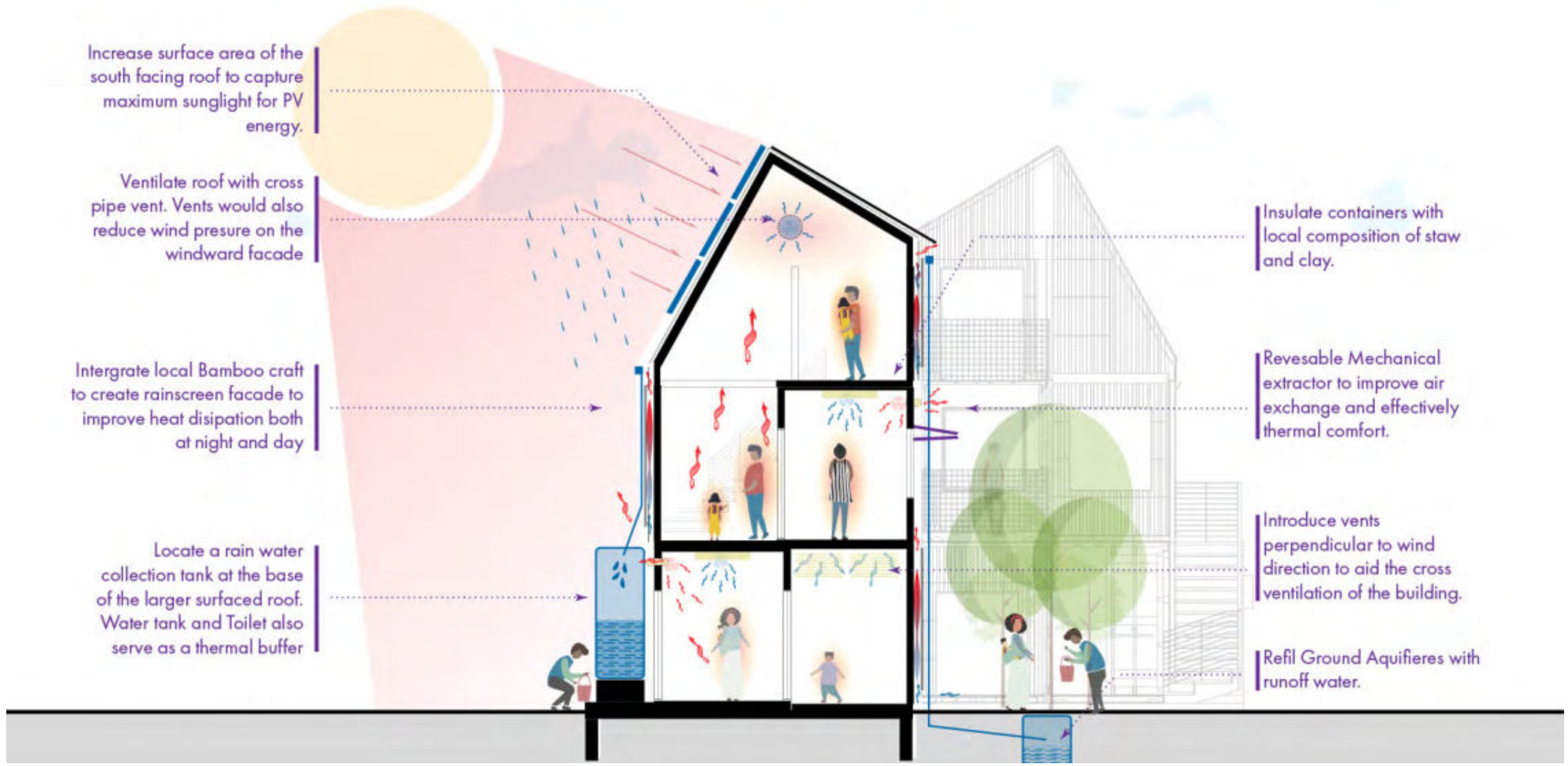


Figure 9.16 Schematic design on cross section of SMART house

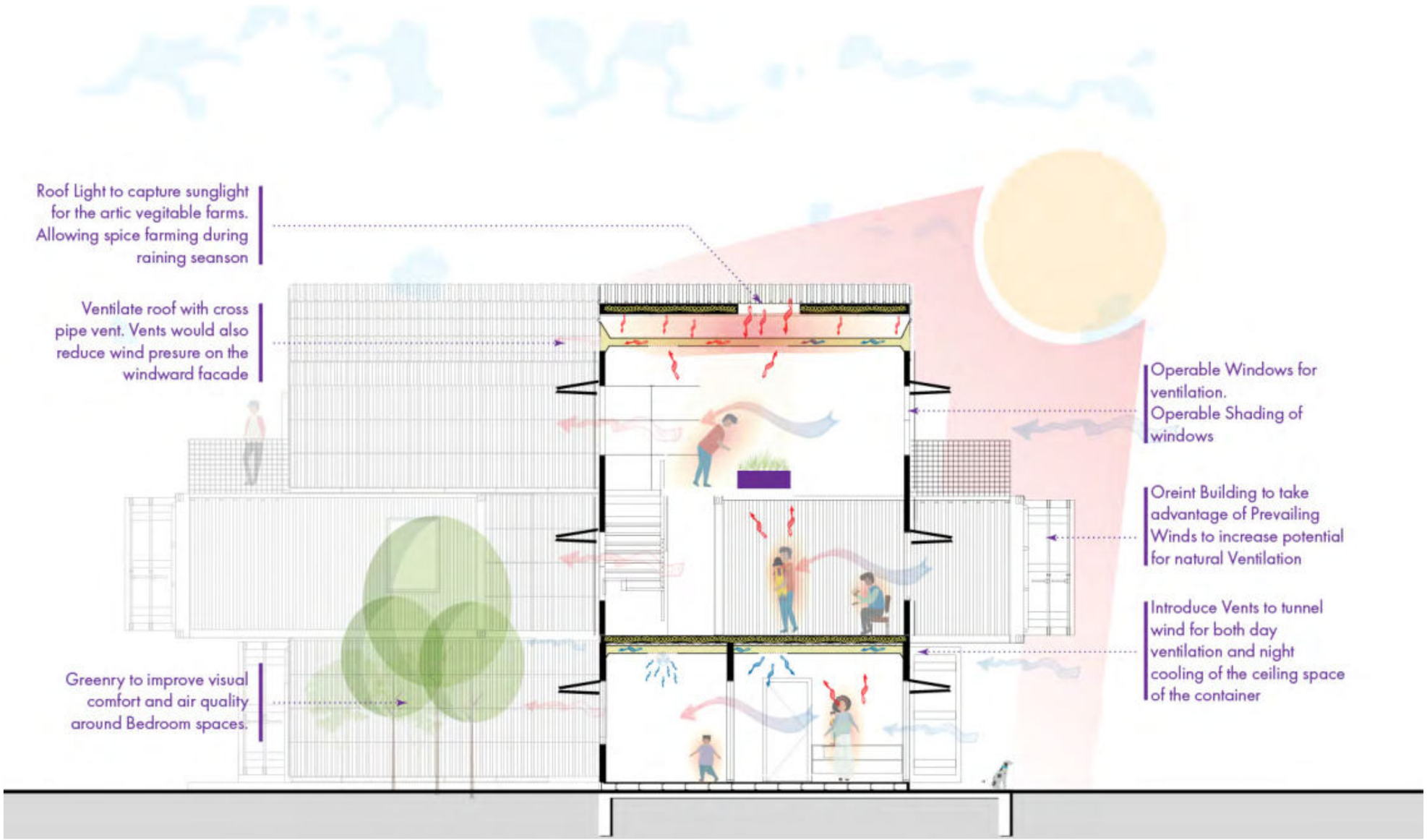
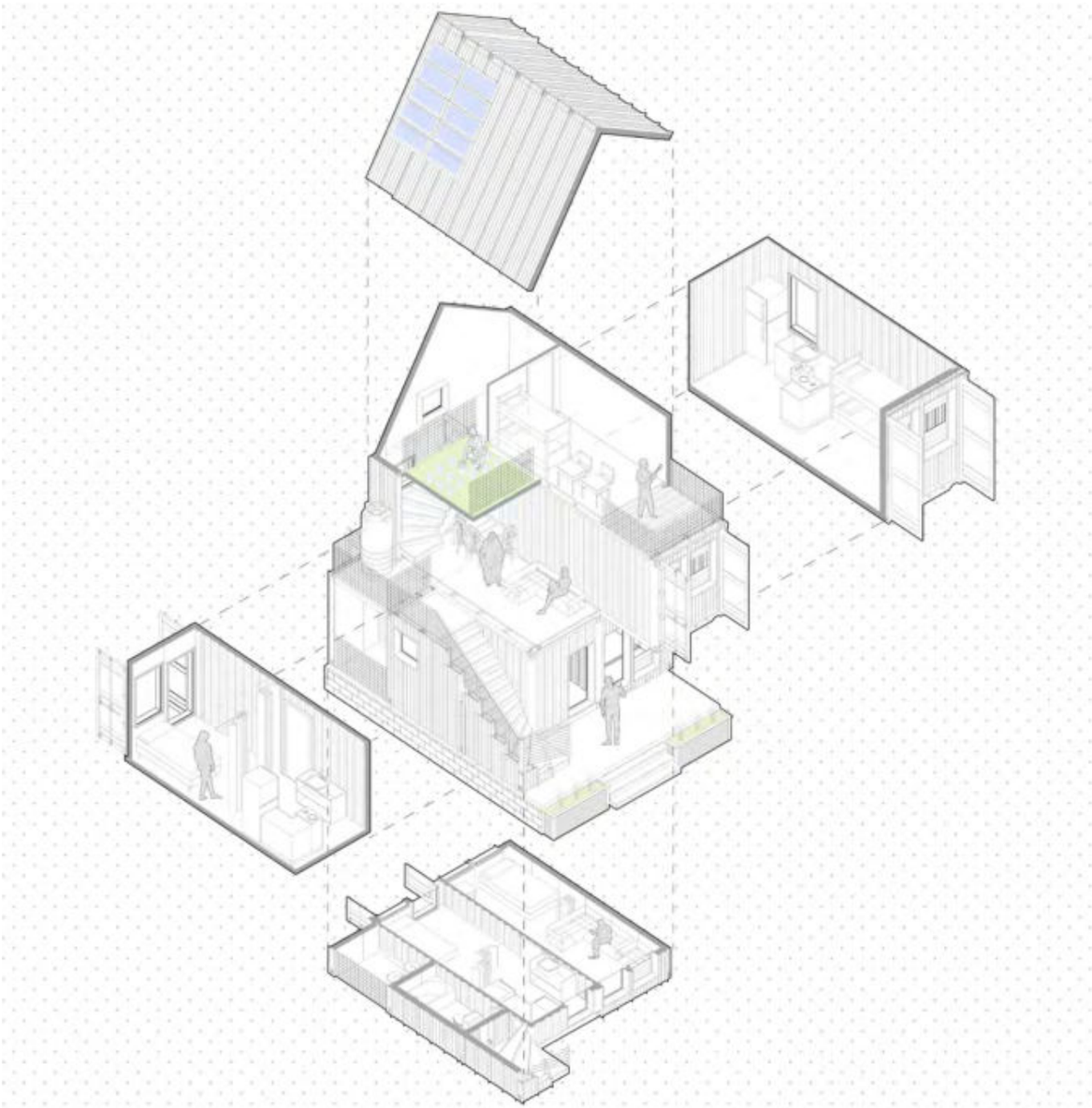


Figure 9.17 Schematic design on longtidunal section of SMART house

9.4 how SMART ?



In the perivous section we have seen that how the building is optimized considering energy demand, orientation, wind and solar radiation. After all, the components carved the final outlook of the building.
In section, we will discuss about the elements of the design which makes the house SMART with the help of discription and illustrations.

- Soft

As a reminder David Sim explains further a concept of a "Soft city" as being related to the getting closer, connecting people and to all aspects of life around them. This idea is applied in our building through the design of pocket green areas in the existing and new buildings which helps to activate the social life between the buildings. The big green court in the South-East part of the site is also intended to be playground for childrens and outdoor space for different events (Figure 9.30).
As mentioned in chapter 07 (pg. 105 green network) of this book, the components of the green network are needed to soften the place or the neighborhood. Within the context of the streets and open spaces there are different elements that would help to make them highly efficient in softening the context.
The above mentioned thoughts are demonstrated by the arrangment of buildings in the site that allows the integration of green areas, walking paths, cycling roots and socialization areas (). Moreover, the entrance has a small verndah space which makes the two families that are living on ground and upstairs to meet there in daily basis(Figure 9.18). The design also considers a bicycle parking space under the stair case which can accomodate three bikes at a time.

Figure 9.18 Soft application on the building level

- Multilayer

As a reminder of the multilayer concept from the previous chapter, it considers the introduction of different function to buildings at medium to higher densities. This approach seeks to consecrate people and functions thus promoting walkability (pg. 109 chapter 07). In this case we considered applying the thoughts in the site and building level. The idea of enclosure, which is composed of groups of buildings that are typically built on the edge of the property and form an inner enclosure, is taken into account when preparing the master plan(Figure 9.30). By doing that, the buildings were able to define the perimeter of the site to create a back yard common spaces.

The buildings along the street are accomodating commercial activities to attract people and local buisnesses. It is also assured that the common spaces can serve multilayred activities such as mini-farms, playgrounds, events and sport activities.

Expandability: The design strategy allows the occupants to expand the spaces based on their family size, economic status and functional requirnment.

The figure below (Figure 9.19) shows the dirction of expansion inside the predefined envelop of the building. The dwellers in the ground floor has the opportunity to expand their house horizontally and the families from upstairs can extend their home horizontally and verically. Both families start to live in the containers with the basic functions such as sleeping area, cooking space and bath room as a starter. Then, they can add additional bed rooms, living and dining spaces later on.

Functional adaptation: The other aspect in which Multilayer can be attained is by fuctional felxiability. The container space can be partitioned using folding bamboo panels to alter different functions.

Site adaptation: The SMART hoses can be arranged in different groups according to the site.

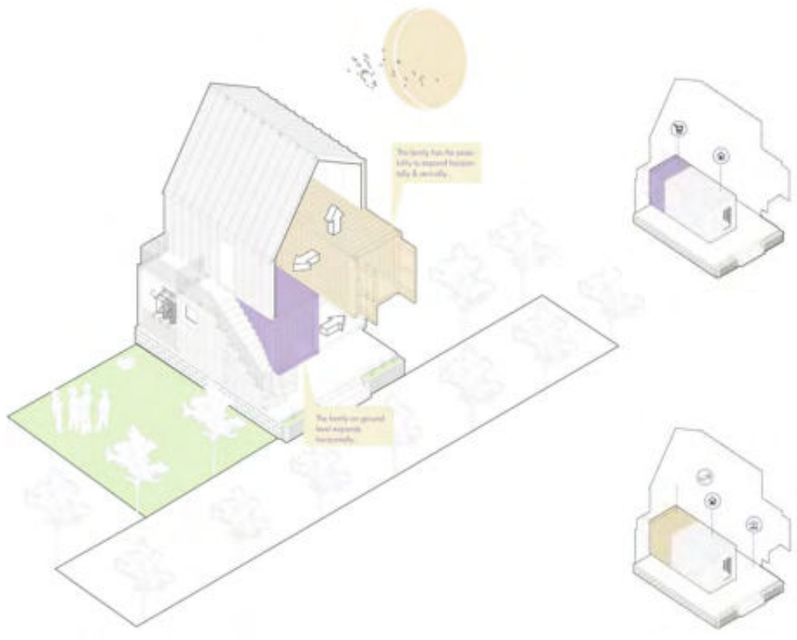


Figure 9.19 Expandability and functional adaptation of the SMART house.

Figure 9.20 Site and functional adaptation of the SMART house

- Agritecture

''The concept of Agritecture is to utilize the architecture not only for habitable spaces but also to produce food. By designing our buildings, cities, public spaces, schools and any civic functions with food in mind, we can make our cities food producers and make food part of urban life process by eliminating the physical barrier between food and us.''

The above statement is taken from the SMART chapter to show the applications of Agritecture in our design. The SMART houses are arranged in the site in such way that they can create a pocket green spaces which becomes a garden.

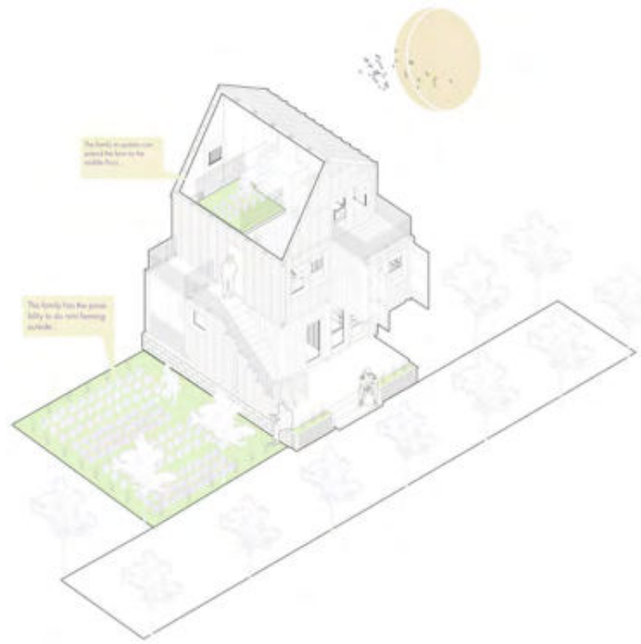
There are 24 modules in overall site and they have 12 individual gardens shared by the families with the ratio of 4:1. Using the outdoor shared gardens, each family can cultivate crops or vegitables for their own consumption (Figure 9.30).

On the other hand, the SMART houses also containes indoor space to grow food. The families at the upper level are more in number compared to the families downstair so, the design integrated a mezzanine floor garden (Figure 9.21).

The small garden can also help to purify the air in the home, because, Plants can absorb harmful gases through the pores in their leaves, filtering and cleaning the air we breathe every day. Not only the small garden have many health benefits, but it also add a nice touch of decor and bright energy to the indoor space. The garden is visually connected from the living room in the double height space which creates cozy and refershing space.

The other option that the dwellers in the upper floor have is that, they can instead change the bed room in second floor to full garden. This will be decided by the owners and dependent on the family size but as of now, the team proposed the space for bed room.

Figure 9.21 Application of Agritecture on the SMART house.



- Robust

Tony Hall in his book Robust city describes ''The concept has a close relation to the concept of the extendibility of buildings, particularly family houses. Whereas this is not appropriate for all buildings, the idea is that it is advantageous if their design allows scope for extending their size with minimal impact on both the original structure and surrounding buildings and spaces.''

The above mentioned concept has already discussed in Multilayer section. Satisfaying the changing needs of the space needs and future population growth.

On the other hand, the SMART houses are built on elevated foundation to protect themselves from flooding (Figure 9.22). Also, the robustness strategies for barrio 11 are discussed in detail in chapter 08 of this book and the structural integrity to resisit cyclons will be discussed in chapter 11.

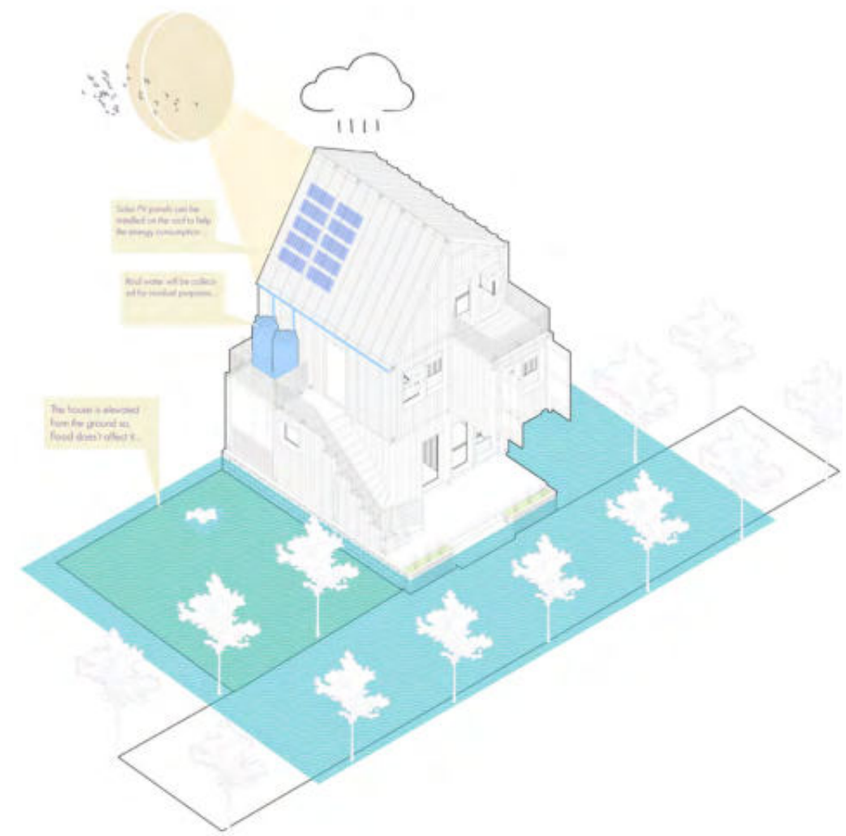
- Technology

In this section the two important technological integration are the PV panels and the Biogas energy production.

The roof design was purposly slanted to be compatiable with the future integration of solar PV panels. Electricity produced by solar cells is also clean and silent. Because they do not use fuel other than sunshine, PV systems do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health.

On the other hand, Biogas is also a clean and renewable form of energy available to low-income households through anaerobic digestion of readily available organic waste. A biodigester converts fermentable organic matter into a combustible gas and organic manure. So both forms of energy makes the SMART house dependent on reneable energy.

Figure 9.22 Application of Robustness and Technology on the SMART house.



9.5 The Study Block

The study block selected was an area within the within Barrio 11 within brownfields. The city of Quelimane has been projected to grow by approximately 146641 people in 2035. This is equivalent to about 64% increase in population. This growth can be assumed to come with its housing issues and inevitably slum growth. The urban block study addresses this issue using the prototype SMART house.

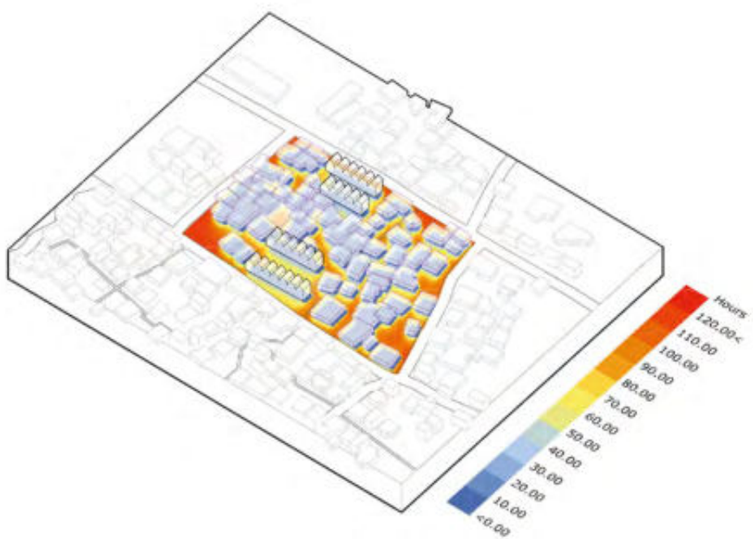
Here the Smart house designed in the previous subchapter is populated to meet the current housing needs of the study block. It is also meant to provide a shelter for the relocated households. The current study block had a Floor area ratio (FAR) of 0.49 for a population density of 0.034. This currently serves approximately 240 inhabitants. Superimposing the city's growth increase by 2035 onto the current block, approximately 155 new inhabitants could be expected. The living building challenge classifies areas of FAR of 0.5 – 1.49 to be small towns or city edge. This classification guided the team's assumption of a proposed FAR for the study block. With the relocation of settlers from the green belt area and the future growth of the city in mind, we assumed a FAR of 1.

Thus, the design here begins with a record of the houses below 30sqm. These houses were deemed open for either reconstruction, upgrade, or expansion. The housing need within the neighborhood was established to be approximately 25 two story buildings needed to satisfy the assumed FAR of 1. This assumes a household to be made up of 3 occupants under a sharing 30sqm space.

The selection of the houses and the use of the brown field was aimed at ensuring that the city may grow, but in a limited horizontal area. Since the SMART house provided shelter for more than a family, it was clear that introducing the smart homes was going to be an integral addition to limiting horizontal urban expansion.

Three different housing typologies were explored to understand the possible advantages that could inform the final layout. The typologies were the Row housing, the individual(scattered) and the compact (high density). These are discussed using their effect on the Softness.

Figure 9.23 Row housing arrangment and study



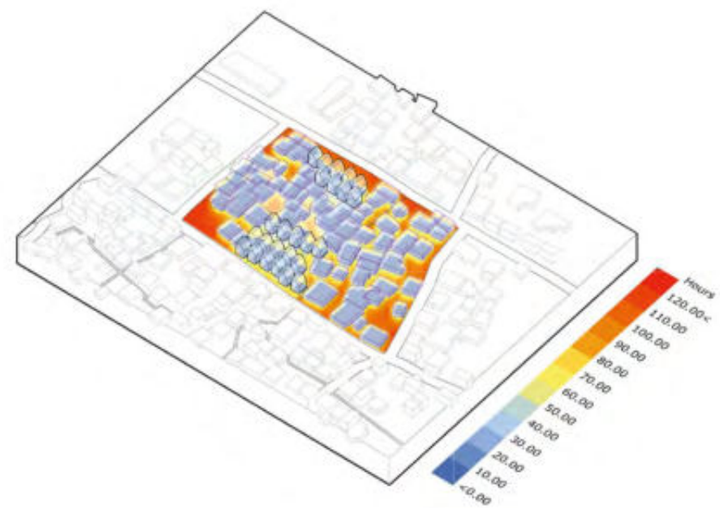


Figure 9.24 Individual house arrangment and study

Figure 9.25 Compacted arrangment of houses and study

Figure 9.26 The final arrangment that has been selected

- Soft

Softness as has been explained throughout this book, is aimed at connecting people. Thus, we explored the effects of the housing typologies on the potential for encounter. The individual here fails as it isolates residents. The compact on the encourages high interaction due to the increased proximity. The row provided a combination of both ends.

The potential for encounter is further examined in terms of comfortable places of encounter. The arrangements of the buildings can potentially create thermally comfortable hours in the outdoors. This provides a potential place of encounter. The three typologies show the following results.

Here, the charts display the number of hours within the year with outdoor temperatures higher than comfortable (using the universal thermal comfort). Thus, the charts give an indication of the typology creating favorable outdoor condition for encounter. It is found that the staggered arrangement with small garden on it has better performance considering all parameters discussed.

Table 9.24 The results of the different arrangment of houses in the selected site

Housing arrangment	SV factor	EUI	Avg. Dicomfortable hours/year
Individual	0.85	595.68	36.73
Compact	0.43	454.75	40.63
Row houses	0.36	524.51	39.02
Final selected	0.32	652.43	37.58

- Phase one

According to the analysis given above, we identified the buildings which floor area per person is below the standard to be demolished. As a base line 30 sqm was used to identify the mentioned buildings (Purple buildings in fig). On the other hand, the buildings in yellow color are identified as to be upgraded. The existing vegitation is also kept to be integrated with the newly added buildings.

- Phase Two

In this stage, the construction of 24 new foundations will begin. We grouped the SMART houses in different parts of the site so that the sense of community can be acheived. In addition, the arrangment of the SMART houses creates a pocket green areas between the houses which are suitable for socialization and any form of outdoor activity.

- Phase Three/Four

These can be considered as the final construction phases in which the owner of the new houses will bring the containers to place on the foundations that already built. The families on ground floor (Couples) of each SMART house can start living immediatly after placing the container. The families who own the upper floors (Big family) can place there containers on the already built steel framed structure and start to live inside.

The final stage would be expanding the existing living spaces horizontally and vertically accordingly. These can be done whenever the family is economically ready.

Figure 9.27 Phase one, demolishing and upgrading

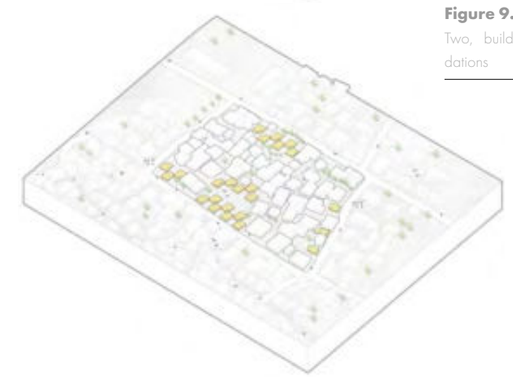


Figure 9.28 Phase Two, building the foundations

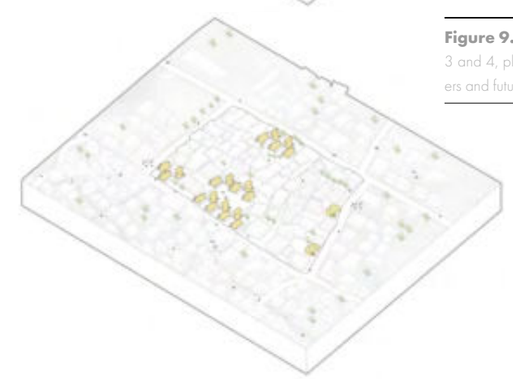


Figure 9.29 Phase 3 and 4, placing containers and future expansion

Figure 9.30 The Master plan. It shows the SMART house arrangment, the green areas and the new added routes which connects the site with barrio 11

Figure 9.31 Street elevation

SBT

Sustainable building technology

Sustainable building Technology means improving our social and environmental footprint at every stage of the product life, from raw material extraction to end of life of Raw materials. Our responsibility begins with the raw materials we use, which are all sourced in line with the latest environmental and social guidelines. The design of SMART house advocates the use of locally sourced materials such as bamboo, Straw, Containers and Timber. It should be noticed that the definitions of sustainable construction vary from place to place, and are constantly evolving to encompass varying approaches and priorities. In our case, we designed the building to be constructed mostly by the local knowledge and labour, which highly support the transfer of western building technologies to be contextualized and used by local communities.

10 Holistic Yet SMART

Improving the sustainability of the Design

What to Expect

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10.1 Building Optimization.

The building optimization is has been carried out using passive strategies only. The choisce of maintinanig only passive strategies was based on the low cost agenda that is coupled with slum design. Finally the optimsation seek to meet the higher standards outlined by the Living builing challenge. Thus the building is set to become a symbol of the what can be achieved using local material abundant in the region. By this concept the building would satisfy the beauty Petals on completion.

10.1.1 Baseline Models

To optimize the building, a base model for comparison is require as well as standard for study. To understand also how well the strategies are performing also we considered the localized construction techniques for the metal and wooden structures. The since the climate of the Quelimane has been classified by ASHRAE as 1b, it was very appropriate the baseline envelope requirements set out in ASHRAE 90.1. Next was a consideration of the construction technique found in the area to represent the start Basline bare model. This decision was important since the ASHRAE baseline was more of an idealized situation that was not common to the construction industry of Quelimane. The final envolpe layers are outlined in the table below.

10.1.2 Benchmark Parameters

The stricter and more rigors EN15251 serves as a compliment to the study of comfort while optimizing the building. Recommendations from other guides as CIBES and the EN15251 were used to study in detail the comfort requirements needed for the building. The EN1521 provides the base framework of the adaptive model which is derived using the running mean temperature. This approach was preferred over the ASHRAE due it use of the outdoor temperature for the adaptive comfort. The use of the adaptive comfort model also required a set target class to satisfy. For this the team chose to achieve the class 2 based on the EN15251. To calculate the running mean temperature the following formular was adopted based on the EN15251.

Category II

upper limit: $Qi\ max = 0{,}33\ Qrm + 18{,}8 + 3$

lower limit: $Qi\ min = 0{,}33\ Qrm + 18{,}8 - 3$

where Qi = limit value of indoor operative temperature, oC

Furthermore the set recommended temperature range considered was base on table A.3 of EN15251 category 2 assuming the cooling range. These presumptions adapted the comfort model to climate of Quelimane. To manage and stream line the data obtained from simulations towards understanding the building in relation to the climate, the team adopted an energy metric, comfort metrics and a recommendations from CIBSE.

- Quality sleep;

CIBSE recommends one parameters for the assessment of overheating risk. It recommends maintaining peak bedroom temperature below 26C to promote good quality sleep. It stipulates that, quality sleep may be compromised above 24C. 26C is thus a threshold set to a maximum of 1% of the annual hours. Here the 1% of the annual hours is restricted to between 22:00 and 7:00. This is correspondent to 33hours a year.

- Overheating hours;

This was an inferred parameter establish by the team. The parameter refers to all hours withing the year when the indoor temperature exceeds the upper limit target. In this case the target is base on the category 2 of the EN15251.

Figure 10.1 U-vlaues of the envelopes used as the baseline.

Base Model	Maximum Uvalues [w/m2K]									
	Glass	Glass Frame		Roofs		Ceiling	Metal Frame	Wood Frame walls	mass Wall	Floors
Base Model Ashrae for climate 1_2010	-	-	5.84	0.388	-	-	0.573	0.546	-	0.2
Base Model Metal Wood	0.71	3.65		5.88	-	5.58	5.88	5.58	-	5.58
Base Model Ashrae for climate 1	0.3	6.82	-	-	4.26	0.2	-	0.47	1.12	0.36

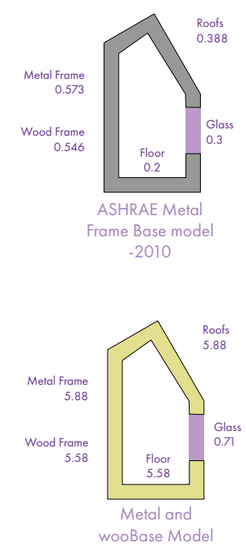


Figure 10.2 Base Models for the ASHRAE and the Starting case

- Energy Use Intensity;

This refers to the energy consumption of the building per annum per square meter. This is commonly used to indicate the building performance. However in this study, it use to indicate the predicted energy demand of the project. The conditioning assumption used to predict this energy demand is an idealized air.

10.1.3 Sample Zones

To measure the effects on the building strategies applied on the comfort of the building, the team identified worst performing spaces representing the metal container and the wood construction. CIBSE adicvies that the sample space be the zone a)with large glazing areas, (b) on the topmost floor, (c) having less shading, (d) having large, sun-facing windows, (e) having a single aspect, or (c) having limited opening windows .

The Bedrooms on both the second floor and first floor bedroom were identified in this respect. The Second-floor bedroom would inform decisions relating to the roof and wooden wall construction due to its excessive exposure to the northern sun. On the other hand the first floor bedroom would inform for the decisions relating to the treatment of the container structure.

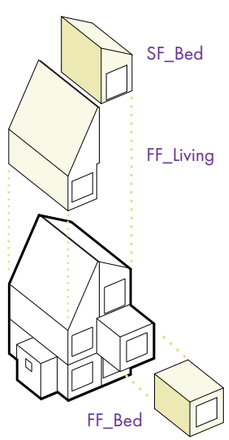


Figure 10.3 Sample zones

10.1.4 Optimization strategies

The break down of the energy on the initial simulation of the base case revealed high demand for cooling all year round. Further observation of the breakdown showed that energy gains into the building were dominated by the conduction from the opaque surface thus the envelope. The solar gains is next identified source of heat. Based on these observation the following passive strategies have been selected; Opaque layer, ventilation and Glazing shading. These are discussed individually the next sections.

Study Model	Cooling	Heating	EUI
Base Model Ashrae	113.80	0.16	113.96
Base Model B Metal	400.22	6.80	407.02

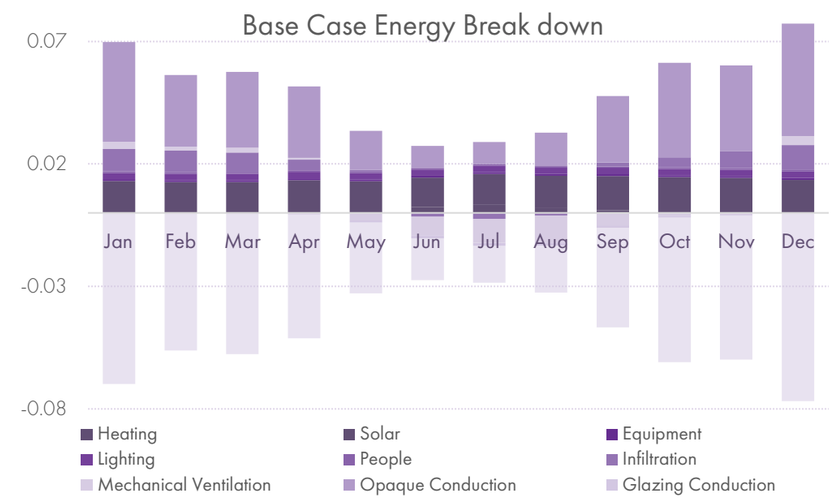


Figure 10.4 Energy Break down of the base case.

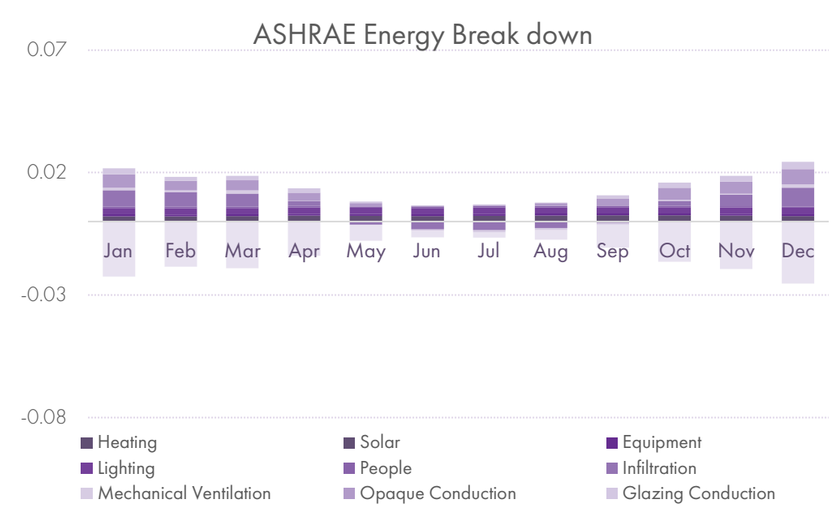


Figure 10.5 Energy Break down of the ASHRAE

10.2 Opaque Strategies

The selection of materials for the layering of the structure is based on the architectural decision to work with localized sources. This constraints the designer to find thermally performing materials that can found locally. The decision is also guided by the building living challenge Materials Petal. With respect to imperative 13; Living economy sourcing the following materials were chosen(Table 10.25)

- Insulation - Compressed straw

Straw is commonly found in local construction of Quelimane. In developed countries the return to straw for construction has seen the development of the European Straw Bale Gathering. Its thermal behavior has brought so much attention to the use of the material today. Straw is witnessing its renaissance as universities are pushing to get remove the stigma attached to its construction.

Studies into the thermal properties of straw have linked its thermal performance to its compression and its fiber arrangement. Other studies have also showed that straw moisture content affects the conductivity. According to the study by Jean-Philippe, the variation in thermal conductivity of the straw bales was due to density changes. With this in mind the team specified a compressed straw with fibers perpendicular to the heat flowed. This based on the literature of Jean-Philippe is of density about 90 kg/m3 and conductivity of 0.52.

- External Cladding ; Bamboo layer

The bamboo weave common to the locals of Quelimane is adopted as the external layer of the faced of the building. Although it is a cladding, it also serves to protect the layer of compressed straw.

- Ventilation cavity

A ventilation cavity has been decided between the bamboo layer and the water proofing. This is meant to allow the ventilation of the façade. The layer of air is allowed to move by the addition of exhausts in the facade. EN ISO 6946 establishes that the layer may be classified as ventilated if it has over 750mm2 ventilation openings per meter. This is equivalent to an air gap greater than .75mm at top and bottom ends. The air cavity widths 0.05m , 0.025 and 0.075m are studied to ventilate the façade.

- Water Proofing

Constructing the building layers requires a water proof layer against the predominate rains of Quelimane. The material choice for this was Polycarbonate sheet. This is in parallel to aid the exposure of the bamboo cladding. Three different visible transmittance types have been selected. These should aid the users bring variety to the context off similar buildings.

10.2.1 Insulation Variation

The first limitation from the architectural point of view was the maximum wall thickness. The architectural design limited the wall construction to a maximum of 150mm thickness. This meant that the variation of insulation all round the structure would be within 25mm thickness to 100mm thickness. First existing wall envelope part are striped into the their thermal layers in the following tables.

Table 10.25 Materials and their sources

Material	company	Distance form Quelimane	location
Polycarbonate roofing	Paralam	1791 km	58 Malcolm Moodie Cres, Jet Park, Boksburg, 1459, South Africa
bamboo	Local	local	Quelimane
Compressed straw	local	local	Local
OSB	Builders	Mapotu	Estrada Nacional 103 Gingoze Tete Mozambique, 000

Wood Wall Layers	Thermal Conductivity	Gross Density	Specific Heat capacity	Layer Thickness
Timber frame Construction				
Internal Layer				
OSB	0.130	650.0	1552	0.0180
Compressed Straw	0.052	90.0	1256	VAR
Bamboo Layer	0.157	600.0	1492	0.0500
External layer				
Container Wall _ Internal layer				
Internal Layer				
OSB	0.130	650.0	1552	0.0180
Compressed Straw	0.052	90.0	1256	VAR
Container Wall	42.000	7800.0	470	0.0020
External layer				
Roofing _ Internal layer				
Internal layer				
OSB	0.130	650.0	1552	0.0180
Compressed Straw	0.052	90.0	1256	VAR
Roofing Sheet	42.000	7800.0	470	0.0020
External layer				

Figure 10.6 Thermal layer of the envelop design

Envelope	Insulation Variation	Decrement Factor	Time Shift	U-Value	Envelope Thickness
Wood Frame construction	Ins_50	0.874	-3.37	0.63	0.118
	Ins_60	0.864	-3.58	0.56	0.128
	Ins_75	0.848	-3.92	0.48	0.143
	Ins_90	0.831	-4.27	0.424	0.158
	Ins_100	0.818	-4.53	0.39	0.168
Container construction	Ins_50	0.97	-1.29	0.79	0.75
	Ins_60	0.97	-1.45	0.68	0.85
	Ins_75	0.96	-1.72	0.57	0.95
	Ins_90	0.95	-2.03	0.49	0.110
	Ins_100	0.94	-2.25	0.45	0.120
Roof Construction	Ins_50	0.97	-1.21	0.79	0.98
	Ins_60	0.97	-1.37	0.68	0.108
	Ins_75	0.96	-1.64	0.57	0.118
	Ins_90	0.95	-1.95	0.49	0.133
	Ins_100	0.95	-2.17	0.45	0.143

Figure 10.7 Variation of the Insulation layer

Based on the above table it was possible to evaluate the thermal properties of the wall. The analysis used a range of 50mm to 100 thickness of variation in insulation. The outcome of this on the different wall construction's U-value, time shift and decrement factor are outlined in the table below(Figure 10.7).
Comparing to the standards, the above time shift and decrement factors can be said to be bad for all the construction. With that said, the effects of the various insulation variation is further seen in the following graph(Figure 10.8).

The chart shows the effects of the insulation with respect to the variation in peak temperatures higher than the expected from the tables. A closer look at the charts reveals that below 0.75mm thickness of insulation around the wall envelop the reduction in peak temperatures would be on the low(Figure 10.10).

The effects of the different insulation thickness is further examined on its ability to increase the comfort of occupants. It is observed that again the insulation thickness above 75mm out perform the lower thickness.

The yearly discomfort is where the effects of the insulation variation is seen best. It is observed that although the 100m thick insulation out performs the 75mm insulation, its over heating periods in the year were about 3% higher. A percentage difference in the night comfort is also seen here(Figure 10.9).
From these observations a minimum of 75mm insulation was selected for the envelope.

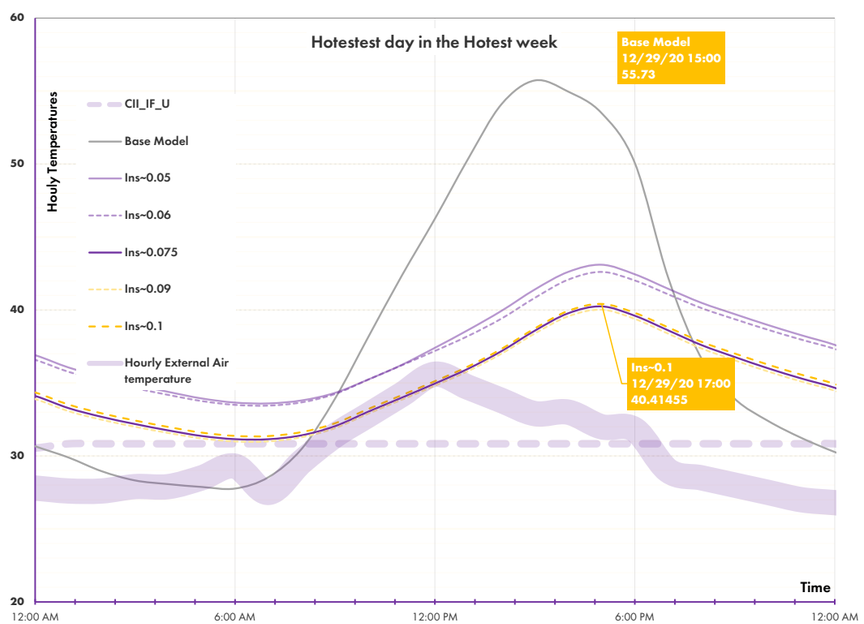


Figure 10.8 Time shift of the hottest day of the hottest week

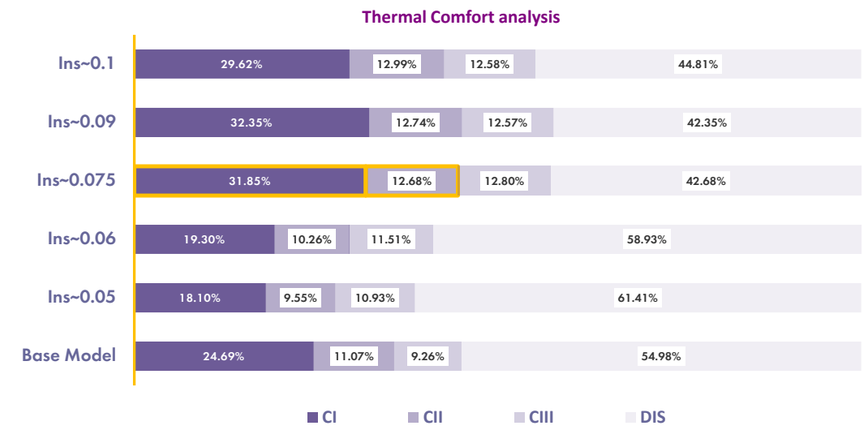


Figure 10.10 Effects of the Insulation layer addition on the Thermal comfort analysis based on the EN 15251 categories

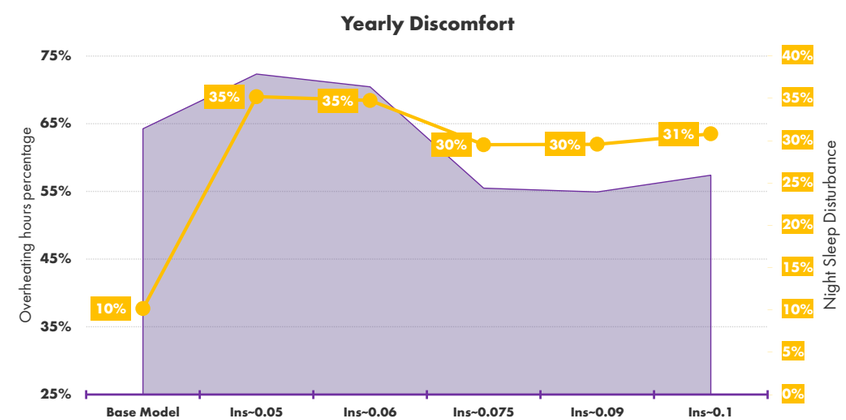


Figure 10.9 Yearly discomfort chart based on the CIBSE Night disturbance and overheating metrics

10.2.2 Roof Alterations

Since the sun angles in Quelimane are typically overhead most of the year, it was necessary to explore the possibilities of overheating and discomfort. For this is analysis the Second floor bed room space was selected. This bedroom is most vulnerable to the effects of the roof. The insulation thickness of the roof was varied between 75mm, 100mm and 150mm. From initials runs, the 100mm insulation is noticed to improve the reduce the discomfort from range from 43.36% to 41.27%. the effects on over heating are also observed to have reduced 56% to 54%. This the reduction in

over heating is where the 100mm insulation of the roof outshine the 150mm. this was because at 150mm the insulation thickness the percentage of over heating was 55%. Although the 150mm performed better on the comfort chart (41.27% discomfort) the value added compared to 100mm was not considered to be significant to increase the insulation(Figure 10.10).

Thus rather than increasing the thickness of the insulation to 150mm the team analysis the effects of adding an a ventilated air layer on the 75mm and 100mm roof insulation . Adding the air layers decreased the comfort targets by relatively by decimal values. Its effect on night sleep a was relatively stable for both 75mm and 100mm. On the contrary, it increased the over heating increased by 1 % in the 75mm insulation().

Inclusion, the variation of the roof thickness may been useful in terms of insulation layers while the introduction of air layer reduces the performance of the thinner insulation layer. Further study can be conducted on increasing the layer of air cavity. Although our results showed very no improvement in comfort by the introduction of the roof the air layer the team maintain the layer of air. This was because the variations cased by the air layer were very low.

Table 10.26 The effects of the addition of the air layer the wall's thermal properties.

Variation	Decrement Factor	Time Shift	U- Value	Envelope Thickness
Ins_75	0.85	-3.92	0.48	0.143
Ins_75+ A_40	0.43	-6.47	0.36	0.183
Ins_75+ A_60	0.36	-6.81	0.32	0.203
Ins_75+ A 80	0.32	-7.00	0.29	0.223
Ins_100	0.95	-2.17	0.45	0.143

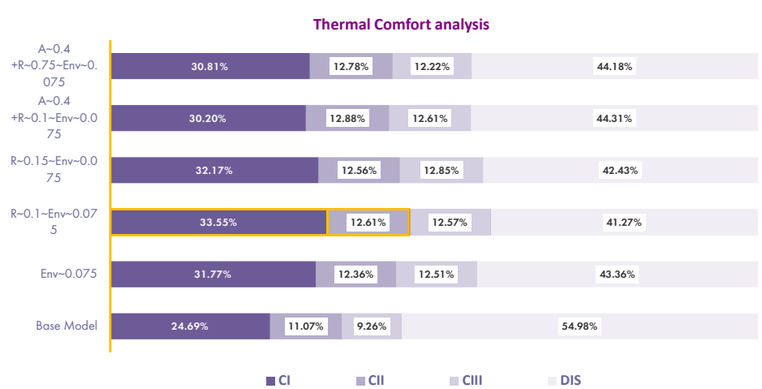


Figure 10.11 Effects of the Extra Roof insulation and the air layers Thermal comfort analysis based on the EN 15251 categories

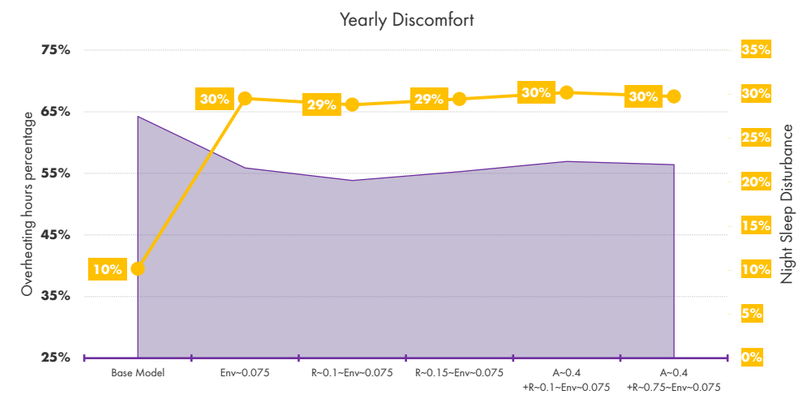


Figure 10.12 Effects of the Extra Roof insulation and the air layers on the yearly discomfort chart based on the CIBSE Night disturbance and overheating metrics

10.2.3 Wall Air layer

At this point the wall is installed with a 75mm thick insulation layer The team thought of the introduction of an air layer between the bamboo layer and the roofing sheets. The idea sterm from the thought of ventilating the façade to in other to cool it. With experience from the roof, the decision was to vary the ventilated area in the wall construction rather than fix it. Thus 3 air layer were studied, 40mm , 60mm and 80mm. The introduction of the air layer are noticed to decrease the U-value of the wall. The table () below demonstrates this.

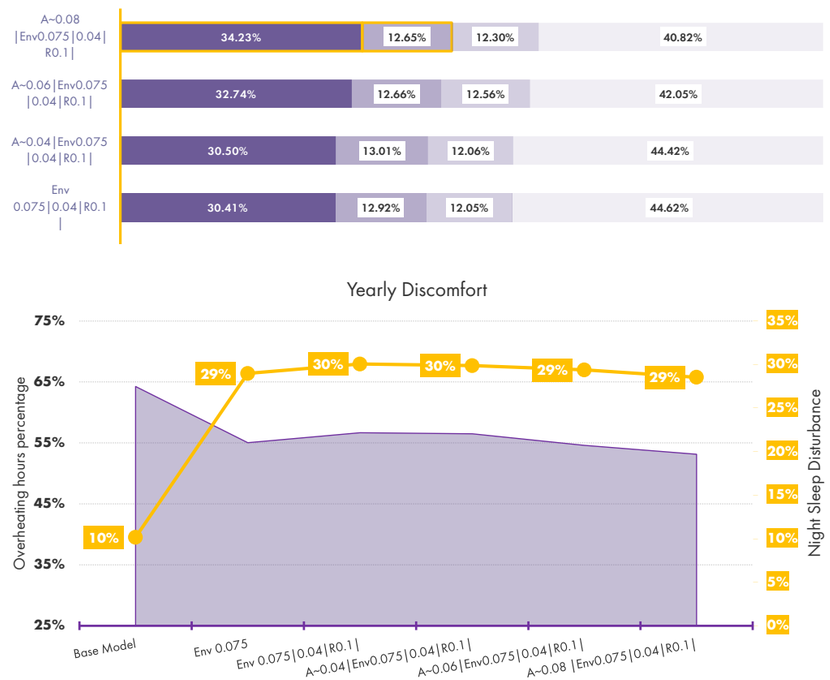
The addition of the air layer first of improves the time shift and decrement factor combination. Now , when compared to the standards it can be considered satisfactory. The effects of the ventilation layer are also noticed in the comfort charts. There is a minimum of about 2% increase in the comfort. The discomfort charts also showed the improvement of 1% in the overheating period and the night sleep discomfort. The improvement exhibited by the 80mm air layer was best. Hence this was selected for the final wall.

10.2.4 Energy Breakdown

The implementation of the opaque strategies were aimed at reducing the gains through opaque elements of the structure. These included the walls and roofs. The above evaluations and decisions have been guided by the comfort. However the energy break down gives a clear picture of how successful the strategies have been in mitigating the opaque related gains.

Table 10.27 The effects of the addition of the air layer the wall's thermal properties.

Variation	Decrement Factor	Time Shift	U- Value	Envelope Thickness
Ins_75	0.85	-3.92	0.48	0.143
Ins_75+ A_40	0.43	-6.47	0.36	0.183
Ins_75+ A_60	0.36	-6.81	0.32	0.203
Ins_75+ A 80	0.32	-7.00	0.29	0.223
Ins_100	0.95	-2.17	0.45	0.143



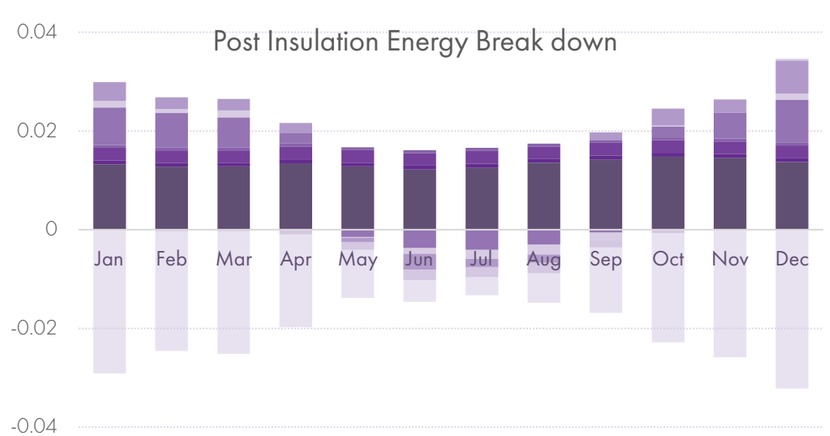


Figure 10.13 Post Insulation ateration energy breakdown. Very effective in reducing the opaque gains

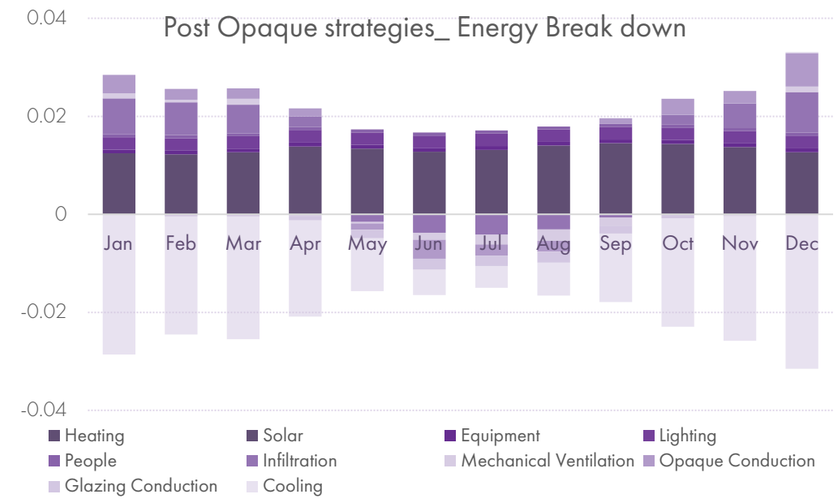
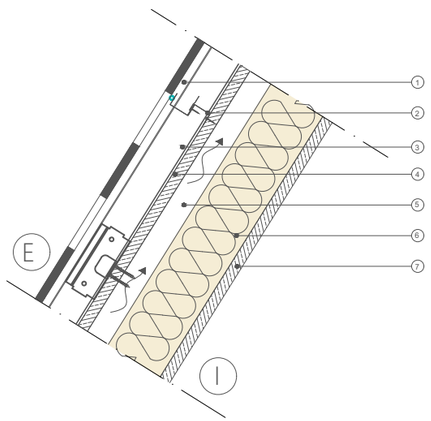


Figure 10.14 Final Break down after the Opaque strategies.

10.3 Opaque Stratigraphy

Figure 10.15 Vertical **Section** Roof with PV Panels @ 58 Degree



1 Photovoltaic model :
Multicrystaline silicon solar cells
3.5cm Thick | 7.6x6.68cm | Weight= 6.5kg |

2 Substructure : Aluminium profile connected at every modular frame section.
0.3cm Thick | 4.0x4.0cm|

3 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |

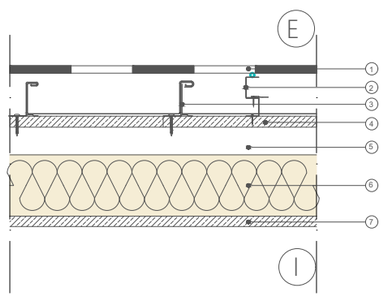
4 Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

5 Ventilation layer: Fully ventilated roof cavity with moving fresh air
|4.0 cm thick moving air layer assumed as a homogenous layer |0.1 w/m.k on the interior side and 0.04 exterior side.

6 Insulation layer : Compressed straw with in the perpendicular direction
10cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3

7 Finish: Plywood coated with penetrating oils waterproofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

Figure 10.16 Horizontal **Section** Roof with PV Panels @ 58 Degree



1 Photovoltaic model :
Multicrystaline silicon solar cells
3.5cm Thick | 7.6x6.68cm | Weight= 6.5kg |

2 Substructure : Aluminium profile connected at every modular frame section.
0.3cm Thick | 4.0x4.0cm|

3 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |

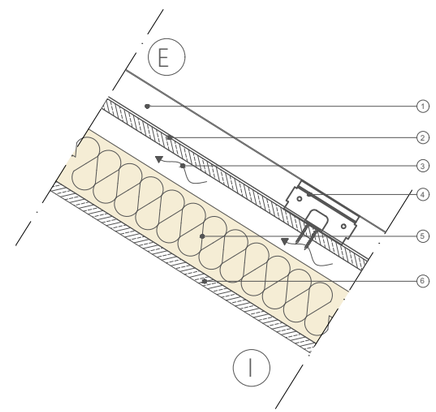
4 Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

5 Ventilation layer: Fully ventilated roof cavity with moving fresh air
|4.0 cm thick moving air layer assumed as a homogenous layer |0.1 w/m.k on the interior side and 0.04 exterior side.

6 Insulation layer : Compressed straw with in the perpendicular direction
10cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3

7 Finish : Plywood coated with penetrating oils waterproofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

Figure 10.17 Vertical **Section** Roof with PV Panels @ 32 Degree



1 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |

2 Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

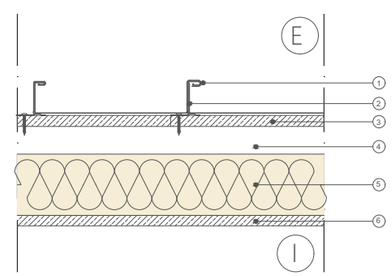
3 Ventilation layer: Fully ventilated roof cavity with moving fresh air
|4.0 cm thick moving air layer assumed as a homogenous layer |0.1 w/m.k on the interior side and 0.04 exterior side.

4 Substructure : Tite-Loc AR clip (Replace based on equivalent form local Supplier)

5 Insulation layer : Compressed straw with in the perpendicular direction
10cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3

6 Finish: Plywood coated with penetrating oils waterproofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

Figure 10.18 Horizontal **Section** Roof with PV Panels @ 32 Degree



1 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |

2 Substructure : Tite-Loc AR clip (Replace based on equivalent form local Supplier)

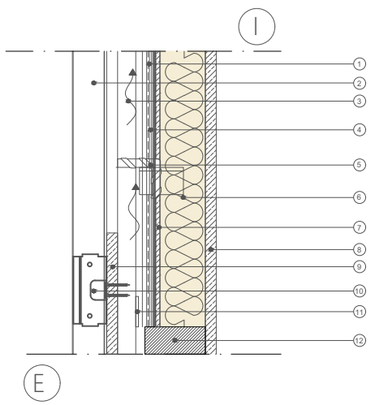
3 Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

4 Ventilation layer: Fully ventilated roof cavity with moving fresh air
|4.0 cm thick moving air layer assumed as a homogenous layer |0.1 w/m.k on the interior side and 0.04 exterior side.

5 Insulation layer : Compressed straw with in the perpendicular direction
10cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3

6 Finish : Plywood coated with penetrating oils waterproofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

Figure 10.19 Vertical **Section** Wall Section



1 Substructure : Wood battens support
2cm x 2cm

2 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |

3 Ventilation layer: Fully ventilated roof cavity with moving fresh air
| 4.0 cm thick moving air layer assumed as a homogenous layer
| 0.1 w/m.k on the interior side and 0.04 exterior side.

4 Sub - Finish Layer: Bamboo layer (sticks aranged / locally aranged / Local Bamboo wattle)
| max of 5cm Thick

5 Structure support: Equal Angled steel pre-nailed into modular frames
| .4cm Thick | 4cm X 4cm

5a Structure support: Reinforcement bar locks (Locally Fabricated according to specification) |
Dia. = 16mm

6 Insulation layer : Compressed straw with in the perpendicular direction
75cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3
Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

7 Substructure: Plywood
0.5cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

8 Finish: Plywood coated with penetrating oils waterproofing
1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

9 Substructure: Plywood
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

10 Substructure : Tite-Loc AR clip (Replace based on equivalent form local Supplier)

11 Sub- Finish Support : Wood batten / bamboo strip
1.25cm Thick | 5cm wide |

12 Structure : Hardwood
4.5cm Thick | 10cm wide |

13 Structure : Hardwood
4.5cm Thick | 14.5cm wide |

Figure 10.20 Horizontal **Section** Wall section

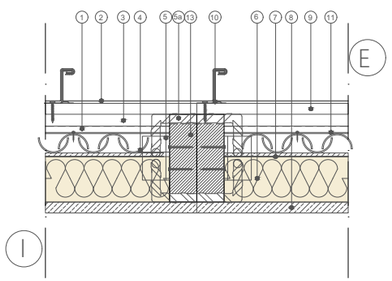
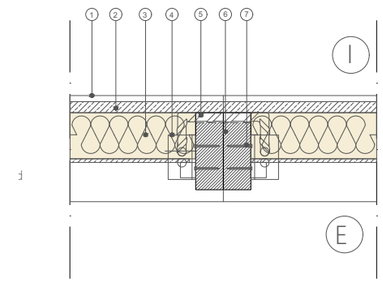


Figure 10.21 Vertical **Section** Floor Section



1 Finish: Plywood
|1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

2 Substructure : Plywood Sub-flooring
1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

3 Insulation layer : Compressed straw with in the perpendicular direction
75cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3
Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

4 Structure support: Equal Angled steel pre-nailed into modular frames
| .4cm Thick | 4cm X 4cm

5 Structure support: Reinforcement bar locks (Locally Fabricated according to specification) |
Dia. = 16mm

6 Structure : Hardwood modules frame
| 4.5cm Thick | 14.5 cm wide

7 Structure support:

10.4 Opaque Connection Details

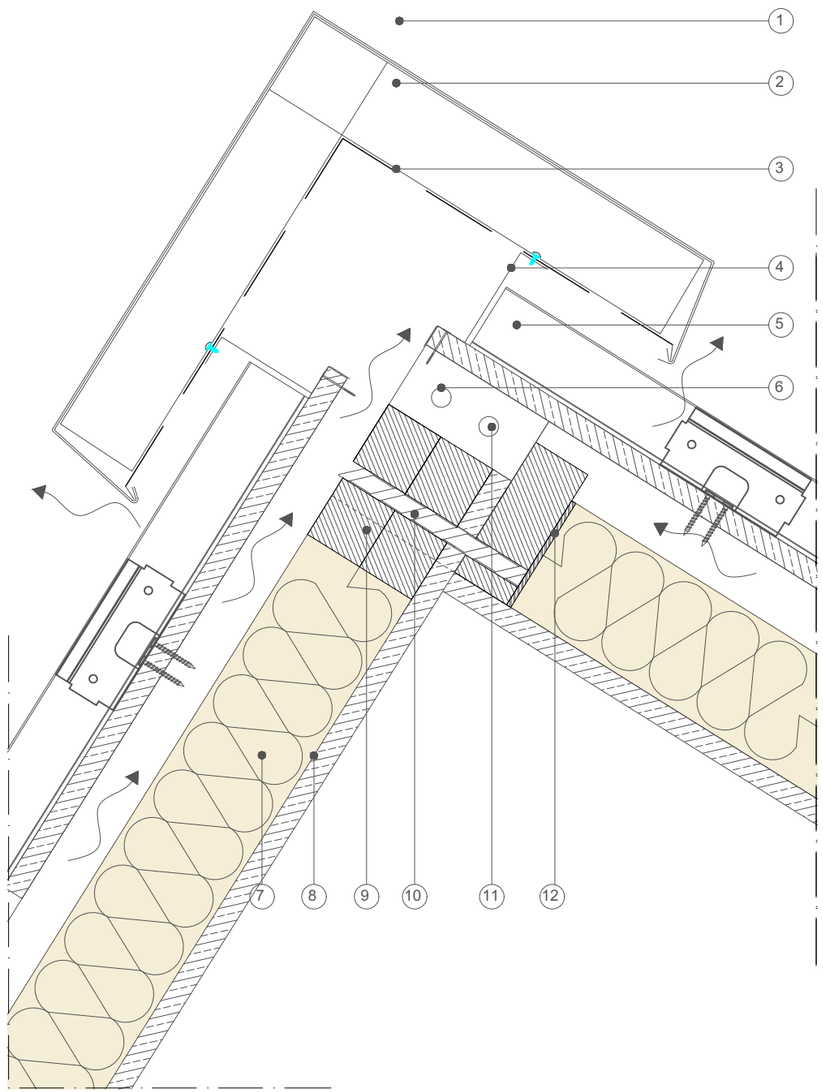


Figure 10.22 Vertical section Roof to Roof connection

1 Finish layer: Aluminum based Ridge cover
| 0.5mm Thick |30 cm wide | λ = 50W/mk |

2 Substructure : Intermittent Spacer
| 40cm centers |

3 Substructure : Perforated metal Vent screen

4 substructure : Continuous Galvanized Z brackets

5

6 Primary Structure support: L bent reinforcement bar fixed between (Locally Fabricated according to specification)
| Dia. = 16mm |

7 Insulation layer : Compressed straw with in the perpendicular direction
75cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3
Substructure: Plywood support for Roofing
| 1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

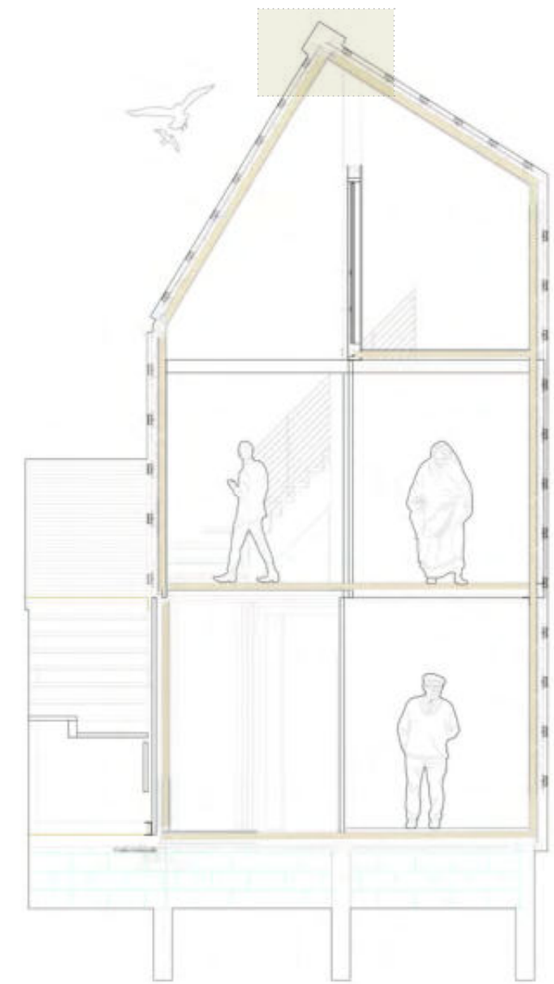
8 Finish: Plywood coated with penetrating oils waterproofing
| 1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

9 Primary Substructure : Hardwood (Roof Module)
| 4.5cm Thick | 10cm wide |

10 Structure support: Reinforcement bar welded to Plate (Locally Fabricated according to specification)
| Dia. = 16mm |

12 Structure support: Weld Plate (Locally Fabricated according to specification)
| .2 cm Thick |

Figure 10.23 Main Section



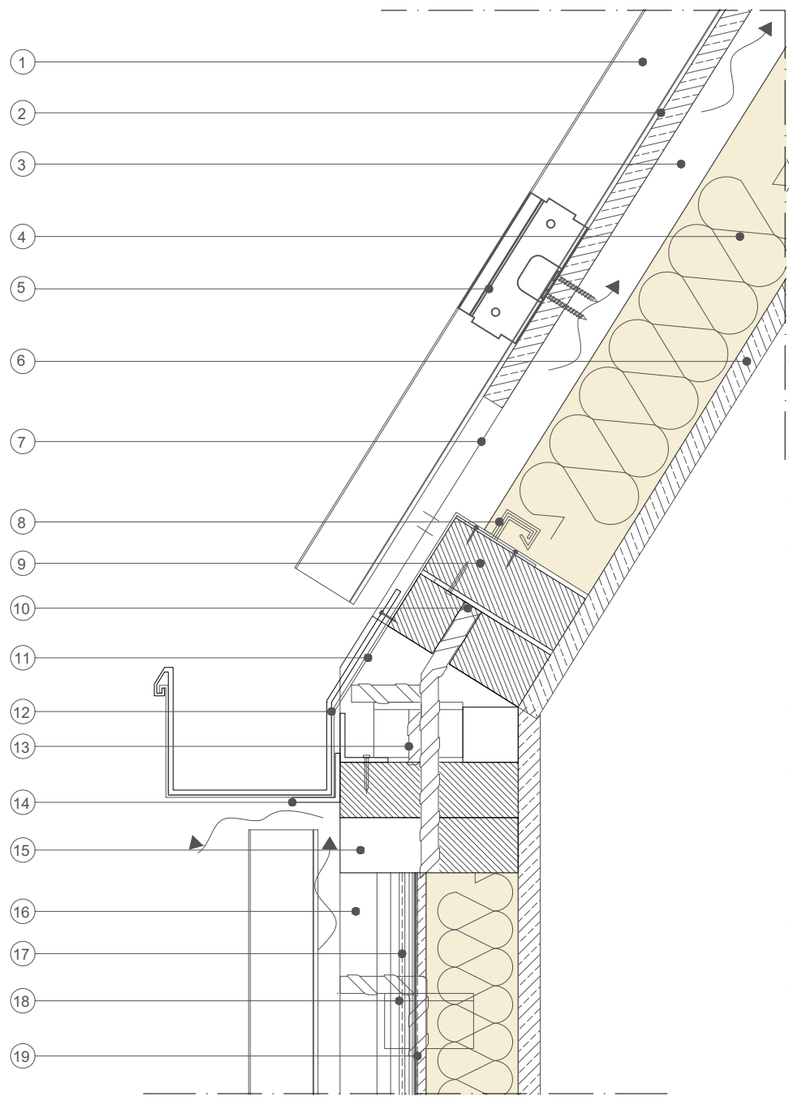


Figure 10.24 Vertical section Roof to Wall connection

1 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |

2 Substructure: Plywood
0.5cm Thick | 25cm wide |Density =600 kg/m3 |λ= 0.44 W/mK

3 Ventilation layer: Fully ventilated roof cavity with moving fresh air |4.0 cm thick moving air layer assumed as a homogenous layer | 0.1 w/m.k on the interior side and 0.04 exterior side.

4 Insulation layer : Compressed straw with in the perpendicular direction
75cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3
Substructure: Plywood support for Roofing
| 1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

5 Substructure : Tite-Loc AR clip (Replace based on equivalent form local Supplier)

6 Finish: Plywood coated with penetrating oils waterproofing
| 1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mk

7 Primary Structure : Hardwood (Roof Module)
| 4.5cm Thick | 14.5cm wide |

8 Substructure Support : Roof Gutter Anchorage
| .2cm thick | 2cm x 2cm Anchor | 7.6 cm wide Plate

9 Primary Substructure : Hardwood (Roof Module)
| 4.5cm Thick | 12.5cm wide |

10 Structure support: Reinforcement bar welded to Plate (Locally Fabricated according to specification)
| Dia. = 16mm |

11 Substructure support : Roof gutter Anchor strips
.2cm Thick | 5cm wide | 55cm long

12 Weatherproofing : Roof Gutter
.2 cm Thick | 10cm X 12.5cm |

13 Structure support: Equal Angled steel pre-nailed into roof modular frames
| .4cm Thick | 4cm X 4cm

14 Substructure Support : Equal Angled steel pre-nailed into wall modular frames
| .4cm Thick | 4cm X 4cm

15 Primary Substructure : Hardwood (Roof Module)
| 4.5cm Thick | 14.5cm wide |

16 Primary Structure : Hardwood (Wall Module)
| 4.5cm Thick | 14.5cm wide |

17 Sub - Finish Layer: Bamboo layer (sticks arranged / locally arranged / Local Bamboo wattle)
| max of 5cm Thick

18 Structure support: Equal Angled steel pre-nailed into wall modular frames (for lateral frame connections)
| .4cm Thick | 4cm X 4cm

19 Substructure: Plywood
0.5cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK

Figure 10.25 Main Section

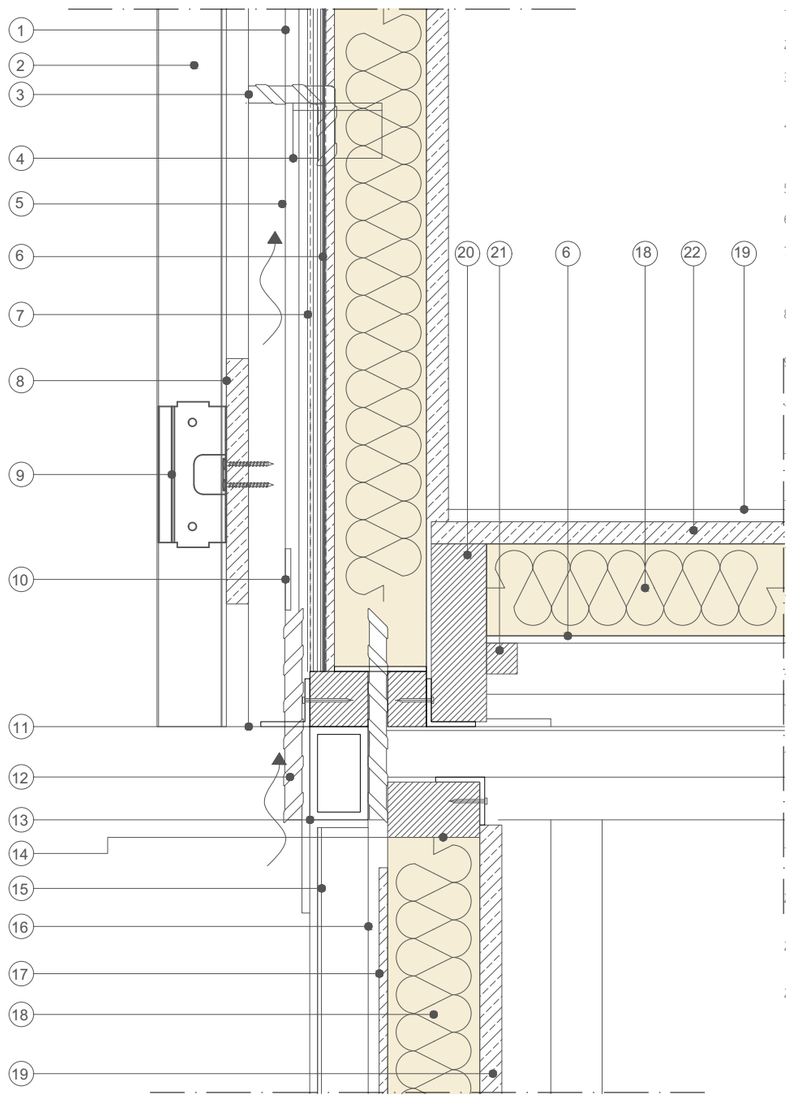


Figure 10.26 Vertical section Wall to Contain top rail connection

1 Substructure : Wood battens support
2cm x 2cm
2 Finish layer: Long Span Aluminium based standing seam sheets
0.5mm Thick |5 cm wide | λ = 50W/mk |
3 Structure support: Reinforcement bar locks (Locally Fabricated according to specification) |
Dia. = 16mm
4 Structure support: Equal Angled steel pre-nailed into modular frames
| .4cm Thick | 4cm X 4cm

5 Substructure : Wood battens support
2cm x 2cm
6 Substructure: Plywood
0.5cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |
7 Sub - Finish Layer: Bamboo layer (sticks aranged / locally aranged / Local Bamboo wattle)
| max of 5cm Thick

8 Substructure: Plywood
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

9 Substructure : Tite-Loc AR clip (Replace based on equivalent form local Supplier)

10 Sub- Finish Support : Wood batten / bamboo strip
1.25cm Thick | 5cm wide |

11 Structure : Hardwood
4.5cm Thick | 14.5cm wide |

12 Structure : Welded Rebar on the container structure support
1.6cm Reinforcement bar

13 Container Structure : Top rail
|.4cm Thick | 6cm x 6cm|

14 Substructure : Hardwood
| 4.5cm Thick | 7.5cm wide |

15 Container Finish: Metal sheets

16 Container Finish : Inner layer of Container sheets

17 Substructure: Plywood
0.5cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

18 Insulation layer : Compressed straw with in the perpendicular direction
75cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3
Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

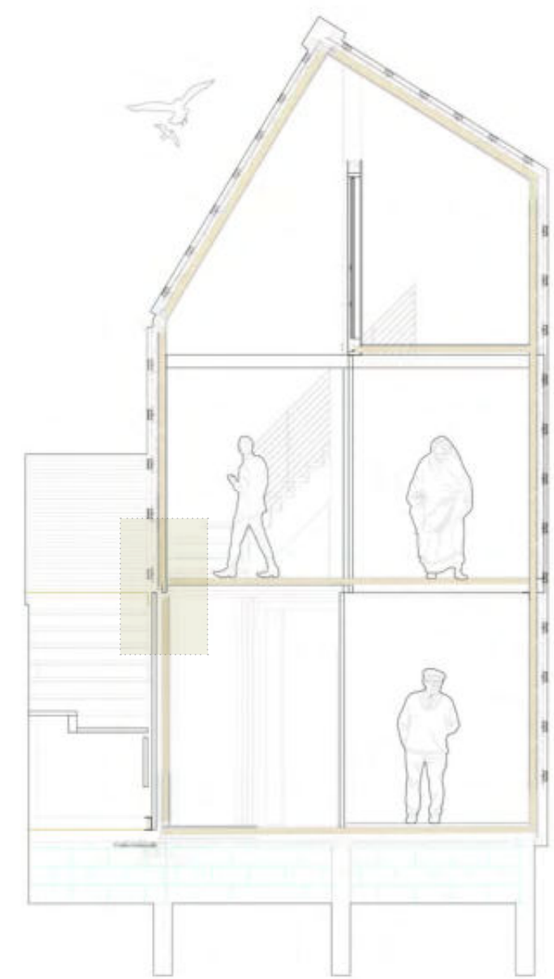
19 Finish: Plywood coated with penetrating oils waterproofing
1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

20 Structure : Hardwood
4.5cm Thick | 10cm wide |

21 Substructure : Wood battens support
2cm x 2cm

22 Substructure : Plywood Sub-flooring
1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

Figure 10.27 Main Section



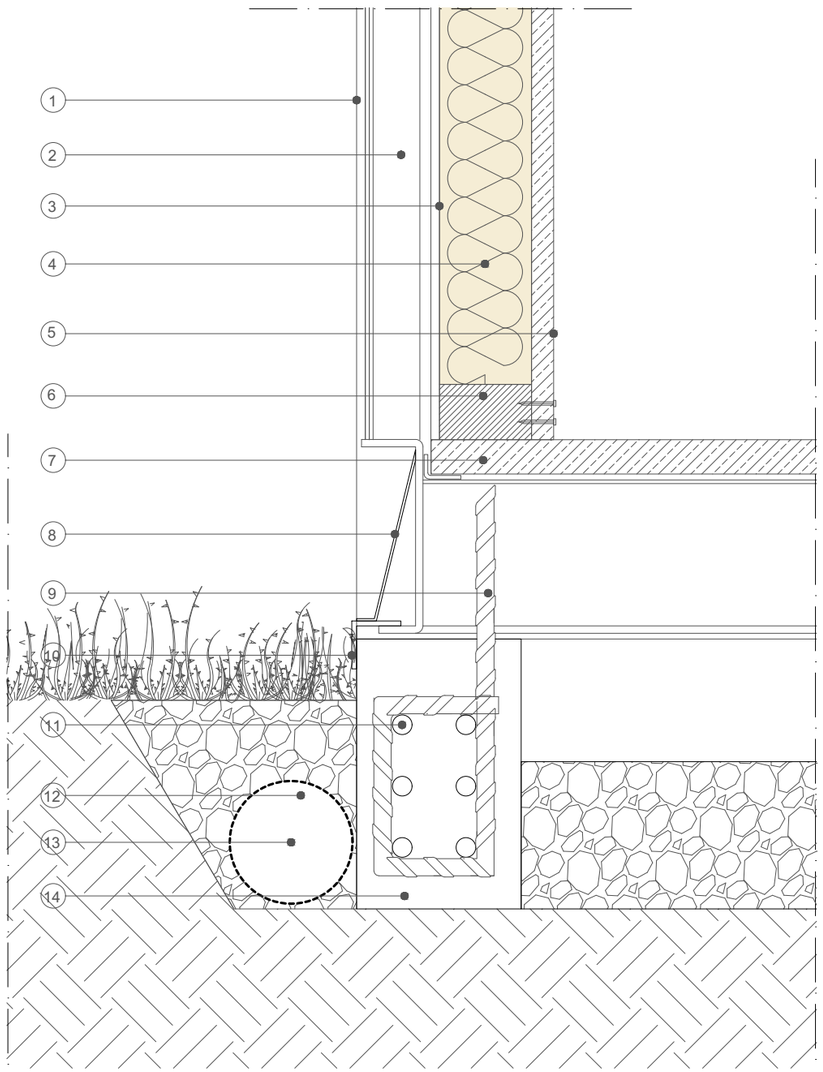


Figure 10.28 Vertical section Container to Ground connection

1 Container Finish: Metal sheets

2 Container Finish : Inner layer of Container sheets

3 Substructure: Plywood
0.5cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

4 Insulation layer : Compressed straw with in the perpendicular direction
75cm Thick | λ = 0.052 W/mK | Density = 90.0 kg/m^3
Substructure: Plywood support for Roofing
1.8cm Thick | 5cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

5 Finish: Plywood coated with penetrating oils waterproofing
1.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

6 Structure : Hardwood
4.5cm Thick | 7.5cm wide |

7 Container Substructure : Plywood flooring
2.8cm Thick | 100cm wide |Density =600 kg/m3 |λ= 0.44 W/mK |

8 Weatherproofing Strip: L bent Metal sheet weld to angled steel
.2cm Thick | 13cm X 1.6 cm |

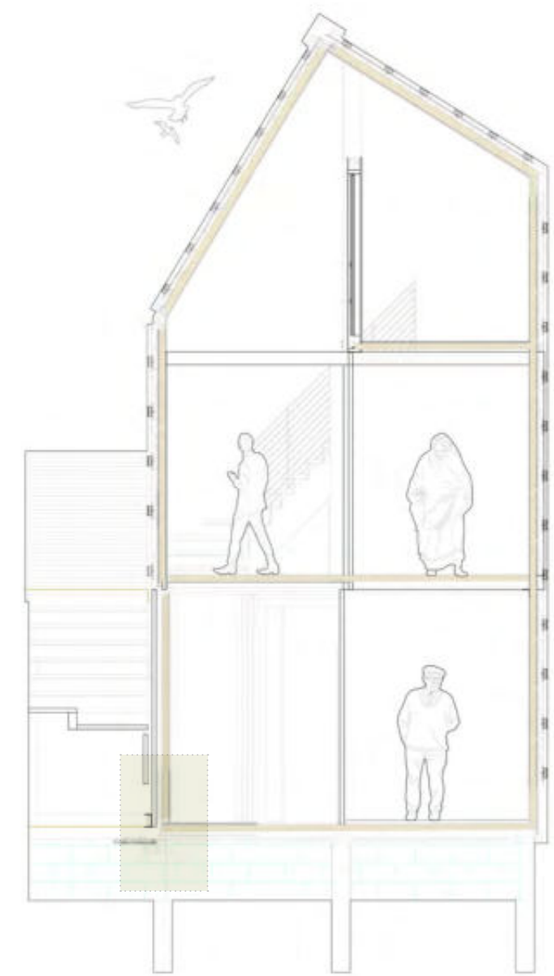
9 Structure Support : P bent Reinforcement Bar
Dia 1.6cm

10 Weatherproofing Strip : Angle steel
.4cm thick | 4cm X 4cm |

11 Weatherproofing Strip : Gravels for Splash dissipation and foundation protection
| Dia range 2cm - 5cm |

12 Drain : Perforated PVC pipe
Dia 10cm

Figure 10.29 Main Section



10.5 Transparent Strategies

The transparent facade mainly consist of the windows. The widow dimension was fixed at a width of 900mm due to the modular approach used in the structure. For the selection of window to wall raio, research paper by Mamdooh ALwetaishi was consulted. In his research, he studied the effects of 5%, 10%, 20% and 30% window to wall ratios on buildings within a hot dry and hot humid climates. He suggested the use of 10% in the hot dry and 20% maximum in the hot humid. However the study was not natural ventilation based, as such study admitted to reduced air exchange due to the 20% window to wall ratio by calling it sufficient. In relation to Quality lighting higher window to wall ratios tend to improve the daylight of the spaces.

10.5.1 Daylight Analysis

For the purpose of quality daylight, the team select a window to wall ratio of 60%. This was initially analyzed to understand its effects on the quality of daylight in the space. The metric used to evaluate the day of the spaces for this study were Spatial daylight Autonomy and the Annual sunlight exposure.

The SDA deals with the measure of daylight illuminance sufficiency for a given space. (El-Haggar, Mousa and El-Morsi, 2016) It represents the percentage of the space that surpasses the minimum required for the function, for 50% of the occupied hours during the year. The threshold falls between 55% and 75%.

The ASE on the other hand evaluated the discomfort from the direct sunlight. Its reports the percentage of floor area that exceeds 1000lux for more than 250hours in a year . The acceptable levels is 7% and the preferred being 3% of the analysis area.

- Base Case

Using a a window to wall ratio of 60% , it was observed that the general SDA was highly appreciable while the the ASE was about 16% over the preferred recommendation. From the ASE diagrams, one can notice the percentage area affected was mostly due to the penetration of sun light. With this observation, three test cases were establish to improve the ASE(-Figure 10.26).

Window Head Shading

The three cases studied here examine the effects of shing the 1/3 of the window area from the head height. This was conceived in order to minimize the penetration of sunlight and thus reduction in the ASE recorded. This resulted in the reduction of the effective window to wall ratio from 60% to about 40% generally(depending on the spacing of the shades).

All shades used in this section of the analysis were assumed to be metallic sheets of the *** reflectivity. The shade case included the following spacing(Table 10.32,Figure 10.27):

The test results showed little improvement differences between the dense and medium space effects on the ASE. The reduction the initial 23.0% was observed to be 15.5% on the average for both cases. The lightly spaced shades performed the least.

A closer look at the sample room on the second floor revealed the effectiveness of the best performing shades achieved a reduction ASE from 36.9% to 22.6% (about 38% better ASE levels). It must be noted that in all the cases studied so far the effects on the SDA still remained in appreciable levels.

No.	Shade Name	Description
1	Dense	- Shades spaced at 100mm centres
2	Medium	- Shades spaced at 150mm centrers
3	Light	- Shades spaced at 200mm centrers

Table 10.28 Nomenclature of the Study Shades

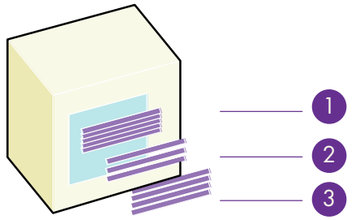


Figure 10.31 Metal louvres studied

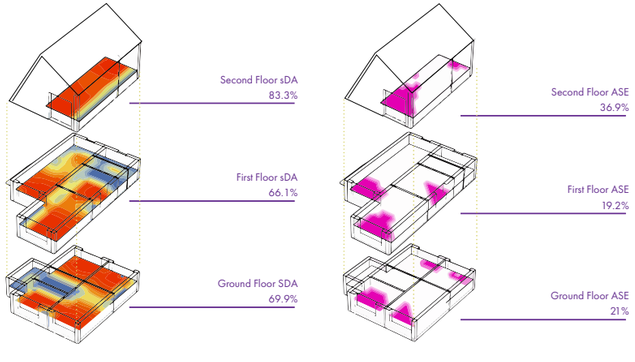


Figure 10.30 Results of the base case Light Metics

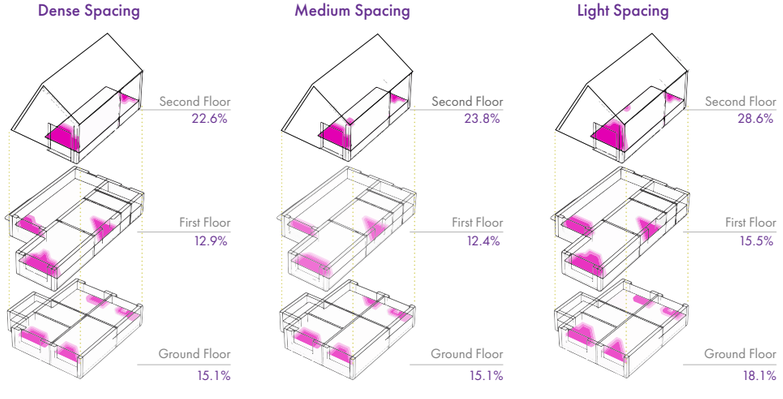


Figure 10.32 Base Models for the ASHRAE and the Starting case

The effects of these shading obviously reduced the transparent façades solar gains into the building. These effects were measured to understand how the provision of the shades were effective in regards to the last comfort findings.

With the introduction of the shades, the comfort levels are noticed to increase. The minimum improvement towards category 2 comfort range is from 44.78% (Final Opaque Façade) to a 49.77% (using the light shade). However since the ASE levels had to not reached the target range a further test was conducted.

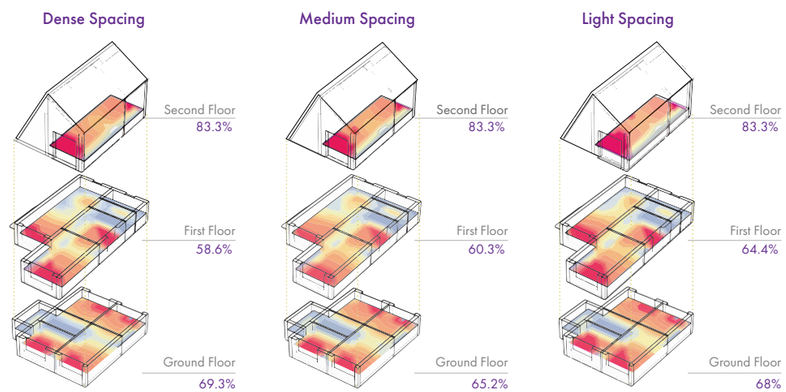


Figure 10.33 Results of the base case Light Metics for shading combinations

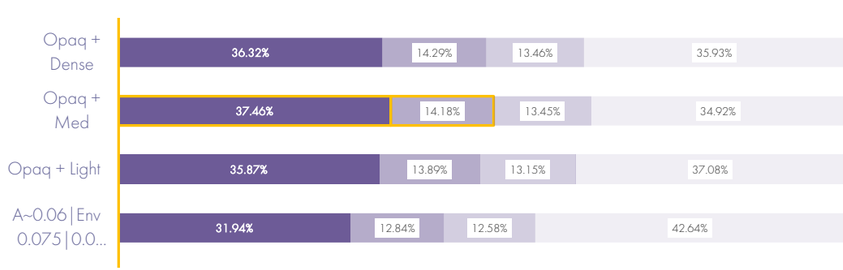
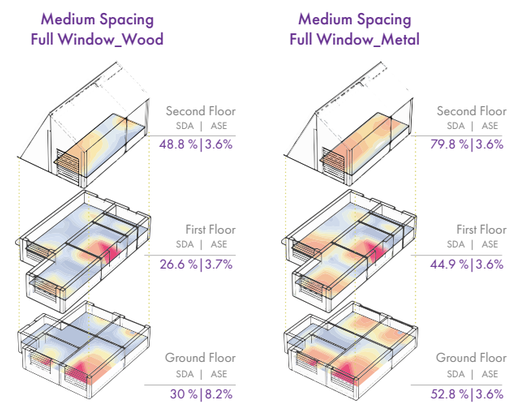


Figure 10.34 Comfort metric comparision of the Dense, Opaque and light Shades

- Full Window shades

The study the initial shading revealed the medium and the dense shading were more effective. While the proved effective they could not reduce the ASE to appreciable levels. Thus a a full shade was employed using the medium size shade spacing. Two cases were explored here, the use of wood and the use of metal sheets.



What Next ?

Table 10.29 Daylight Metrics after applying tthe fshade fully using wood and metal at medium spacing

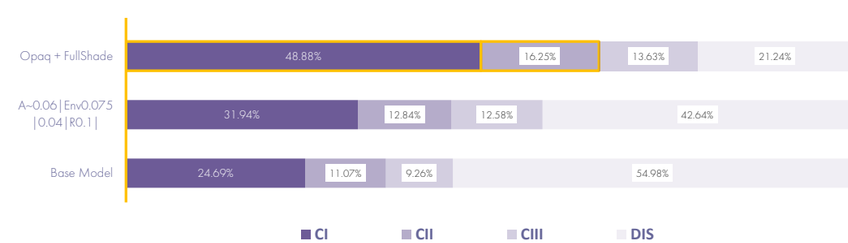


Figure 10.35 Comfort metric comparision of the Full shades , the base csae and the ASHRAE

Using wood panels resulted in lower quality of lighting as seen from the results of the SDA. This prompted the team that using wood as a full shade would not be appreciable for the lighting levels. The metal blades on the other hand was able to bring the ASE down to quality levels while maintain normal SDA levels. The effects of the full shading of the windows also drastically reduced the overheating periods. Such a reduction was highly appreciated. But despite this improvement the team sought to modify the shading to help improve the quality of views from the spaces. Thus the final window shading was conceived. It adopted 2/3 of the fully shaded window while keeping a clear view from the mid section. This approach increased the discomfort range from the 35% to 38%. The night discomfort also saw an increase from 24% to 25%.

Figure 10.37 Results of the base case Light Metics for shading combinations

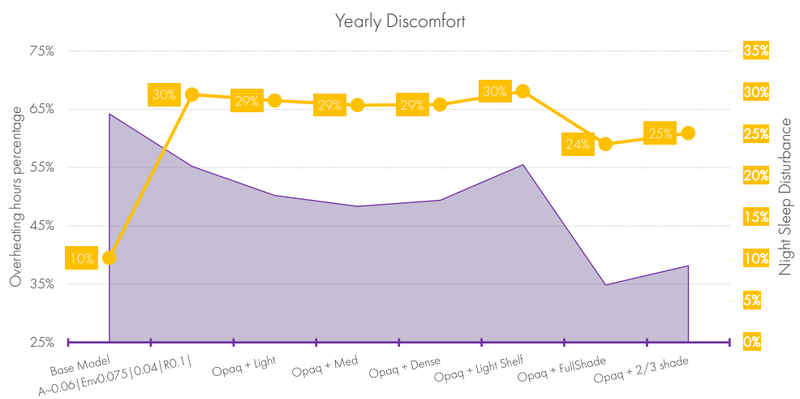
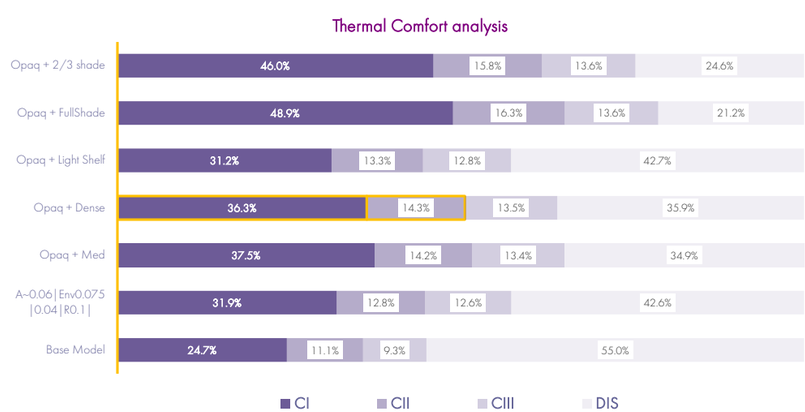


Figure 10.36 Comfort metric comparision of the Dense, Opaque and light Shades



- Shading Effectiveness

This shading systems adopted in the light analysis was discussed focusing on the effects on lighting and comfort. Here the final selected shade is compared with the full shade to understand and thus verify the effectivness of the selected shades.

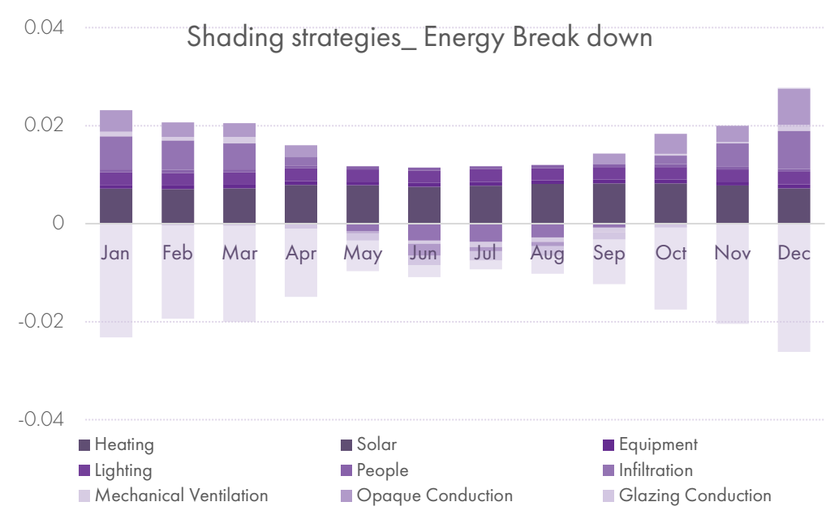


Figure 10.38 Post Shading Strategies Energy breakdown

10.5.2 Natural Ventilation

For the natural ventilation analysis, the first approach was to check if the use of night ventilation could improve on the night sleep quality. This was necessary a check because of the inability of any of the previous strategies to improve this drastically.
The night ventilation model was set to be activated from 7pm to 8am. The assumption was to use only 40% of the window current window area for this purpose. The choice of 40% was too take into security issues account. The result were favorable. The night discomfort drop from 25% to 12%(equivalent to about 50% reduction)

With the effects of night natural ventilation observed the team now sought to investigate the possibility of improving the comfort for the occupants using day time ventilation. The day time ventilation was assumed to be activate only when the temperatures inside were indoor above 22 degrees and the out door temperatures were above 14 degrees. These constrains made the energy model a more close to reality. The schedule was the natural ventilation on the contrary was model to assume people in the house daily from 9am to 6pm.
The results showed an improvement in the comfort levels. The night time sleep quality shifted by a 1 %. The same was also observed with the overheating periods.

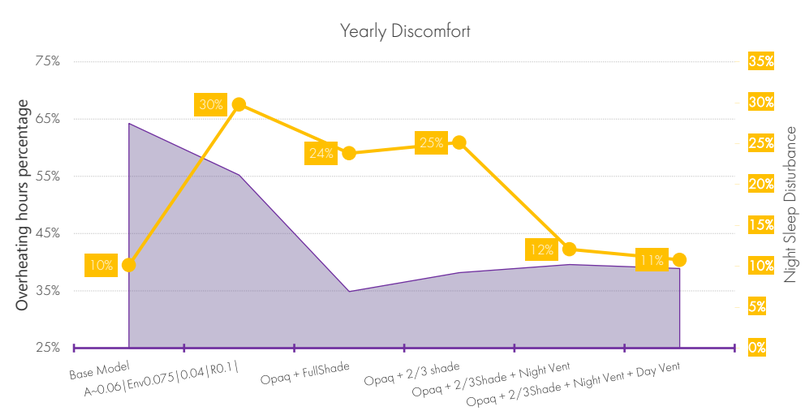


Figure 10.40 Discomfort metrics for assessing the effect of the natural ventilation strategies with the shade

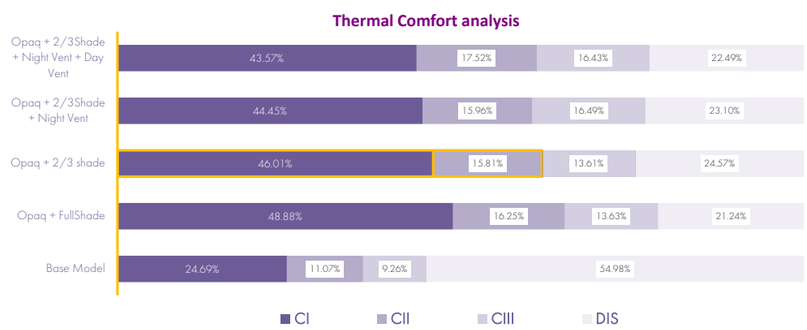


Figure 10.39 Comfort metric assessment of of the improvements caused by the ventilation strategies

10.5.3 Energy Breakdown

The implementation of the transparent strategies was aimed at reducing the gains through transparent elements of the structure. The energy break down gives a clear picture of how successful the strategies have been.

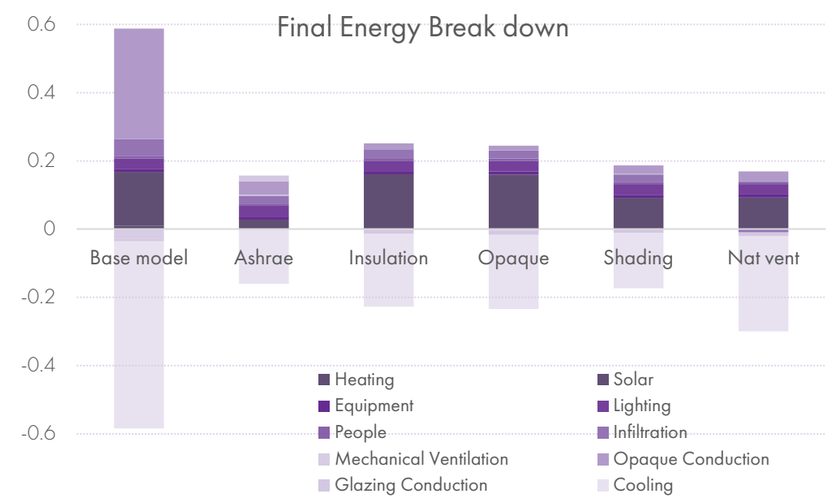
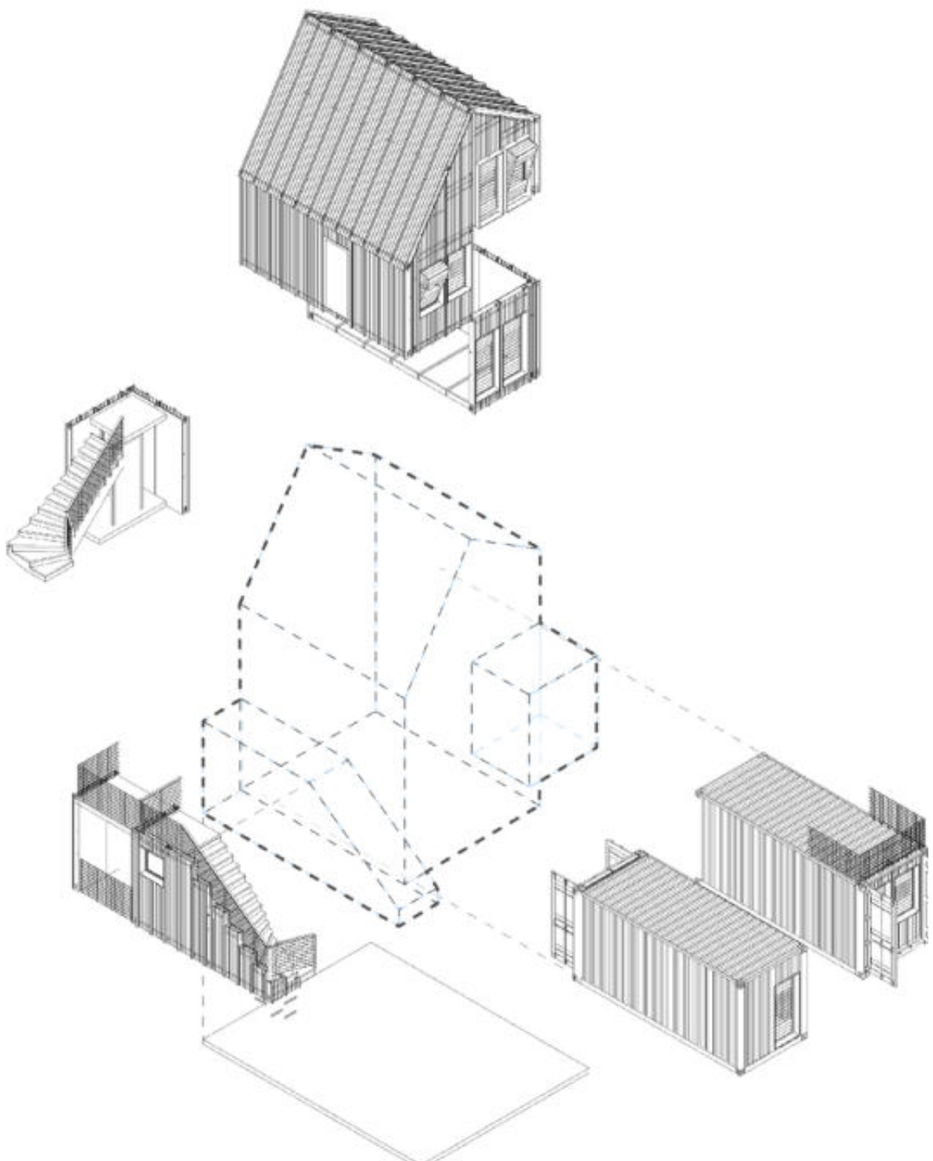


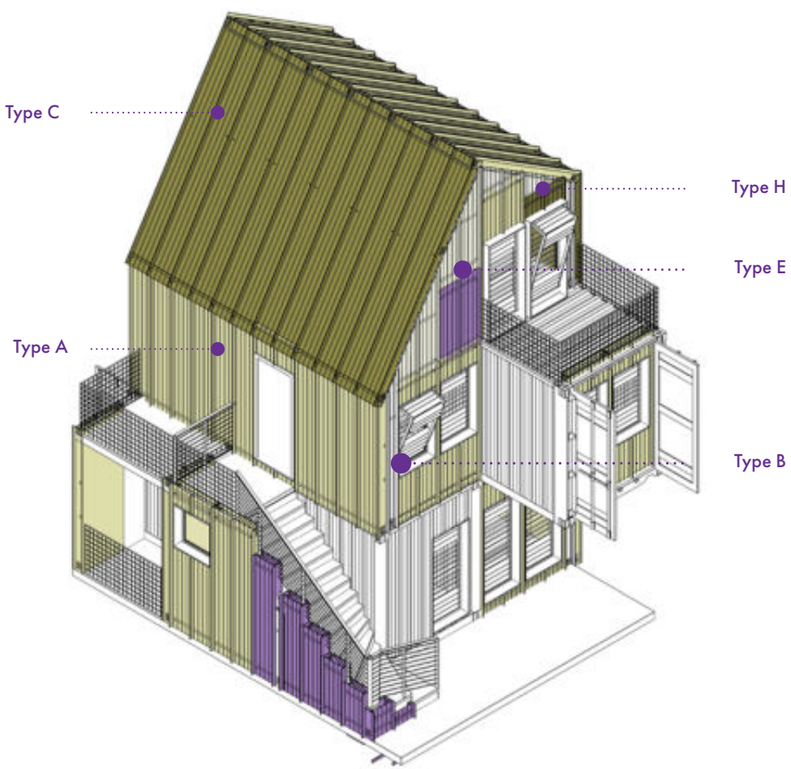
Figure 10.41 Effects of the strategies on the Energy break down. from the base model to the Natural ventilation strategy

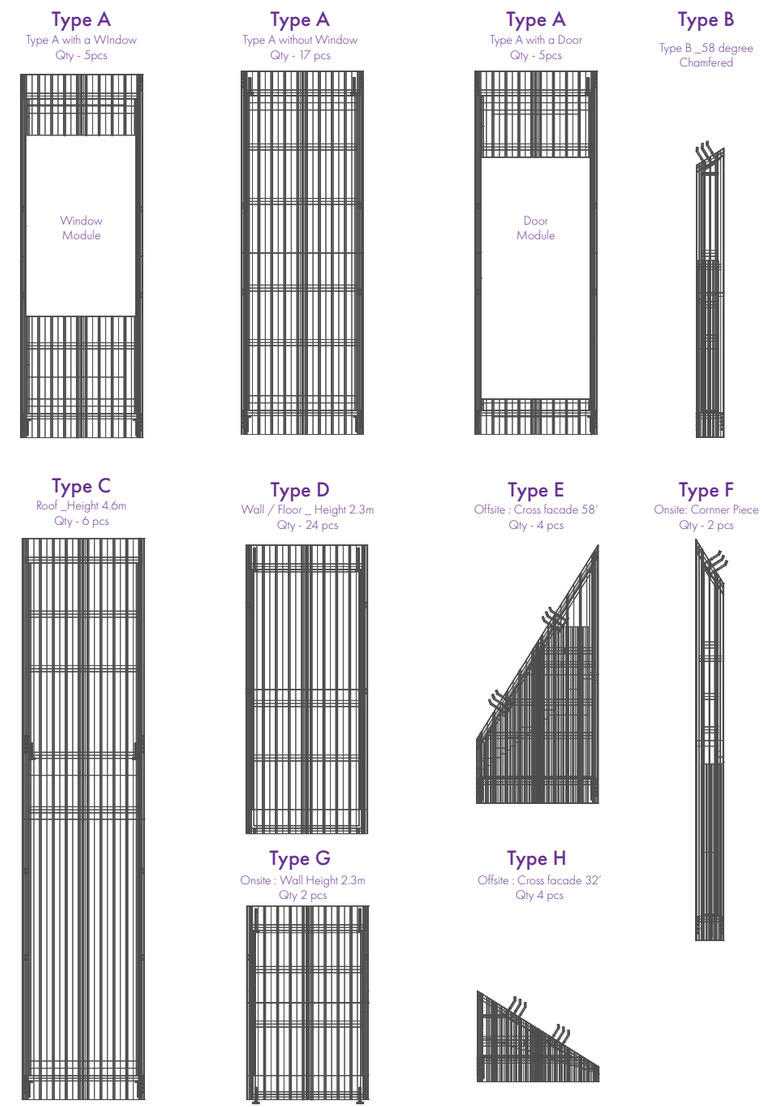
10.6 Modular Sections



The structure has modular parts the make would make the off-site production of the compressed straw and the facade modules a breeze. The team has proposed that these modular parts become a the spirit of the new SMART slums. Slums that would produce and reuse. Slums that function as a better circular economy.
This blow up introduces the major sections of the building. The Facade modules that make up the structure have been quantified to give an express the modular nature of the construction.

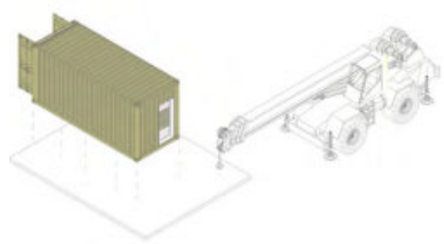
The Module types have be envisioned as one to be carried out off-site. The team thus came upp with module types A -H. The variations in type A are meant to house Windows, Doors. The modules are also thought of to allow the pre-construction of the frames according to the type. Although modularity can most often restrict the use of variety , the team managed to achieve the a variety towards beauty in the roof form. This thus resulted in the module type C, E and H. Modules type G, F and B would be adjusted on-site.



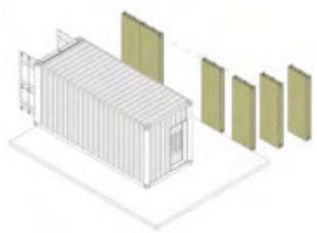


10.7 Dry construction process

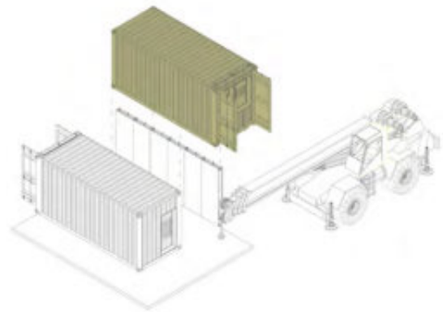
A



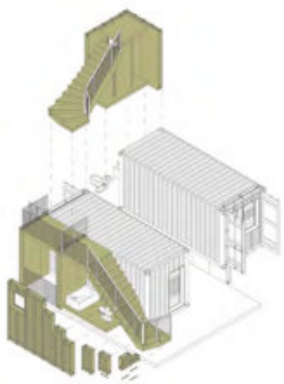
B



C



D



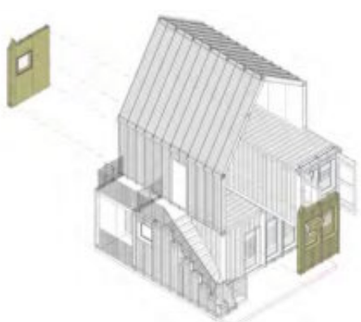
E

F

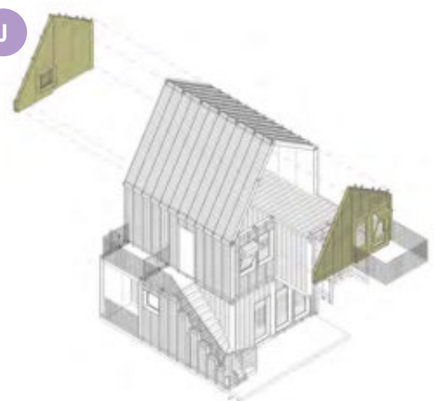
G

H

I



J



Modular

Modular buildings and modular homes are prefabricated buildings or houses that consist of repeated sections called modules "Modular" is a construction method that involves constructing sections away from the building site, then delivering them to the intended site. Installation of the prefabricated sections is completed on site. Prefabricated sections are sometimes placed using a crane. The modules can be placed side-by-side, end-to-end, or stacked, allowing for a variety of configurations and styles. After placement, the modules are joined together using inter-module connections, also known as interconnections. The inter-connections tie the individual modules together to form the overall building structure.

11 SMART | Structure

Making the modules stand.

What to Expect

11.1 Basics of the design 246

11.1.1 Design Process 246

11.2 Wind actions 252

11.1 Basics of the design

The following section details out the structural analysis of the structure based on a limit state design in accordance with Eurocodes (structural design of concrete structures), Eurocode 3 (Structural design of steel structures) and Eurocode 5 (Structural design of timber structures).
The design situations considered throughout the analysis pertains to the persistent; normal use of the structure and under exceptional actions, particularly under the acting effect of cyclones
Both ultimate and serviceability limit verifications are carried out to evaluate the ultimate capacity under failure and during service.

11.1.1 Design Process

The procedures that should be followed when designing a structure are:
1.Choice of the structural framing concept,
a.The layout of the structural members
b. The type of connections, i.e. simple, semi-rigid or moment resisting
c. The stability of the structure at all stages (during construction, use and demolition).
2. Determine the actions (loading) on the structure and its members.
3. Analyse the structure, including evaluation of frame stability.
4. Design individual members and connections.
5. Verify robustness.
6. Choose the sub-grade.
7. Specify appropriate protection of steel/wood/concrete, e.g. against fire and corrosion#

11.1.2 Structural layout

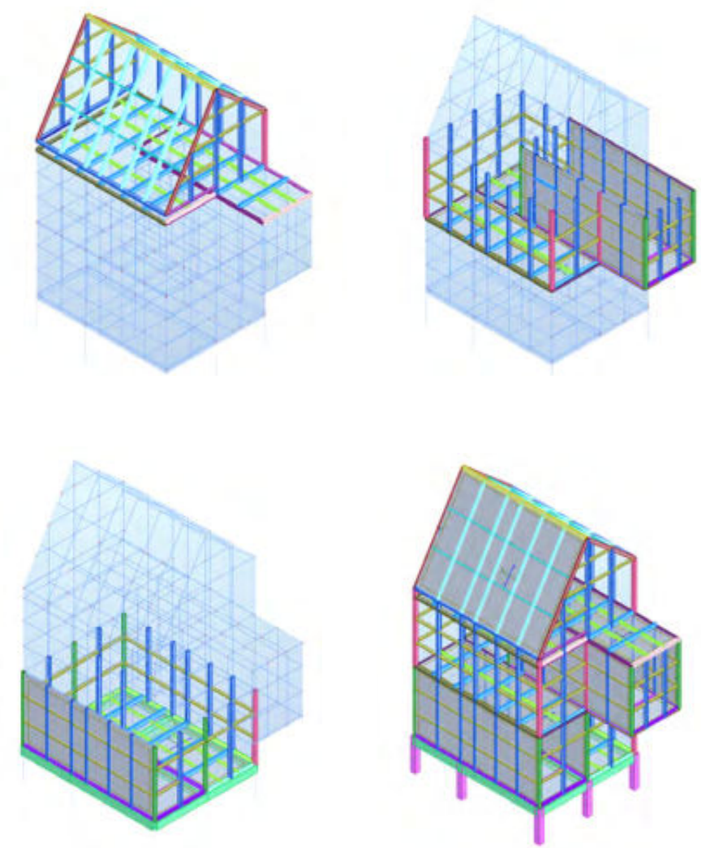
General description and structural scheme
The building structure is formed via the interconnection of timber modular units to the structural parts of two shipping containers laid out as shown in figure...The structural grids are placed following the edge of the vertical and horizontal edges of the container units. Container units are made from weathering steel and their strength grades are comparable to S335 steel.
The duo pitched roof follows the angles of 60° and 30° and does not have overhangs. This is minimise the possibility of uplifts from wind loads in the event of strong winds as is typical from occasional cyclones.
Combination of the module units provides twin timber members that acts as rafters. These are interconnected furtheron with rigde blocks to provide a rigid connection at the apex. The modules are provided with lateral bracings to minimise the possiblity of lateral buckling thus enhancing the lateral rigidity. Singular sections from the end modules form the verge rafters from where loads are transferred via the module posts to the foundations.
Rigid connections are formed where the roof connects to the walls by means of rigid blocks and the details are shown in fig...
Side frames of the floor module combines to form twin joist laced with single section bracings as shown in fig... to form the timber floor system whilst the the wall modules connects to provide twin timber posts through through which loads are transferred to lower beams. Since the shipping containers are fitted with angled steel top rails and C-channels are the base, these combine with conncected timber beams to transfer loads to hollow corner posts and the intermediate twin posts that forms the wall of the container.
At the ground level, a grid of reinforced concrete beam and columns received load from the superstructure and are transferred through concrete columns to the isolated foundations.
The overall layout uses rigid and semi-rigid connections throughout the structure by making use of lightweight timber structure, S335 steel and reinforced concrete desribed in subsequent sections.

11.1.3 Materials

The following section defines the properties of the selected materials. As mentioned, the choice of container permits the use of weathering steel units as part of the structure. This offers the additional advantage of corrosion resistance in marine-prone environments such as Quelime (the project site). Other materials under consideration are steel reinforcement, timber and concrete.
Designed value of timber, Xd = kmod . Xk /Ym,
where Xk id the characteristic value of a strength propoerty
Ym is the partial factor for a material property
Kmod – is modification factor taking into accoint duration of load and moiture content
Based on the epw weather data for Quelimane, the

outdoor relative humidity exceeds the 85% for at least 20 weeks per year. As a result the structural timber was designed to service class 3. Accorningly, the average mosture content, Um > 20% and humdity is higher in comparison with service class 2.
Load duration class – The selected load duration class is permanent thus the order of accumulated load duration of the charateriscic load is more than 10years.

Table 11.30 Energy demand comparison of the Base case and the ASHRAE



concrete C25/30				
Description	Unit	Value	Formula	Remark
c		1.5		Partial safety coefficient for concrete
fck	N/mm2	25		Characteristic compressive cylinder strength of concrete at 28 days
acc		0.85		Coefficient that takes into consideration the long-term effect resulted from the way of loads application
fcd	N/mm2	14.2	(acc * fck)/⊠c	Design value of concrete compressive strength
c,adm	N/mm2	15	k1 * fck	Allowable compressive strength under characteristic combinations
fctm		2.6	0.3(fck)2/3	Medium tensile strength
fctk,0.05	N/mm2	1.8	0.7 fctm	Characteristic tensile strength
fctd	N/mm2	1.2	act (fctk;0.05/⊠c)	Design tensile strength
act		1		Coefficient that takes into consideration the long-term effect on tensile strength and of unfavourable effects from the way load is applied
Ecm	N/mm2	31000	$22(fctm/10)^{0.3}$	Secant modulus of elasticity

Steel reinforcement				
Type	High ductility steel type			B450C
Ys	1.15			Partial safety coefficient for Steel
fyk ≥	450	N/mm²		Characteristic Yield strength of reinforcement
fyd	391	N/mm²	fyk/Ys	Design Yield strength of reinforcement
as,adm	360	N/mm²	k3 * fyk	Allowable strength under characteristic combinations
Es	200000	N/mm²		Steel modulus of elasticity

steel S335				
Type	High ductility steel type			B450C
Ys	1.15			Partial safety coefficient for Steel
fyk ≥	335	N/mm²		Nominal yield strength
fu		N/mm²	fyk/Ys	Ultimate tensile strength
Es	360	N/mm²	k3 * fyk	Steel modulus of elasticity
Gs	200000		G=E/2(1+V)	Shear modulus
v				Poisson's ratio in elastic stage
	12 x 10^-6 (for T≤100°C	/°C		Co-efficient of linear thermal expansion

timber strength grade C27		
Description	Values	Remarks
fm,k	27	Bending
ft,0,k	16	Tension parallele to grain
ft,90,k	0.6	Tension perpendiculat to grain
fc,0,k	22	Compression parallel to grain
fc,90,k	2.6	Compression perpendicular to grain
f,v,k	2.8	Shear
E0,mean	11.5	Mean value of modulus of elasticity parallel to grain
E0.05	7.7	55 value of modulus of elasticity parallel to grain
E90,mean	0.38	Mean value of modulus of elasticity perpendicular to grain
Gmean	0.72	Mean value of shear modulus
Pk	370	Density
pmean	450	Mean value of density

Table 11.31 Timber Strength class and characteristic values according to EN 338 Selected strength class is C27

Timber basic designed properties			
Description	Values	Unit	Remarks
Ym	1.3	N/mm2	As recommended by EN 1995-1-1
kmod	0.5	N/mm2	As provided EN 14081-1 for solid timber under permanent load
fm,d	10.38	N/mm2	Bending
ft,0,d	6.15	N/mm2	Tension parallele to grain
ft,90,d	0.2	N/mm2	Tension perpendiculat to grain
fc,0,d	8.4	N/mm2	Compression parallel to grain
fc,90,d	1	N/mm2	Compression perpendicular to grain
f,v,d	1.08	N/mm2	Shear

11.2 Actions - Dead Loads

Table 11.32 Allowable strength under load

External wall			
Layer	Thickness or equivalent thickness (cm/m2)	Specfic weight (kN/m3)	Load characteristics (kN/m2)
wooden battens	0.16	4.5	0.0072
aluminum covering	0.05	27	0.0135
bamboo	1.5	7.6	0.114
Insulation	5	0.9	0.045
plywood (substrate + finish)	4.1	5	0.205
class 27 timber structure	4.5	4.5	0.2025
TOTAL			0.5872
At a floor height of 2.8m, the gross linear weight of the external walls without deduction for openings becomes			1.64kN-m
Deducting 20% for openings, the final linear loads becomes of the external wall becomes			1.31kN-m

Internal partition			
Layer	Thickness or equivalent thickness (cm/m2)	Specfic weight (kN/m3)	Load characteristics (kN/m2)
wooden based partition	0.05	20	1
Assuming a 2,5 m span between inside walls, in accordance with the assumptions of EN 1991-1-1, the correspondent equivalent uniformly distributed load is: 1/2.5(linear weight of interior wall)			1.12

floor outside container unit			
Layer	Thickness or equivalent thickness (cm/m2)	Specfic weight (kN/m3)	Load characteristics (kN/m2)
wood finish+plywood substrate	1.8	5	0.09
compressed straw insulation	7.5	0.9	0.0675
class C7 timber joist+joist blocks	2.43	4.5	0.10935
Total			0.26685

inclinde roof 60⁰			
Layer	Thickness or equivalent thickness (cm/m2)	Specfic weight (kN/m3)	Load characteristics (kN/m2)
wood finish+plywood subtrate	1.8	5	0.09
compressed straw insulation	7.5	0.9	0.0675
class C7 timber joist+joist blocks	2	4.5	0.09
Total			0.2475

inclinde roof 30⁰			
Layer	Thickness or equivalent thickness (cm/m2)	Specfic weight (kN/m3)	Load characteristics (kN/m2)
PV Modules + support (4/cos60)	8	2.9	0.232
roof covering (0.5/cos60)	1	27	0.27
Insulation (7.5/cos60)	15	0.9	0.135
Plywood (1.8/cos60)	3.6	5	0.18
Class C27 timber structure (2.6/cos60)	5.2	4.5	0.234
TOTAL			1.051

floor within container unit			
Layer	Thickness or equivalent thickness (cm/m2)	Specfic weight (kN/m3)	Load characteristics (kN/m2)
roof covering (0.5/cos 30)	0.58	27	0.156
Insulation (7.5/cos 30)	8.66	0.9	0.078
Plywood (1.8/cos 30)	2.08	5	0.104
Class C27 timber structure (2.6/cos 30)	3.00	4.5	0.135
TOTAL			0.472863741

11.3 Actions - Wind and Imposed Loads

The fundamental value of the basic wind velocity, vb,0, is evaluated. vb,0 is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open country terrain with low vegetation such as grass and isolated obstacles with separations of at least 20 obstacle heights.
Where the influence of altitude as on the basic wind velocity vb is not included in the specified fundamental value vb,0 the National Annex gives a procedure to take it into account. In the National Annex the followings apply:
vb,0 = b,0v per as ≤ a0
vb,0 = b,0v + ka (as – a0) per a0 ≤ as ≤ 1500 m
for altitudes greater than 1500 m above sea level local weather conditions and exposure can be considered, provided that the basic wind velocity is not less than the one correspondent to 1500 m. The values of b_{0v} , ka,ed a0 are given in function of the geographical position of the site in accordance with the subdivision of the national territory according the to the Italian National Index [Table N.A.1, the same of the table in D.M. 16-01-1996].
According to EN 1990 4.1.2 (7)P and EN 1991-1-4 3.4(1) the fundamental value of the basic wind velocity is a characteristic value and it refers to an annual probability of exceedance of 2%, which is equivalent to a mean return period of 50 years, as assumed for the design working life of the building.
Consequently, since the altitude of Quelimane is approximately 1m thus (< a0 = 1v000m)and the basic wind velocity is:
vb,0 = b,0v = 12.6 m/s (based on the epw wind data as mentioned under the climate analysis)
Starting from the fundamental value, by means of two multiplicative coefficients cdir and cseason, which respectively take into account the influence of wind direction and seasonal weather factors, the basic wind velocity can be calculated as follows [Expression 4.1EC1-1-4]:
vb = cdir cseason vb,0
The raccomended values of cdir = 1,0 e c season = 1,0 are used in accordance to the Italian Natinal Annnex. Therefore, the basic wind velocity is
vb = vb,0 = 12.6 m/s. - The mean wind velocity vm(z) at a height z above the terrain can then be calculated and it depends on the terrain roughness and orography and on the basic wind velocity, vb [Expression 4.3-EC1-1-4]:
vm (z) = cr (z) co (z) vb
where co (z) is the orography coefficient, taken equal to 1,0 (reccomended value), considering that no mountains/hills/cliffs increases the wind velocities by more than 5% as given in the National Annex.
cr (z) is the roughness coefficient It accounts for the variability of the mean wind velocity at the site of the structure due to the height above ground level and the ground roughness of the terrain upwind of the structure in the wind direction considered. The raccomended procedure for the determination of the roughness factor at height z is based on a logarithmic velocity profile and is given by the following expression [Expression 4.4-EC1-1-4]:
cr=kr ln (z/z0) for zmin <=z<=zmax = 200m
cr=cr(zmin) for z<=zmin

where **kr=0.19 (z0/z0,II)^0.07** with z0,II = 0.05m [Ref: Expression 4.5 – EC1-1-4]

From table 4.1 [EC1-1-4], the building located in Quelimane corresponds with category III (Area with regular cover of vegetation or buildings or with isolated obstacles woth separations of maximum 20 obstacle heights such as villages, suburban terrain, permanent forest ; z0 = 0.3& zmin = 5m.

Kr = 0.19 (0.3/0.05)^0.07 = 0.215
Cr(zmin)=0.215 ln 5 = 0.346

Cr(z) = 0.215 ln (z)

The turbulence intensity Iv(z) at height z is evaluated as follows [Ref: Expression 4.7 – EC1-1-4]:
Iv(z) = kI/(c0(z)lnz(z/z0) for zmin < z < zmax
Where kI
Iv=Iv (zmin) for z>zmin
where kI is the turbulence factor, taken equal to the recommend value (1,0) and c0(z) is the orography factor previously described

The peak velocity pressure qp(z) at height z, which includes mean and short-term velocity fluctuations, can then be determined [Expression 4.8-EC1-1-4]:

qp(z) = [1+7 Iv(z)] ½ vm(z)2 = [1+7 Iv(z)] ½ cr(z)2 co(z)2 vb2 = ce(z) qb

where = 1.25 kg/m3 is the air density (raccomended value)
qb = ½ vb2 is the basic velocity pressure [Expression 4.10-EC1-1-4]
ce(z) = [1+7 Iv(z)] cr(z)2 co(z)2 = kr2 ln (z/z0) [7+ ln (z/z0)]1 is the exposure coefficient [Ref: Expression 4.9 and Figure 4.2 – EC1-1-4]

omended for framed buildings which have structural walls and which are less than 100 m high and whose height is less than 4 times the in-wind depth [EC1-1-4 §6.2.(1) c]
Wind in x direction (parallel to the longest side of the building)
According to EN1991-1-4 § 7.2.2 and given that the building height (10 m) is greater than the building dimension in the orthogonal direction to the wind direction (6 m) but less than twice that dimension, the pressure distribution on the windward side is defined as follows:
a lower part extending upwards from the ground by a height equal to the width of the building in the hortogonal direction to the wind direction (ze = b = 6 m) and an upper part consisting of the remainder,

z(m)	cr (z)	Iv(z)	ce(z)	qb (N/m2)	qp (N/m2)
10.45	0.50	0.28	0.74	99.225	73.8
4.54	0.39	0.33	0.50	99.225	49.13

- Wind Actions

The wind pressure acting on the external surfaces, we, can be obtain by the folllowing expression [Expression 5.1-EC1-1-4]

we = cpe qp (ze)

where:
ze is the reference height for the external pressure
cpe is the pressure coefficient for the external pressure that will be specified later on.
Qp(z) is the peak pressure, Pa
The wind force, Fw acting on a structure or a structural element may be determined by vectorial summation of the forces acting on their reference surfaces [Ref - Expression 5.5-EC11-4]:

Fw = cscd i wei Ai

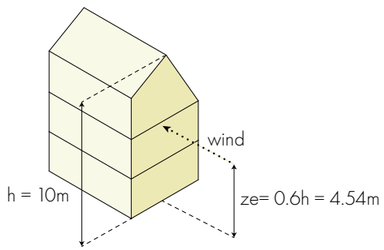
where the structural factor cscd (separeted into a size factor cs and a dynamic factor cd) is taken as 1,0 as

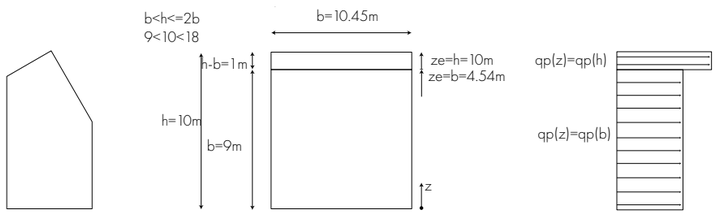
assuming a reference height equal to the maximum height of the building (ze = 10 m). For the leeward side and the lateral sides an uniform distribution of pressure will be considered, the value of which will be calculated assuming a reference height equal to the maximum height of the building2.

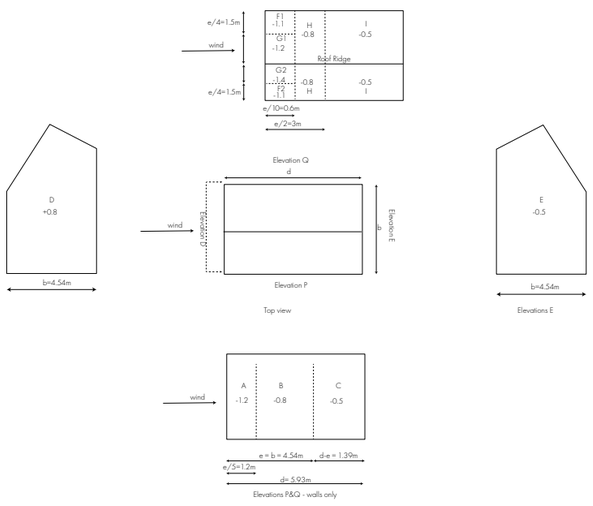
Details of the calculation of the wind pressure at reference heights are reported below:
z(m) cr (z) Iv(z) ce(z) qb (N/m2) qp (N/m2)
10.2 0.49931336 0.283578492 0.744214114 99.225 73.844645
6 0.385228286 0.333808201 0.495162736 99.225 49.132522

- Vertical walls and roof

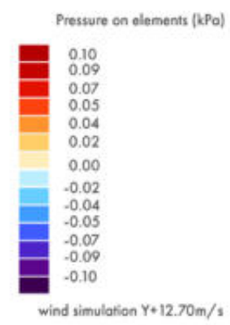
For distribution of windward pressure, Section 7.2.2 of EN 1991-1-4 describes the how it should be distributed depending on h, b, and d. For our building, the wind profile is shown below

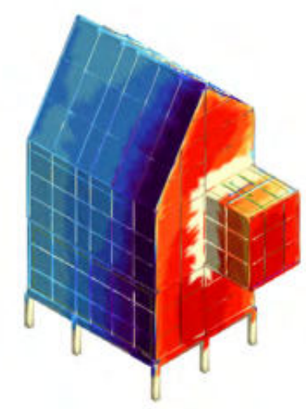






#	pressure co-efficient (Ce)	qp at reference heights		qp reduced to accounts for non-correlation between windward and leeward side	
		we @ z=4.54 & qp = 49N/m2	we @ z=10.45 & qp = 74N/m2	we @ z=4.54 reduced by 0.85	we @ z=10.45 reduced by 0.85
A	-1.2	-58.8	-88.8	-49.98	-75.48
B	-0.8	-39.2	-59.2	-33.32	-50.32
C	-0.5	-24.5	-37	-20.825	-31.45
D	0.8	39.2	59.2	33.32	50.32
E	-0.5	-24.5	-37	-20.825	-31.45
F1	-1.1	-53.9	-81.4	-45.815	-69.19
F2	-1.1	-53.9	-81.4	-45.815	-69.19
G1	-1.2	-58.8	-88.8	-49.98	-75.48
G2	-1.2	-58.8	-88.8	-49.98	-75.48
H	-0.8	-39.2	-59.2	-33.32	-50.32
I	-0.5	-24.5	-37	-20.825	-31.45



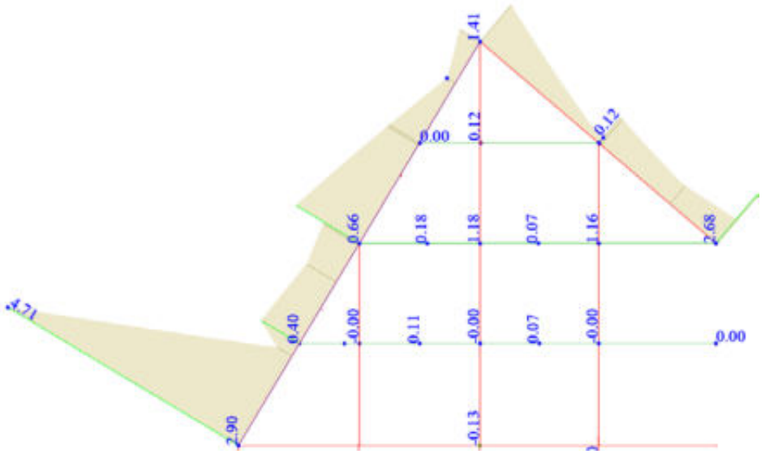


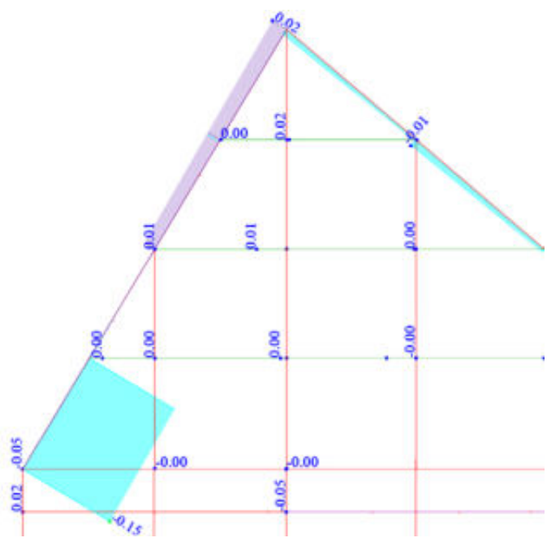
The structural analysis is carried out using linear analyisis based on the theory of elasticity, considering the combination of actions for the ultimate limit states.

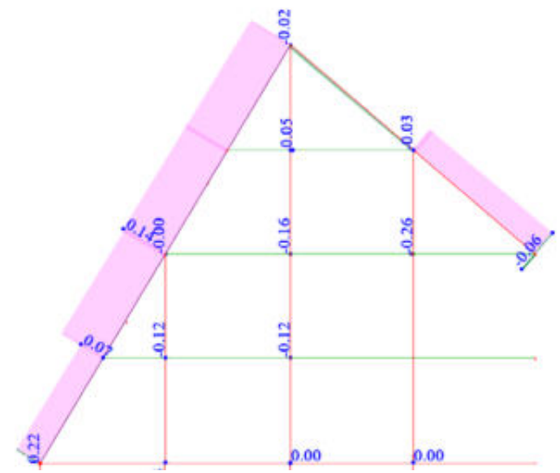
$$\Sigma_{j\geq 1}\Upsilon_{Gj}G_{kj} + \Upsilon_{Q1}Q_{k1} + \Sigma_{i>1}\Upsilon_{Qi}\Psi_{0i}Q_{ki}$$

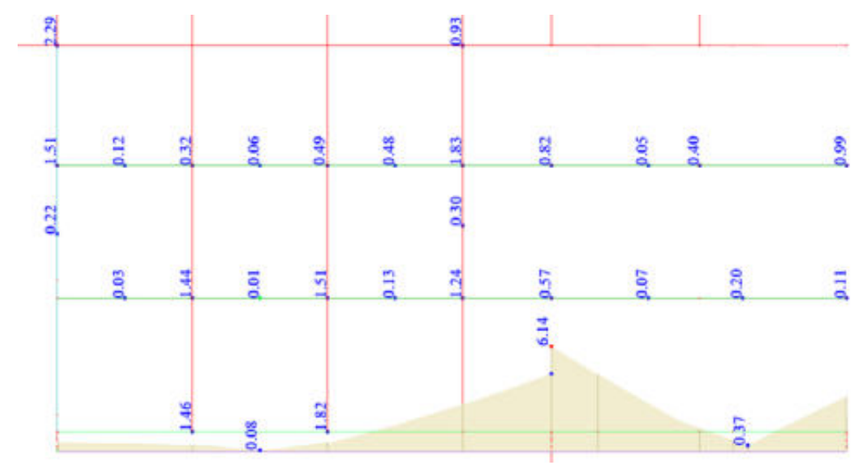
considering that Y_{Q1} = 1.5, Y_G = 1.35, psi = 0.7 and for wind =1.5, where psi takes into account the simulataneous variable actions..

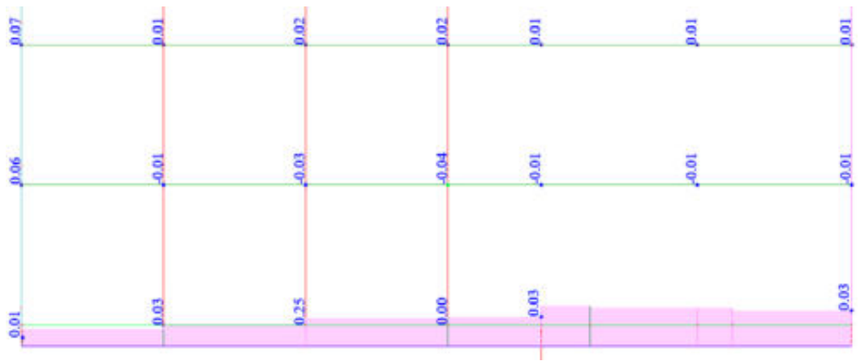
Using the acting loads as earlier described, the, shear and axial force and maximum bending moment diagrams for the critical roof members are calculated for the roof members, critical beams on the ground and

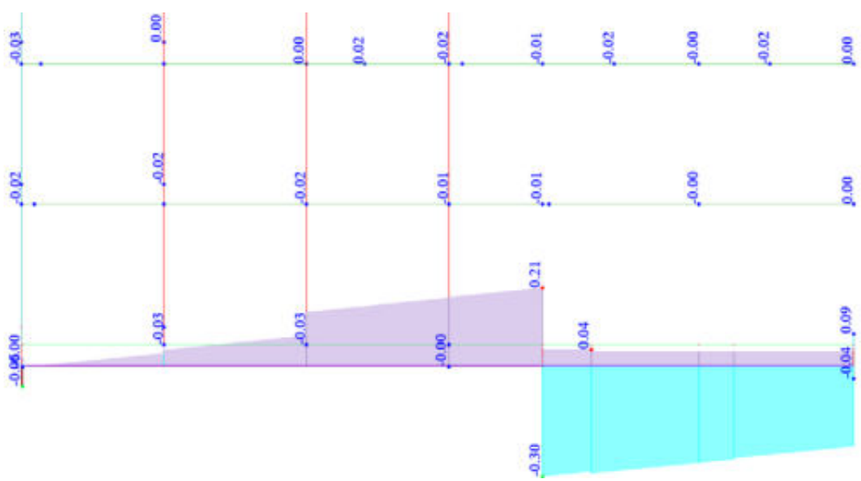












Section Design and verifications

– 4.5 x 14.5cm twin rafter Governing
Load Case: Combination
(G1+G2)*1.35+(Q1+W)*1.50+Q2*1.05

–

bf=9.0 cm
Ay=87.00 cm2
Az=87.00 cm2
Ax=130.50 cm2
tw=0.1 cm
Iy=2286.47 cm4
Iz=881.17 cm4
Ix=708.6 cm4
tf=0.0 cm
Wy=315.38 cm3 Wz=195.79 cm3

Stresses versus Allowable stresses
Sig_t,0,d = N/Ax = -1.56/130.50 = -0.12 MPa
f t,0,d = 7.83 MPa

Sig_m,y,d = MY/Wy= -0.72/315.38 = -2.27 MPa
f m,y,d = 10.46 MPa

Sig_m,z,d = MZ/Wz= -0.59/195.79 = -3.00 MPa
f m,z,d = 13.21 MPa

Tau y,d = 1.5*0.41/130.50 = 0.05 MPa
f v,d = 1.54 MPa
Tau z,d = 1.5*0.54/130.50 = 0.06 MPa

Tau tory,d = 0.02 MPa, Tau torz,d = 0.03 MPa

Factors and additional parameters
km = 0.70 kh = 1.27 kmod = 0.50
Ksys = 1.00 kcr = 0.67
-
VERIFICATION FORMULAS:
Sig_t,0,d/f t,0,d + km*Sig_m,y,d/f m,y,d + Sig_m,z,d/f m,z,d = 0.39 < 1.00 (6.18)

(Tau y,d/kcr+Tau tory,d/kshape)/f v,d = 0.06 < 1.00 (Tau z,d/kcr+Tau torz,d/kshape)/f v,d = 0.08 < 1.00 (6.13-4)

Therefore Section OK !!!
Deflections (LOCAL SYSTEM):
SLS VERIFICATION
u fin,y = 0.1 cm < u fin,max,y = L/200.00 = 1.5 cm
Governing load case: combination
Consider camber u 0,z = 0.0 cm
u fin,z = 0.1 cm < u fin,max,z = L/200.00 = 1.5 cm
Verified

Section OK !!!

SECTION PARAMETERS:
12.5cm twice corner post
ht=1250.0 cm
bf=12.5 cm
Ay=104.17 cm2
Az=104.17 cm2
Ax=156.25 cm2
tw=625.0 cm
Iy=2034.51 cm4
Iz=2034.51 cm4
Ix=3432.2 cm4
tf=625.0 cm
Wy=325.52 cm3
Wz=325.52 cm3

Stresses versus Allowable stresses
Sig_c,0,d = N/Ax = 0.38/156.25 = 0.02 MPa
f c,0,d = 10.15 MPa

Sig_m,y,d = MY/Wy= 0.49/325.52 = 1.51 MPa
f m,y,d = 12.92 MPa

Sig_m,z,d = MZ/Wz= 0.31/325.52 = 0.95 MPa
f m,z,d = 12.92 MPa

Tau y,d = 1.5*-0.12/156.25 = -0.01 MPa
f v,d = 1.85 MPa
Tau z,d = 1.5*0.03/156.25 = 0.00 MPa

Tau tory,d = 0.59 MPa, Tau torz,d = 0.59 MPa

IMM Phase 4

Retrofitting/Optimization

Optimization phase which is the fourth phase of the IMM. At this point, although the system is expected to perform much better than it does in the actual situation, but the transformation is not over whatsoever.
At the end of the transformation you come to the definition of a new CAS, whose performances will be evaluated with the same instruments analysed previously. In particular, the upgrade process takes placemaking a parallel between "old and new".

Investigation

the new CAS Indicators Evaluation of the performance of the new system, explaining the measures obtained from the indicators in order to make a comparison with the CAS before surgery.

local optimization

Following this detailed control of the results obtained from the transformation, begins a new optimization procedure. The result of this last phase is still a provisional CAS, a new starting point for an endless process of transformation.

12 Retrofitting

Analysing the changes to the system.

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12.1 City scale Retroffiting

Figure 12.1 Volume maps before and after retroffiting [left]

- Introduction

As of IMM methdology, it is necessary to cross check the project direction and this is done through the retroffiting phase. The weaker catalyists in IMM phase I (one from horizontal and one from vertical) will be assessed after the neccessary intervention are applied.
In the previous chapter, we conducted barrio scale and city scale investigation and intervention which all together activated the performance of the city of Quelimane interms of connectivity, complexity and compactness.
It also gave interesting results which leads to SMART approach to the city. Similarly, in this chapter we included the optimization of both barrio and city level after the new additions are applied.
The maps from the previous analysis and the new maps will be compared to understand the changes and our vision on how the area would be in the future. The analysis begins with horizontal and vertical investigation in city sacle and followed by barrio scale.

12.1.1 Volumes & Voids

The maps.below shows the comparision between the existing and the new interventions in the city scale level regarding volumes. The major changes can be noticed in barrio 11 area because of the newly added residential unites.
On the other hand, a considerable amount of volumes has been moved from the flood exposed zone and are integrated to SMART housing project. In addition, the volumes which has been located in the new citypark area are now suggested to be relocated to other area. This buildings include restaurants, shopes and residentials, however, the former ones will remain in the city park to extend their services for the public. and the residentials will be interated to the SMART housing intervention.
Regarding the voids, the map shows the newly added open spaces by considering the minimum standard requirment (9 sqm per person) through out the city park, city belt and the residential units. The new residential units has their own garden area as part of the design which balances volume-void ratio.

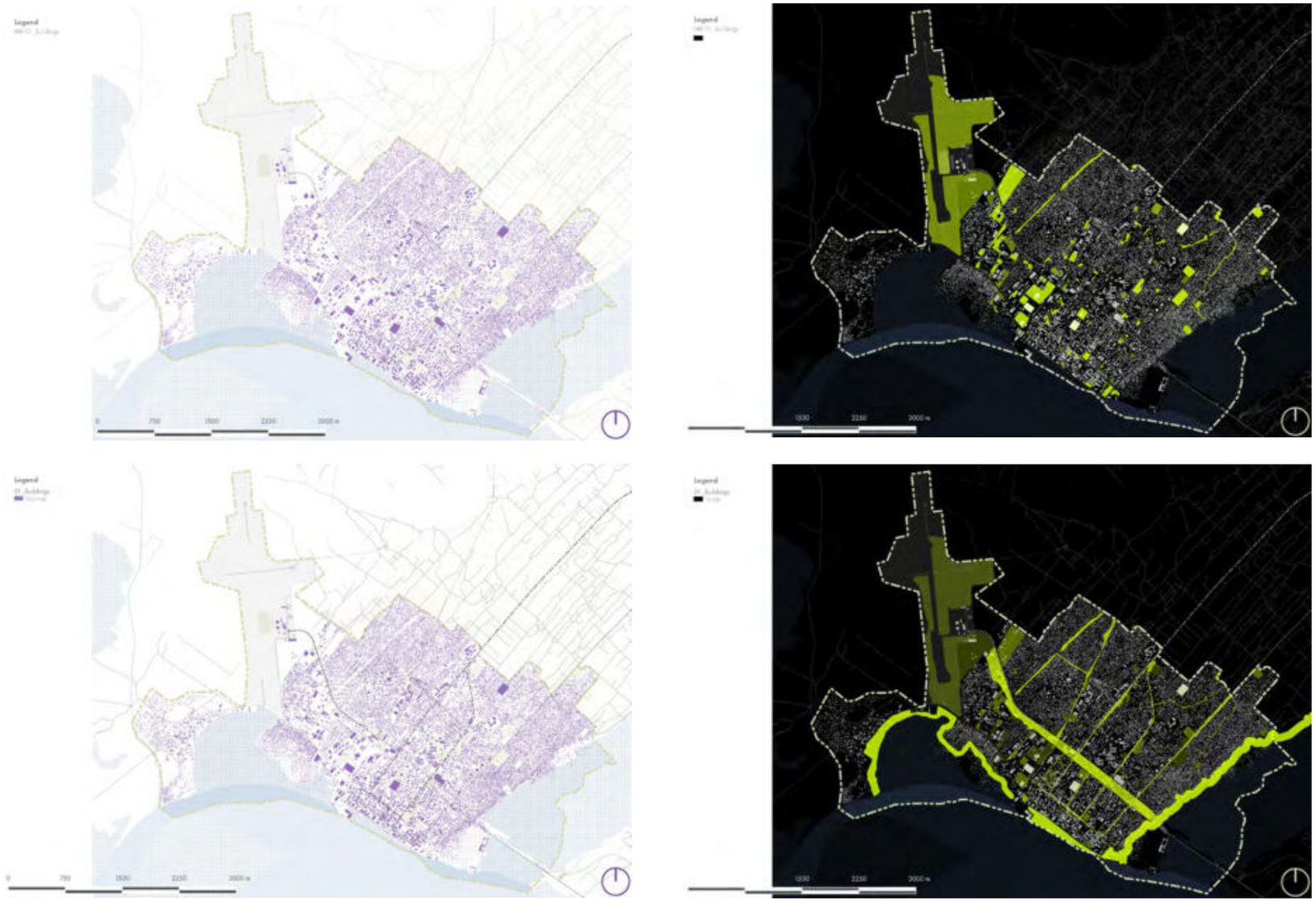


Figure 12.2 Void maps before and after retroffiting [right]

Figure 12.3 Types of use mape before and after [left]

12.1.2 Types of Uses

One can recall that the map for types of uses containes key functions such as sport services, waste collection points, shopping and bars. From the previous analysis, barrio 05 and 17 were having most functions compared aganist the city.
From the comparissions of the map below, the new map shows a better distribution of different types of uses following the linear city park, the green belt and the commercial activities included in the SMART housing. The small kiosks along the city park serves as an outdoor bar by selling food and drinks whereas the public library and festival plazas adds variety to the city functions.

12.1.3 Transportation

From the previous investigation, it is found that the transportation was facilitated by motobike and buses (3 stops). Based on that, we upgraded the existing system into CCRT and chapabike system. The system introduces separated Vehicular and bike transport routes also adds bikesharing spots. We also introduces [ ] bus stops near the airport, infront of the commerical and industrial institute and the Eastern part of the slum where barrio 11 is located.
By doing this, the Eastern and Western part of the city is now connected by chappa transport and also the inhabitants walk maximum of 5 min on average to access the system from their home.

Figure 12.4 Transportation map before and after [right]

Figure 12.5 Porosity maps before and after the retroffiting [left]

12.1.4 Porosity

Noticing that porosity is the superimposition of void and volume, it is normal not to appriciate the difference between the exisitng and new map. It is because we did not introduced new volumes to the city center or all studied barrios except in barrio 11. The percentage value of porosity for barrio 11 has increased when compared to the porosity of the existing figures in the perivious map.

12.1.5 Proximity

Remembering that proximity is the superimposition of volume and function layers but also measures the quality of movment by walking in a city. From the maps below, it is easier to spot the difference because of the addition of new functions along the street parks and the city belt. In addition, the integration of new functions in the SMART housing which faces directly to the streets makes the functions reacheable in walking distance for that particlar barrio. In general, SMART intervention included variety of uses which distributes these function in more walkable cathement area.

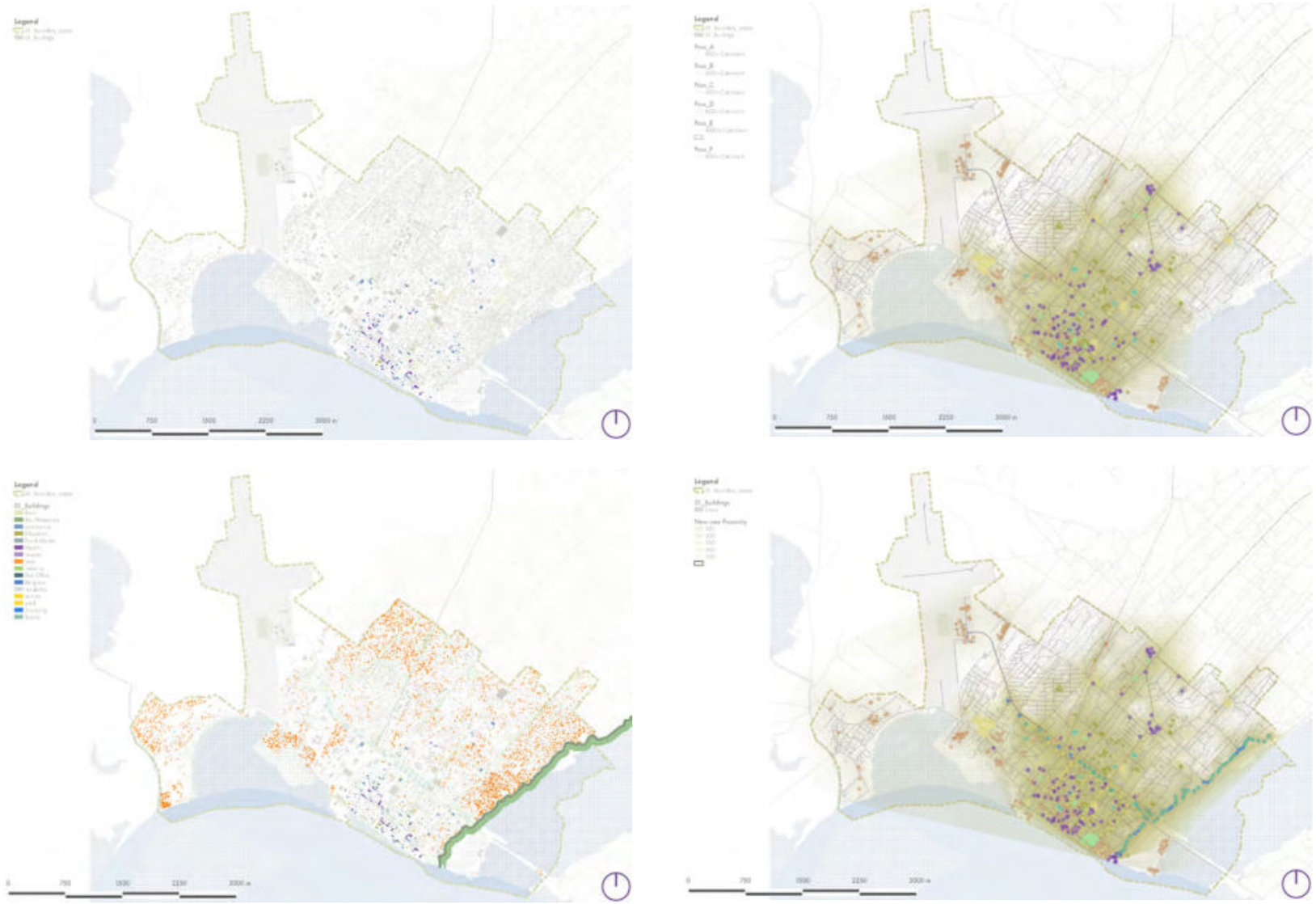


Figure 12.6 Proximity maps before and after the retroffiting [right]

Figure 12.7 Diversity map before and after the retrofitting [left]

12.1.6 Diversity

The synergy between the voids and functions from horizontal investigation gives diversity map, it is also noticed that the functions are catagorized into Neccessary regular, Neccessary optional, and Optional activities.
Multilayer, one of the SMART tool, helped us to integrate some variety of functions such as open food market (NRA), parks (NOA) and sport fields (OA). These functions makes the diversity map more advanced when compared to the initial state. In addition, the commercial activities in the ground floors of SMART houses increased the scope of diversity in barrio 11 which makes the slum inhabitants to access NOA.

12.1.7 Accessibility

To .give reminder, accessibility is the superimposition of function and transportation. The tool Soft, from SMART intervention plays a big role in linking the city and adding more cathement areas. The bike system create accessibility to the existing functions to the inhabitants from the East and West part of the city. Moreover, Multilayer tool also plays important role interms of layering new functions in both city and barrio scale.

Figure 12.8 Accessibility maps before and after the retroffiting [left]

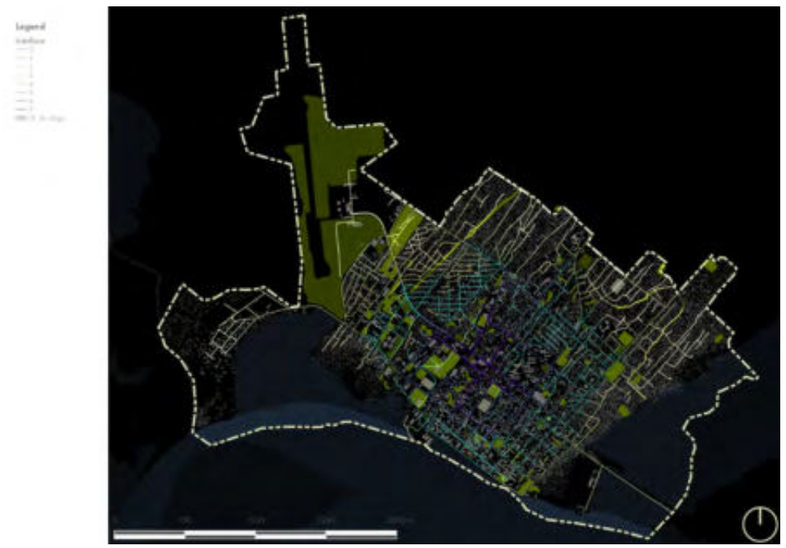
Figure 12.9 Interface maps before and after the retroffiting [left]

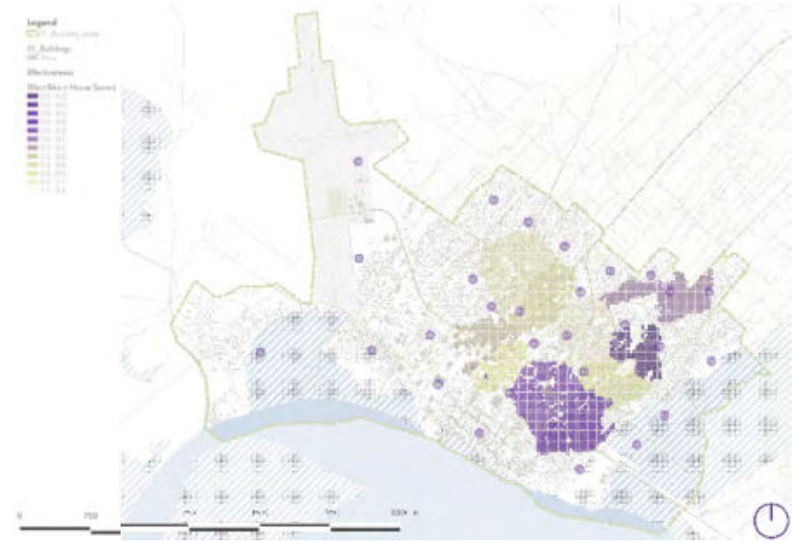
12.1.8 Interface

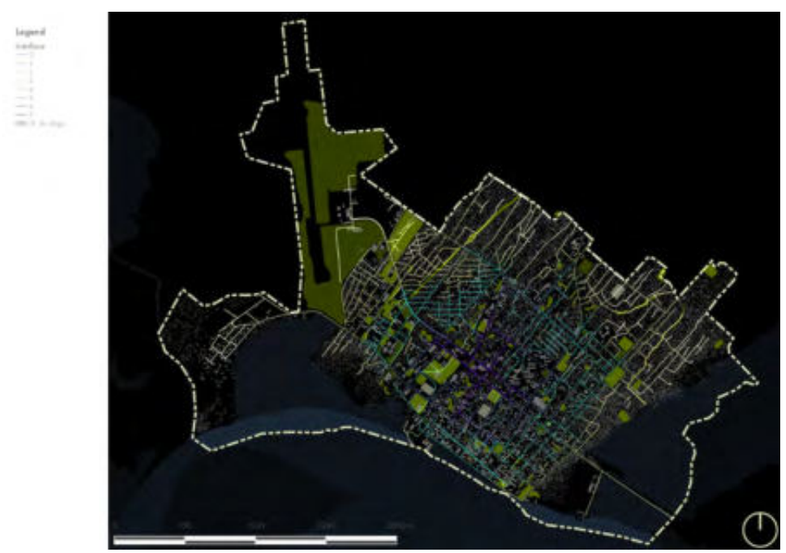
The synergy between void and transportation would give interface map. From our expectation also the obtained results shows little or no change throughout the city scale level. However, due to an introduction of some links in barrio 11, it has less significance change in the overall city scale level.

12.1.9 Effectiveness

The effectiveness map is the overlay between transportation and volumes from the previous analysis. It was found that the Eastern and Western part of the city (where most slums are located) was in lack of transportation accessibility eventhough there were some local functions among the slum areas (this data is obtained from primary source in the city). This leads us to integrate transportation nodes to activate the existing functions to become accessible by the other part of the city as well. On the other hand, the city center has a potential transportation facility so, we integrated it with the linear city park to get more types of uses.







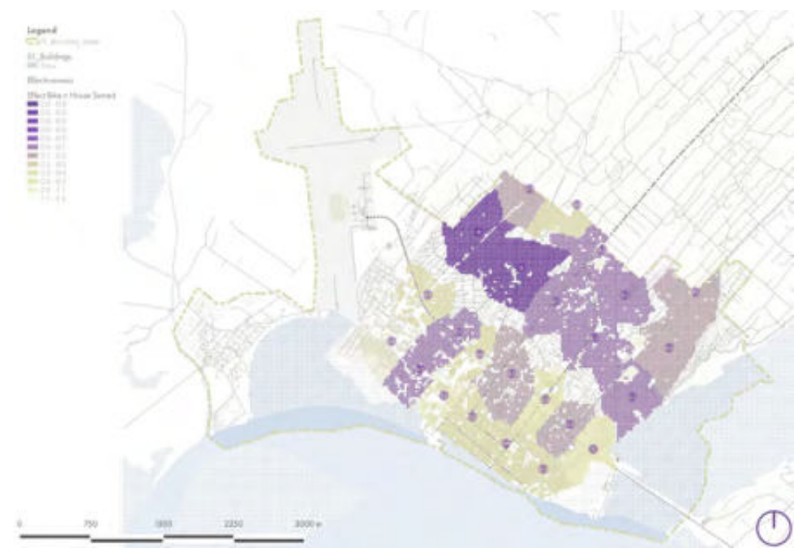


Figure 12.10 Effectiveness maps before and after [left]

12.2 Barrio scale Retrofitting

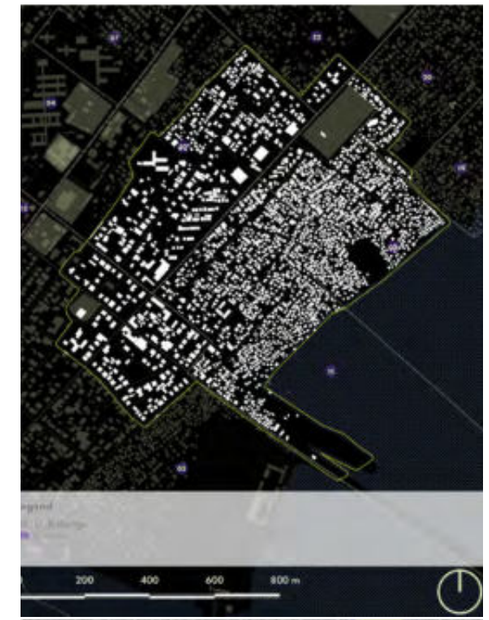
Figure 12.11 Volume maps before and after the retrofitting

- Introduction

In this part of the analysis, the retroffiting will be focused on barrio 11. This is because, the team had selected a particular project site in which the architecture design applied.
Barrio 09 has been part of the local scale analysis in section of this book, however, the focus of the retrofitting shifted to barrio 11 only.
It is also clear that the city scale interventions has a direct or indirect influence in barrio 11. IMM, being multiscale, has given us the opportunitty to analyse and relate diffrent scale interventions. .

12.2.1 Volumes & Voids

In this case, the analysis compares the former map with the map after the retrofitting are applied. It is clearly shown in the map that, the addition of the new volumes in the project area has also affected the entire barrio 11 and the effect will be discussed in the next residential volumes was to reduce overcrowding in a single household. Before adding new volumes to the project area, the total number of inhabitants has been calculated together with the average number of people per household. The obtained population number is used to calculate the expected volume needed in that area and the value again compared with the current volume. The result shows there is a need to add more volumes without affecting the voids which are neccessary to compliment the intervention.



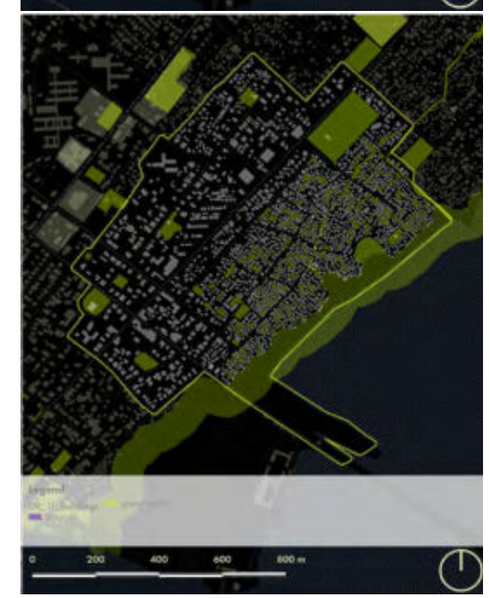


Figure 12.12 Trasportation map before and after the rettroffiting

12.2.2 Transportation

Regarding the transportation, we introduced two motobike stations which makes most inhabitants to walk maximum of five minute cathment area to reach to the stops. The new additions are supposed to facilitate existing motobike system. When the two maps are compared, it is possible to see the important from 28% to 55%. When comapred to the average transport link in the city.

12.2.3 Types of Uses

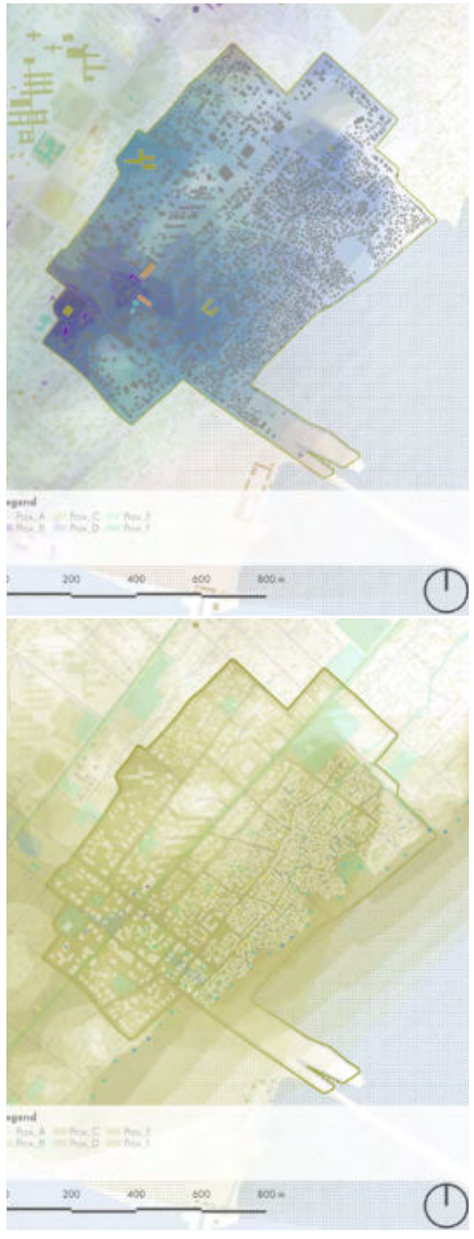
Thanks to the Multilayer tool, it was possible to integrate local businessess such as shops in the ground floor of the SMART houses in which added new functions to the area. This new functions has helped to increase the percentage of types of uses by some percent which was only small intially. The types of functions introduced are the waste collection points which also are part of the city scale intervention.

Figure 12.13 Types of uses map before and after the retroffiting

Figure 12.14 Proximity maps before and after the retroffiting

12.2.4 Proximity

As indicated in the map below, there is a little difference between the existing and the new proximity map. This is because of the addition of both volumes and functions. By doing this, we increased the quality of movement along the two parallel streets of the project area. People can intereact with the new added functions while passing by these two streets.



12.2.5 Accessibility

To .give reminder, accessibility is the superimposition of function and transportation. The tool Soft, from SMART intervention plays a big role in linking the city and adding more cathement areas. The bike system create accessibility to the existing functions to the inhabitants from the East and West part of the city. Moreover, Multilayer tool also plays important role interms of layering new functions in both city and barrio scale.

Figure 12.15 Accessibility maps before and after the rettroffiting

Figure 12.16 Interface maps before and after the re-roffiting

12.2.6 Interface

The Interface map is a kind of map which is difficult to analyse locally out of the big context. However, we tried to include the immediate surroundings of barrio 11 into the analysis to make meaningfull result.
The result shows a better linkage of the routes because of the introduction of new routes and bike stops which already discussed in chapter 08 (barrio scale intervention).

12.2.7 Effectiveness

In.this case, the introduction of new volumes (SMART houses) through Multilayer and the additions of transportation nodes through soft intervention. The changes that occured can be read from the effectiveness maps below.

Figure 12.17 Effectiveness maps before and after the rettroffiting

Figure 12.18 Diversity maps before and after the retroffing

12.2.8 Diversity

Using the multilayer tool, it was possible to integrate diverse of functions such as bikecafe, community farm spots, open areas for sport activities and local shops in the ground floors of the SMART house. The additions make barrio 11 more diversified compared to the initial stage.

12.2.9 Porosity

The additions of volumes and voids to the project have affected the new porosity map. It increased the volume percentage by little amount and also affected the building distribution per hectare but in less significant way.

Figure 12.19 Porosity maps before and after the retrofiting

12.3 Conclusion

Africa is now the fastest growing continent in the world, the African Development Bank's Annual Development Effectiveness Review 2013 states. The report, just published, says this growth has been driven mainly by improved economic governance on the continent and the private sector. The economic growth and the rapid urbanization of African cities has a global effect if not leaded by sustainable approach.
With our proposal and intervention ideas, we tried to correlate the UN sustainable development goals and the African 2063 agenda to help and facilitate different governmental policies and approaches. Both the city scale and barrio scale interventions have a positive impact by activating the socio-economic activities of the city of Quelimane.
The team also believes that, the application of IMM to different cities who are facing different urban problems such as slums and informal settlements would help the designers and policy makers to give the right solutions.
At last, our work would also open an avenue for different interested parties to do a research on the other barrios which are already identified. The application of the IMM can also be adopted to various medium-sized African cities.

L'Africa è ora il continente in più rapida crescita al mondo, afferma l'Energy Development Effect Review Review 2013 della African Development Bank. Il rapporto, appena pubblicato, afferma che questa crescita è stata trainata principalmente dal miglioramento della governance economica nel continente e nel settore privato. La crescita economica e la rapida urbanizzazione delle città africane ha un effetto globale se non guidato da un approccio sostenibile.
Con la nostra proposta e le idee di intervento, abbiamo cercato di correlare gli obiettivi di sviluppo sostenibile delle Nazioni Unite e l'agenda africana del 2063 per aiutare e facilitare diverse politiche e approcci governativi. Gli interventi sia a livello di città che a livello di barrio hanno un impatto positivo attivando le attività socio-economiche della città di Quelimane.
Il team ritiene inoltre che l'applicazione dell'IMM in diverse città che devono affrontare diversi problemi urbani come baraccopoli e insediamenti informali aiuterebbe i progettisti e i responsabili politici a fornire le giuste soluzioni.
Alla fine, il nostro lavoro aprirà anche una strada per le diverse parti interessate a fare una ricerca sugli altri barrios che sono già stati identificati. L'applicazione dell'IMM può anche essere adottata in varie città africane di medie dimensioni.

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