Final Report

Sustainable Mobility in Sub-Saharan African Cities

Ibukunoreoluwa Odele

Dissertation Supervisor: Clemence Cavoli – Lecturer at UCL

Department of Civil, Geomatic, and Environmental Engineering

University College London

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DECLARATION & PERSONAL STATEMENT

The project has been carried out by ……..…Ibukun Odele…..……………

The author has read and understood the College's policy regarding plagiarism and the submission of coursework. The authors confirms that, except for commonly understood ideas and concepts, or where specific reference is made to the work of other authors, the contents of this report are their own work. This dissertation is presented in 68 pages including bibliography and appendices. It contains approximately 7563 words, 25 figures and 12 tables.

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Abstract

Improving access to key services in rapidly growing cities like Maputo is a major challenge, especially where semi-formal and informal transport systems operate in parallel. This project explores how integrating the city's planned BRT system with its existing Chapas network could improve accessibility to healthcare, education, employment, and recreational amenities. The analysis uses travel-time isochrones, weighted amenity scoring, and population projections for 2023 and 2028 to measure access across different travel time bands and assess the role of network design and population growth. Results show that the integration leads to a clear improvement in accessibility, with around 330,000 more people able to reach essential services within 60 minutes. However, gains are uneven, with some fast-growing peripheral areas still underserved due to infrastructure constraints. These findings suggest that infrastructure improvements and better integration with semi-formal modes of transport could make urban transport more inclusive and responsive to future growth in Sub-Saharan African cities.

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1. Introduction

1.1 Urban Transportation In Sub-Saharan Africa

Urbanisation across Africa has intensified over the past two decades, with particularly rapid growth in Sub-Saharan Africa (SSA) and Asia. In 2017, over 90% of the global rural population resided in these two continents, but migration trends have since shifted toward urban centres, as individuals and families seek better economic opportunities, access to services, and improved living standards (Mittal et al., 2023). In SSA alone, the urban population doubled between 1995 and 2015, and it is projected to double again by 2035 (Mittal et al., 2023). However, this unprecedented pace of urban growth is often unmatched by proportional infrastructure investment, resulting in increased pressure on essential services, including transportation.

Transport systems, comprising of physical infrastructure, service networks, and regulatory frameworks, play a pivotal role in shaping access to education, employment, healthcare, and recreational amenities. Yet in many cities across SSA, transport infrastructure remains underdeveloped, fragmented, and unable to meet the mobility needs of growing populations. Challenges such as traffic congestion, poor road infrastructure, lack of investment in formal public transport, and limited regulation of informal services significantly constrain accessibility (Bueno Rezendede Castro et al., 2022).

Accessibility in transport, as defined by Negm et al. (2025), refers to the ease with which people can reach desired opportunities and services. A robust transport system facilitates the seamless movement of people, enabling inclusive participation in economic life. In contrast, dysfunctional systems exacerbate inequality by creating barriers to mobility, particularly for low-income and peripheral communities (Haq & Schwela, 2012). In this context, the sustainability and inclusivity of urban transport systems have become key priorities in the development agendas of SSA cities.

This dissertation builds upon a growing amount of academic contributions that have explored mobility, informality, and accessibility in SSA. Projects such as TRANSITIONS and T-SUM have analysed paratransit networks and identified accessibility gaps, particularly in cities like Maputo and Freetown (Behrens et al., 2021). In Mozambique, the Mapas dos Chapas project has produced one of the most detailed mappings of semi-formal bus routes to date. This study contributes to and extends these efforts by applying spatial analysis to evaluate how the proposed BRT system may reshape accessibility patterns in Greater Maputo. In doing so, it offers new insights into the potential of integrated transport systems to reduce both social and spatial exclusion.

1.2 Project Aim and Scope

This study explores public transport accessibility in the Metropolitan Maputo Area (MMA), focusing on the integration of Chapas, Maputo's dominant minibus network, with the proposed Bus Rapid Transit (BRT) system. It assesses how this integration could improve access to key services such as education, healthcare, and employment, particularly for underserved areas. The analysis includes:

- Mapping population and amenity distribution in the MMA
- Measuring accessibility gaps using isochrones and catchment analysis

- Assessing the impact of population growth and network integration on accessibility
- Visualising results through thematic maps and statistical summaries

With these objectives, the study seeks to address the following research question:

“To what extent can integrating the semi-formal Chapas and formal BRT networks improve access to essential services for more of Maputo’s population, and how does this align with high demand corridors and projected growth?”

2. Background & Literature Review

2.1 The Maputo Metropolitan Area (MMA)

2.1.1 Maputo's "Cement" and "Reed" city

Maputo's urban landscape reflects a deep spatial divide rooted in colonial planning and post-independence growth, commonly described as the split between the "Cement City" (Cidade de Cimento) and the "Reed City" (Cidade de Caniço), as shown in Figure 1 and 2. The Cement City, developed during the Portuguese colonial period, was formally planned and well-serviced, featuring paved roads and structured drainage, primarily serving settlers and elites. In contrast, the Reed City emerged informally on the urban periphery to accommodate a rapidly growing population, characterised by makeshift housing built with materials like reed and corrugated metal, often lacking access to basic services such as proper sanitation and water. This enduring duality has contributed to entrenched spatial inequality, shaping present-day disparities in access to infrastructure, access, mobility, and opportunity across the region (Stacciarini et al., 2022).

Figure 1. Geographic extent and satellite view of Cement City (Cidade de Cimento), Maputo. Left: Polana Cimento neighbourhood boundaries over OSM basemap. Right: Satellite imagery of Polana Cimento "A" Source: OpenStreetMap (2025); Google Earth (2025)

Figure 2. Satellite image of high-density informal settlement in KaMavota, Maputo. An area representative of the "Reed City" (Cicade de Canico). Structures are densely cluster with irregular street layout, reflecting unplanned urban growth typical of Maputo's peri-urban areas.

2.1.2 Population Growth

Maputo has experienced sustained population growth over the past four decades, driven by natural increase and rural-to-urban migration. According to the Comprehensive Urban Transport Master Plan (2014), the population of Greater Maputo, comprised of Maputo, Matola, and parts of Marracuene, was projected to grow from 2.2 million in 2012 to 3.7 million by 2035 (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014). Much of this growth has occurred in peripheral areas such as Matola and Marracuene, reflecting decentralised urban expansion (see Figure 3). The youth dominated nature of this growth has placed added pressure on essential services like employment, education, healthcare and transportation, reinforcing the need for more inclusive and future proof mobility planning.

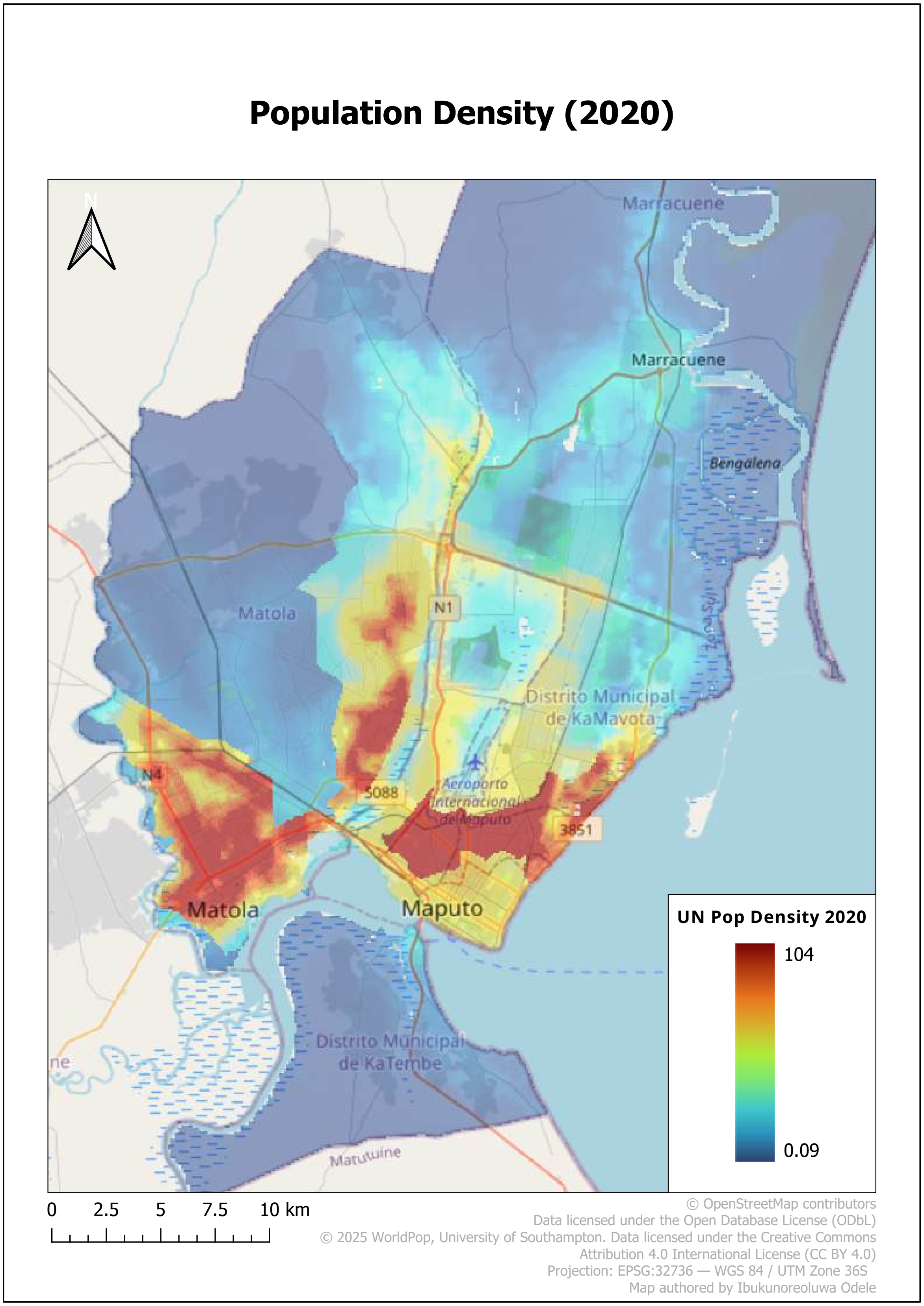

Figure 3. Population density map of the greater Maputo Area in 2020, highlighting higher concentration in central Maputo and southern Matola, and emerging growth in peripheral areas such as Marracuene. Source: WorldPop (2025)

One key driver of migration is the centralisation of social and economic opportunities in Maputo, offering better access to services and employment. Households are drawn to the city in pursuit of improved living standards, particularly higher paying jobs often lacking in rural areas (Giannotti et al., 2021). However, the mismatch between rapid population growth and infrastructure provision has accelerated informal settlement patterns and placed growing pressure on existing mobility networks.

2.1.3 Urban Sprawl and poverty

Urban sprawl refers to the outward, often unplanned expansion of the city into peri-urban and rural areas. In Maputo, this has been driven by rising housing costs in the centre, pushing lower-income communities to settle in outlying areas like Laulane, Zimpeto, and Matola-Gare (Mottelson & Jenkins, 2024). These peripheral zones often lack basic infrastructure and reliable public transport links, limiting access to the city (Behrens et al., 2021; Massingue & Oviedo, 2021).

The result is a fragmented urban form, where opportunity is concentrated but housing is dispersed. This spatial mismatch contributes to a concept called transport-related social exclusion and reinforces cycles of socio-economic marginalisation in the MMA.

2.2 Transport in Maputo Metropolitan Area (Case Study)

2.2.1Transport Related Social Exclusion

Transport-related social exclusion refers to the inability of individuals to fully participate in society due to inadequate access to transportation (Luke, 2024). This exclusion can be understood across several dimensions:

- Spatial – limited access to key destinations
- Temporal - excessive travel times
- Financial - unaffordable transport costs
- Physica - barriers related to disability or poor infrastructure

(Luke, 2024)

These dimensions offer a framework for evaluating how transport infrastructure in Maputo affects accessibility to opportunities. In many cases, residents often face commutes exceeding two hours, driven by spatial isolation and congestion (Oviedo et al., 2024).

2.2.2 “Myluvs” and “Chapas” (Informal/Semi-formal transportation)

Informal and semi-formal transport services, collectively referred to as paratransit, play a dominant role in Maputo’s mobility landscape. Informal services are defined by their lack of regulation, flexible routing, and absence of formal schedules, often operating as demand-responsive systems in areas underserved by the state or municipality (Agbiboa, 2020; Klopp & Cavoli, 2019). Whereas semi-formal transport are more organised, typically operating with partial licensing and under a transport union (Mokoma & Venter, 2023).

“MyLuvs” are open-back pickup trucks commonly used in rural and peri-urban areas to provide low cost, informal transport where formal alternatives are unavailable. They operate within a legal grey area, having faced regulatory restrictions in the past with government policy seeking to phase out such modes (Klopp & Cavoli, 2019)). However, due to their adaptability and demand responsive nature, they help better serve marginalised communities with limited road infrastructure highlighting their functional importance (Durant et al., 2023a). Moreover, high capital and maintenance costs make private vehicles unattainable for most households, making informal services essential for the majority despite concerns over safety and congestion (Agbiboa, 2020; Behrens et al., 2021).

"Chapas" are semi-formal minibuses that dominate Maputo's urban core and peri-urban fringes. They represent the backbone of everyday mobility for a majority of residents, operating an estimated fleet of over 3,000 vehicles (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014; Tembe et al., 2019)). Chapas operate in a loosely coordinated but heavily relied upon network, with their modal share accounting for approximately 32.9% of daily trips as shown in Figure 4, only second to walking (Tembe et al., 2019).
Despite their prevalence, paratransit systems face significant challenges, including overloading,

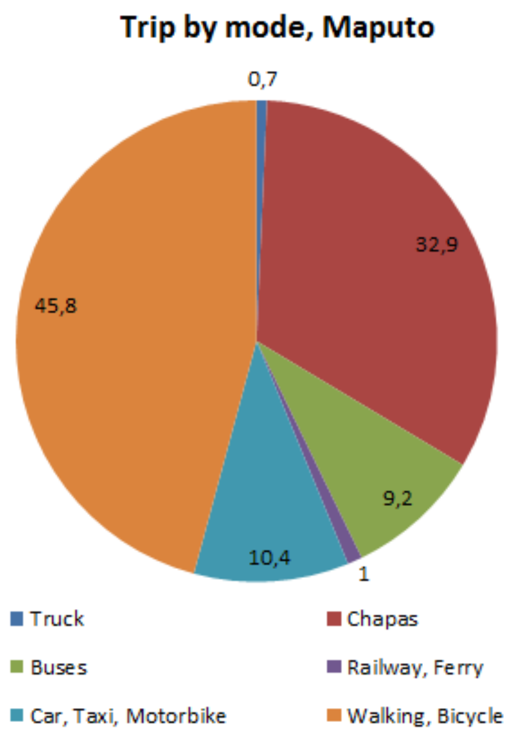

Figure 4. Modal Share of daily trips in Maputo.
Source: Mapas Dos Chapa Project.

safety concerns, limited regulation, and contribute to urban congestion. Service routes are typically concentrated along high demand corridors, but they operate independently of a unified network (Ndibatya & Booysen, 2021). GPS data from projects like Mapas Dos Chapas has been used to map these services as seem in Figure 5, revealing spatial inefficiencies and service gaps (Goletz & Ehebrecht, 2020)

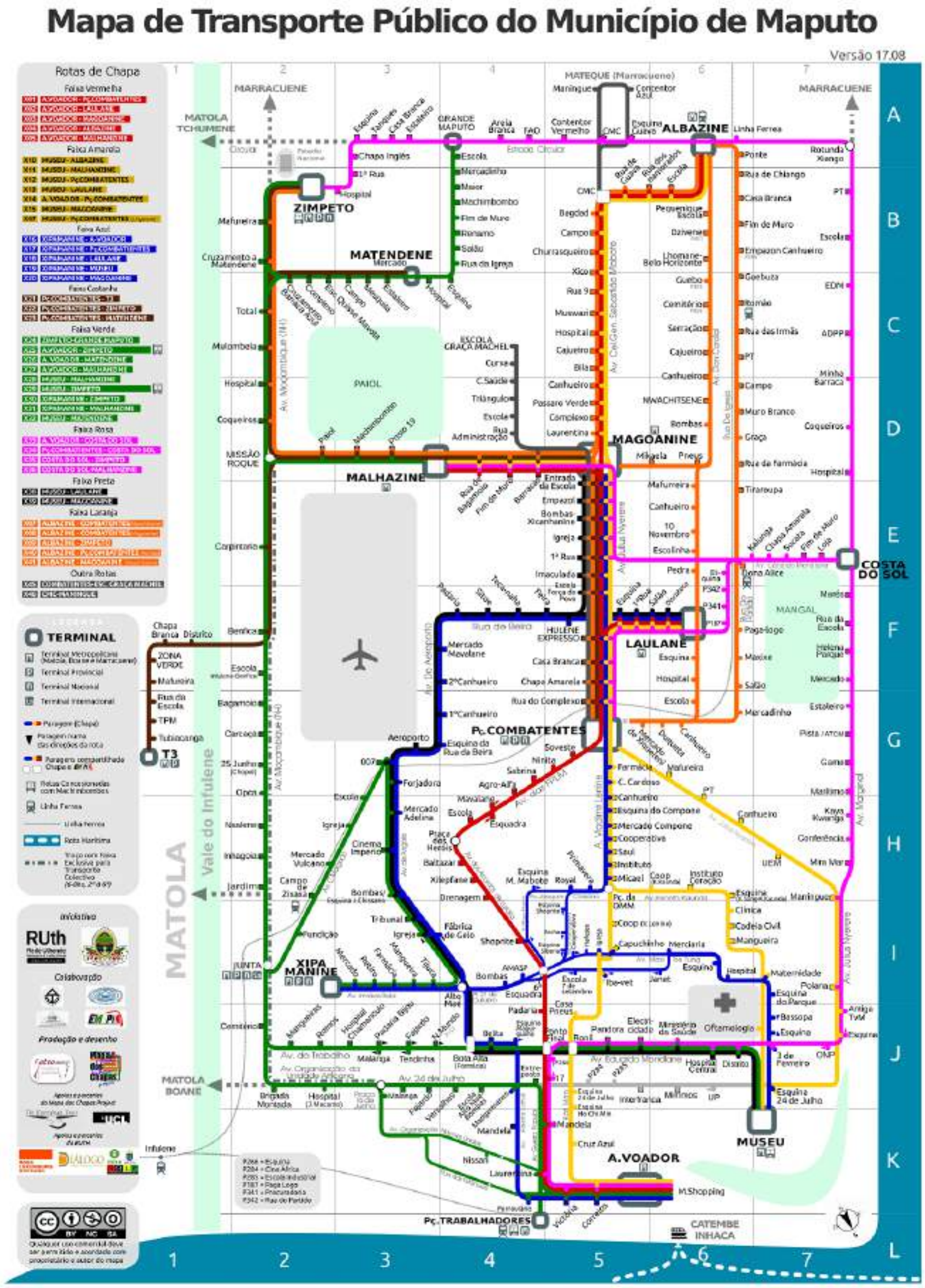

Figure 5. Mapped Chapas routes across Maputo Municipality. Source: Mapas Dos Chapas

2.2.3 Planned BRT System (Formal Transportation)

Formal public transport refers to systems that are planned, regulated, and operated by public or licensed entities, often with timetabled services and designated stops. In Maputo, the shift towards formalisation is symbolised by the creation of the Agência Metropolitana de Transporte (AMT) and the planning of a Bus Rapid Transit (BRT) system.

The BRT project, first proposed in 2014 and under active development since 2023, is designed to connect Maputo with Matola and Marracuene via six high-capacity, segregated and mixed corridors as seen in Figure 6 (Behrens et al., 2021; Durant et al., 2023a). These corridors are intended to bypass urban congestion and provide faster, more reliable service. The BRT system is also expected to reduce dependence on private cars and relieve pressure on the overburdened Chapas system (Haq & Schwela, 2012).

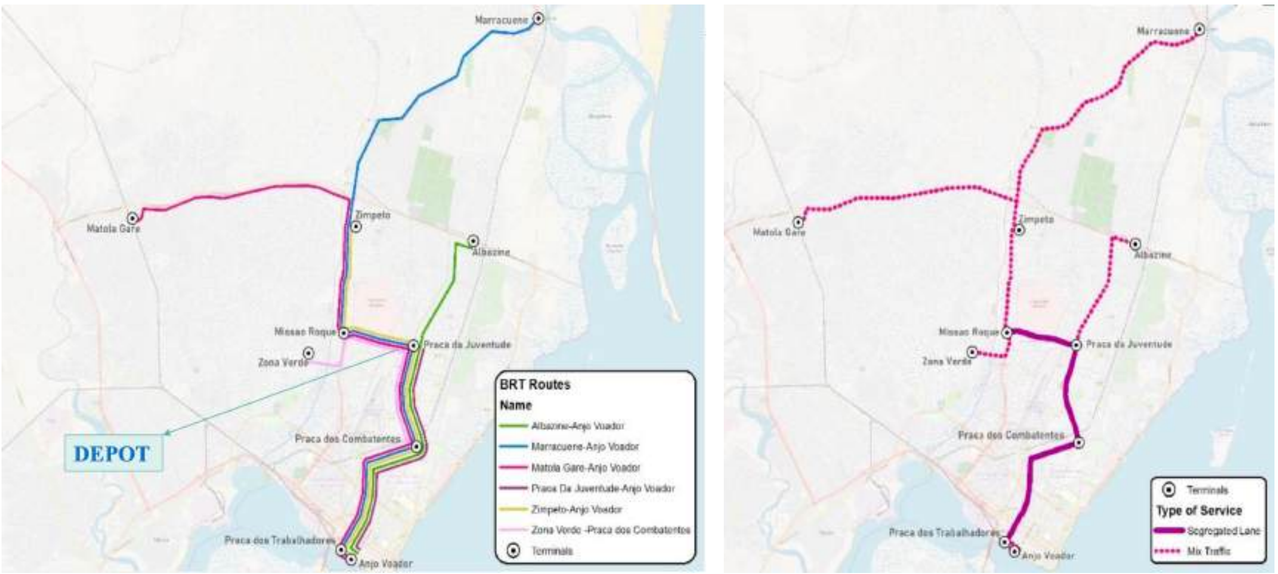

Figure 6. Planned BRT corridors in Maputo. Left: the six proposed BRT routes, Right: The mixed traffic and segregated lane segments.

It must be acknowledged that the transport planners recognise that the BRT alone cannot meet current demand making integration with semi-formal modes essential. Current plans include the use of feeder routes, e-ticketing systems, and infrastructure for intermodal transfers at key terminals (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014).

2.2.4 Multi-Modal Integration

The current modal split in Maputo is reliant on public transport buses, however many roads remain unpaved or in poor condition, limiting the reach and reliability of large buses and formal transport. (Agbiboa, 2020; Behrens et al., 2021). Rail and conventional buses exist but are limited in network coverage and frequency, partly due to underinvestment and weak institutional support (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014). This context highlights the urgent need for a multimodal system that enhances integration without displacing vital semi-formal services.

Multimodal integration refers to the coordination of various transport modes, formal and informal, into a seamless, efficient urban mobility system (Ho & Tirachini, 2024). In Maputo, this concept is increasingly prioritised as part of the long-term strategy for inclusive mobility. Sietchiping et al.

(2012) mentions how multimodal systems improve network efficiency, reduce transfer times, and enhance accessibility for low-income users. Lessons can be drawn from cities such as Lagos, Nigeria, where the BRT has been integrated with informal "Danfo" minibus routes through route rationalisation and depot-sharing strategies (Karner & Ming Zhang, 2019).

In Maputo, the success of such efforts will depend on effective governance, public-private partnerships, and community participation. If implemented effectively, multimodal integration could significantly reduce transport-related social exclusion by enhancing affordability, accessibility, and reliability across the urban mobility landscape.

2.2.5 Economic Implications of BRT Integration

While much of the literature focuses on service design and spatial planning, some sources also touch on the economic implications of introducing BRT systems in cities with large informal transport sectors like Maputo.

In the case of Maputo, the Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary (2014) outlines concerns that replacing Chapas with the BRT system could affect the incomes of existing operators, especially where route overlaps exist. Some mitigation measures are discussed, such as offering the Chapas operators compensation or allowing them to own shares in new operating companies (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014). This mirrors examples from Lagos and Bogotá, where BRT rollout disrupted informal operators so inclusive frameworks were put in place (Otunola et al., 2019).

Financially, the feasibility of BRT depends heavily on ridership levels and fare design. In Maputo, there are concerns that current average fares may only be enough to cover operating costs, and that some combination of higher fares or concessional finance might be needed for long-term sustainability (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014). For residents, this could mean higher costs, particularly if BRT stops are not easily accessible, pushing people to rely on multiple modes, paying more overall.

This tension between affordability and operational cost recovery is at the core of integration debates. It prompts important insightful questions such as, should Chapas be excluded from the BRT corridors entirely, or continue operating as feeder services?

3. Methodology

3.1 Methodological Overview

This project adopts a spatial and network-based methodology to assess accessibility within the Maputo Metropolitan Area (MMA), examining the impact of integrating the current semi-formal minibus system ("Chapas") and the proposed Bus Rapid Transit (BRT) network. It combines geospatial data analysis, travel time estimation via Google's API services, and network-based accessibility modelling in QGIS.

This study focuses on evaluating the spatial distribution of population and key amenities (education, healthcare, employment, social & recreational), and quantifying the potential time savings from the BRT integration. The methodology follows three main phases outline in Figure 7:

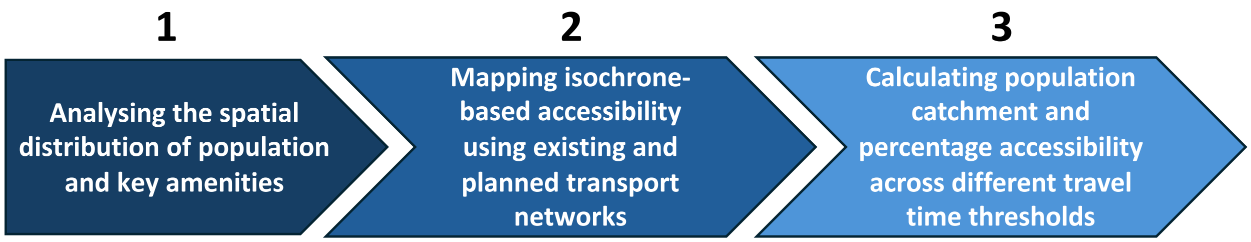

Figure 7. Key methodology phases for project analysis

This approach allows for a comparative evaluation of current versus future accessibility scenarios and assesses how these changes may benefit or disadvantage different regions within MMA.

3.2 Data Sources

This study draws on a range of geospatial, transport, and demographic datasets shown in Table 1:

Table 1. Data sources used and their descriptions

Data Source	Description	Reference
OpenStreetMap (OSM)	Road networks, Chapas routes and bus stops (digitised data from the Mapas dos Chapas project).	OpenStreetMap (2025)
Google Maps Directions API	Used for travel time estimates and route profiles, accessed under free-tier usage limits.	(Google, 2025)
WorldPop (2023 & 2028)	High-resolution population raster data (100m x 100m); used for current and projected population estimates.	WorldPop (2025)
MoveMaputo Project	Source of planned BRT routes used for digitising BRT for integrated transport scenario.	(Arthur, 2023)
Feasibility Study Documents	Literature-derived proposed speeds estimate to inform network travel time modelling assumptions.	JICA (2014)

3.2.1 OpenStreetMap (OSM)

OpenStreetMap provided the base map and foundational spatial infrastructure, including road networks, Chapas routes, bus stops, key amenity points and shapefiles. The loaded Chapas network was verified by cross checking the routes within the relation matched the routes in the Mapas Dos Chapas map seen in Figure 8. The attribute table was then inspected and revealed distance and duration for each multi-part feature which represented a named route within the Chapas system.

full_id	r7335531
osm_id	7335531
osm_type	relation
route	bus
colour	NULL
wheelchair	NULL
via	NULL
roundtrip	NULL
seats	NULL
type	route
to	Praça dos Combatentes
ref	X12i
public_tra	2
opening_ho	5:30-22:00
network	Chapas
name	X12: Museu - Praça dos Combatentes
from	Museu
fare_curre	MZN
fare	10
duration	30
distance	12
direction	1

Figure 8. Attribute table of a feature within the Chapas relation. Source: OpenStreetMap (2025)

3.2.2 Google Maps Application Programme Interface (API)

Travel time data for mixed-traffic conditions was extracted using Google's Places API (new) and Routes API. A Microsoft Excel sheet configured through the "API Connector" Google Sheets add-on was used to automate travel time and distance calculations between origin - destination pairs. The API request specified:

- Origin and destination coordinates
- Travel mode ("driving" for mixed-traffic analysis)
- Units in kilometres
- Day/time selection for peak periods (6–9 AM, 4–7 PM) across the week

Google's routing algorithm, which uses a combination of live GPS data, historical trends, and predictive modelling, enabled realistic journey time estimates for both Chapas and BRT routes along corridors with mixed traffic (Google, 2025).

3.2.3 Open Spatial Demographic Data

Population count data was obtained from WorldPop (2023 & 2028, Mozambique), provided as a GeoTIFF raster. The dataset offers high-resolution estimates of population per 100m² pixel, which were used to assess the spatial distribution of residents and support isochrone-based catchment analysis (*WorldPop : Population Counts 2023*, n.d.; *WorldPop : Population Counts 2028*, n.d.).

3.2.4 Literature-Derived Inputs

BRT speed along the segregated lanes were set to 60 km/h. This is based on the feasibility study from the JICA/AMT 2014 Comprehensive Urban Transport Plan (Comprehensive Urban Transport Master Plan for the Greater Maputo Final Report Executive Summary, 2014).

3.3 Tools and Software

3.3.1 QGIS (Geographic Information System)

Table 2 states all the processing tolls used to run the analysis:

Table 2, QGIS tools and plugins used and their description.

QGIS Tool / Plugin	Description
QuickOSM	Plugin for downloading and importing OpenStreetMap data directly into the QGIS workspace.
OSM Place Search	Tool used to extract municipal and district boundaries from OSM.
QNEAT3	Plugin used for network-based spatial analysis, including isochrone generation.
Field Calculator	Used to compute travel times, average speeds, and attribute-based accessibility scores.
Snapping Tools & Topology Checker	Ensures geometric accuracy and network connectivity by identifying and correcting errors.
Raster and Vector Analysis Tools	Used for mapping population and amenity distributions using spatial layers.
Zonal Statistics	Computes population statistics within isochrone polygons for accessibility

3.4 Spatial Analysis Methods

The spatial analysis was limited to the Maputo Metropolitan Area (MMA), which includes the Maputo City, municipalities of Matola, and adjacent peri-urban zones. However, the municipality of Boane and Distrito Municipal de KaNyaka were excluded from the study area, as the proposed BRT network does not extend into these regions as seen in Figure 9. All layers, including population density, amenities, and transport networks, were clipped to the boundaries of the region of focus accordingly to ensure that only features within the BRT-affected area were retained. This defined spatial boundary was used consistently across both the spatial and network analyses.

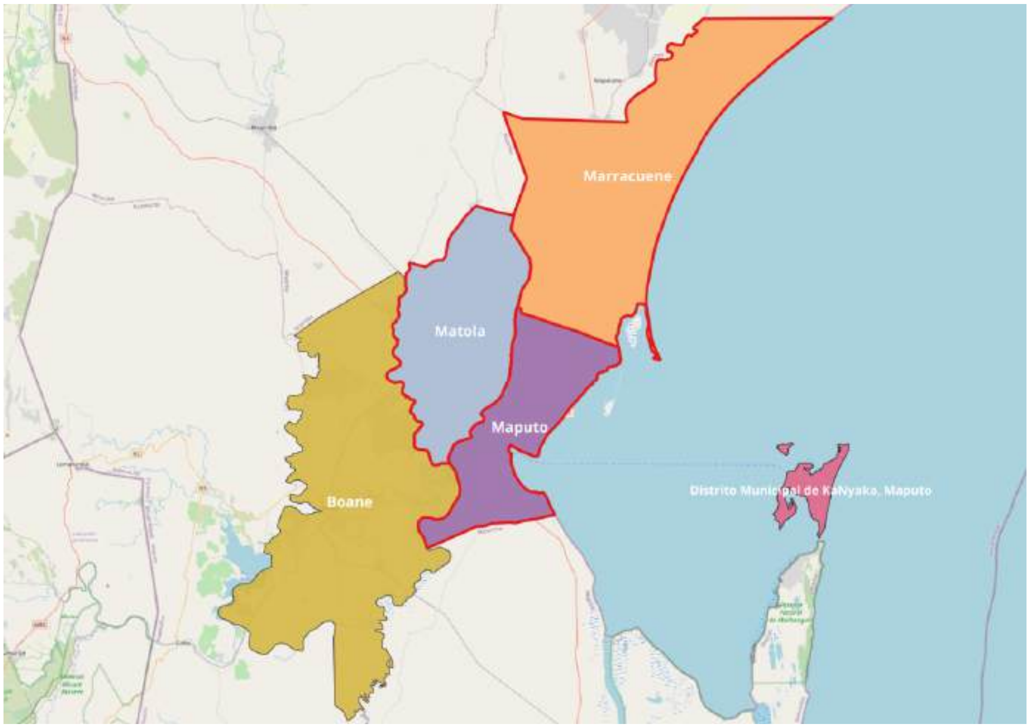

Figure 9. Area of Focus for this analysis highlighted in re, restricting the municipalities of focus to Maputo, Matola and Marracuene. OpenStreetMap (2025)

3.4.1 Population Density Mapping

Population count data for Mozambique downloaded from WorldPop (2023 & 2028) and loaded into the map, raster layer was initially in the EPSG:4326 coordinate reference system (CRS) and was reprojected to EPSG:32736, a projected CRS appropriate for spatial analysis in southern Mozambique, which supports accurate distance and area calculations in metres. EPSG:32736 was made to be the default CRS for every layer within this project. The raster layer was then clipped to the study boundary, focusing only on the urbanised areas of Maputo and its metropolitan fringe. This visualisation enabled clear interpretation of high- and low-density areas for subsequent catchment analysis.

3.4.2 Key Amenity Identification and Categorisation

QuickOSM was used to extract OSM data for amenity locations:

Table 3. Amenity categories and the type of facilities selected for analysis.

Amenity Category	Examples of Features Selected	Total Amenity Mapped
Education	Schools, colleges, training centres	336
Employment	Industrial zones, office complexes, commercial buildings, shops	4,427
Healthcare	Clinics, hospitals, health posts	177

Amenity Category	Examples of Features Selected	Total Amenity Mapped
Social & Recreational Amenities	Shops, markets, religious buildings, leisure venues	3,662

The categories in Table 3 were selected because they represent the core urban functions that people rely on for a decent standard of living (Maket et al., 2024). Education, healthcare, and employment are foundational for socio-economic advancement, while access to recreational and social amenities contributes to well-being, inclusion, and overall quality of life. Prior studies in African cities have also used similar categories to assess equity in access-based urban development (World Bank, 2017). Including these categories enables a more holistic understanding of how transport accessibility shapes everyday experiences in the Maputo Metropolitan Area (Maket et al., 2024). Moreover, access to a diverse set of urban amenities, rather than single destination accessibility, is increasingly recognised as a core component of equitable and sustainable city design (Muhammad Mulyadi et al., 2022).

Polygon features (e.g. hospital grounds, markets) were converted to centroids to represent them as nodes (points) to use as origin locations within the network. While traditional accessibility models often treat all amenities equally to avoid assumptions about demand, this study incorporates weighted amenities to better reflect the functional relevance of different facility types. This approach has been used in other Sub-Saharan African contexts to capture the varying importance of services in meeting daily needs and planning inclusive infrastructure.

3.4.3 Grid Creation and Opportunity Density

To assess the concentration of amenities across the city, a vector grid of 1,000m x 1,000m was generated and clipped to the study area (shown in Figure 10). A spatial join was used to count the number of amenity points within each grid square to compute opportunity density within the grid.

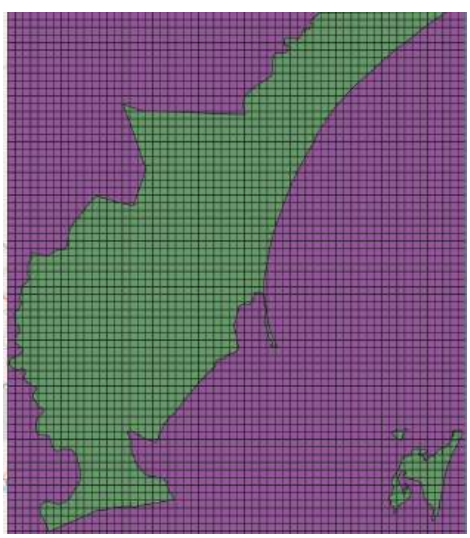

Figure 10. Grid clipped to area of focus for amenity count per cell

This process produced a simple but effective surface to compare opportunity-rich versus opportunity-poor areas. By comparing these grids with the population count maps, the study could assess whether marginalised communities located in peri-urban zones also faced poorer access to amenities, a central concern in the literature on transport-related social exclusion (Agbiboa, 2020; Luke, 2025).

3.5 Network Creation Methods

Network analysis was utilised to model spatial accessibility within Maputo's public transport system, examining both the current Chapas (minibus) system and the proposed BRT corridors. The objective was to estimate travel time by generating isochrone bands at defined intervals, enabling the analysis of catchment areas and the comparison of accessibility coverage across districts and regions.

3.5.1 Chapas Route and Bus Stop Mapping

The base network of Maputo's Chapas system was loaded from OpenStreetMap and then clipped to the defined study boundary of MMA, ensuring alignment with the same area of focus used in spatial analysis (see Figure 11).

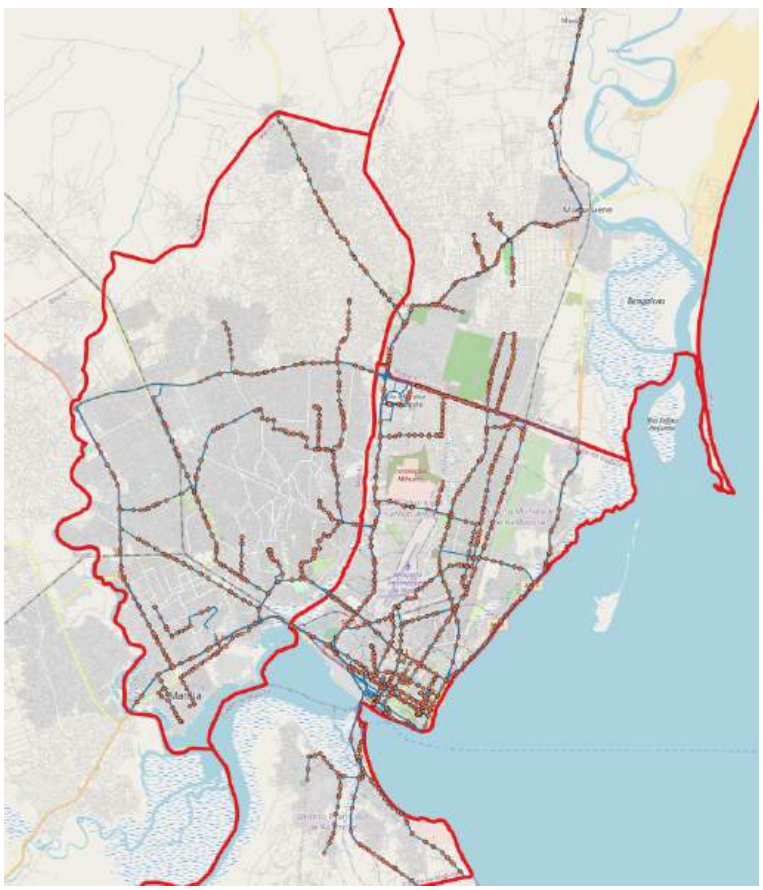

Figure 11. Clipped Chapas network to area of focus. Source: OpenStreetMap (2025)

To prepare the data for analysis the following steps in Table 4 were taken:

Table 4. Network data preparation steps, including attribute creation and field calculation.

Step	Attribute Name	Action Taken	Field Expression Used
1	length_m	Calculated geometrical length (in metres) of each multipart Chapas route using Field Calculator	length($geometry)
2	avg_speed_kmh	Calculated average speed using known duration (in minutes) data and length	$\left(\frac{length\_m}{1000}\right) \div \left(\frac{duration}{60}\right)$
3	avg_speed_kmh	Assigned calculated average speed as the route's speed attribute	N/A (value retained from previous calculation)
4	avg_speed_kmh	Where duration was missing, applied default average speed from Google API-based average (30.88 km/h)	N/A (value manually input as 30.88 km/h)
5	Geometry	Split multipart Chapas routes into singlepart features to support routing analysis	Processing Toolbox > "Multipart to Singleparts"
6	length_m	Recalculated length for singlepart segments to ensure routing accuracy	length($geometry)
7	speed_kmh	Created new field speed_kmh to standardise naming across merged layers; copied avg_speed_kmh values into this field	avg_speed_kmh

This data transformation was crucial for enabling segment-level travel time modelling and for simplicity later on when merging with the BRT and the highway layers into a single, integrated multimodal graph.

3.5.2 BRT Network Mapping

To model the proposed BRT network, a PNG map from the MoveMaputo project was georeferenced using QGIS as shown in Figure 12 (Arthur, 2023). Control points were placed on high-contrast landmarks and major road intersections to maximise alignment accuracy. The aim was to overlay this proposed network with the existing Chapas network and determine potential corridor overlaps.

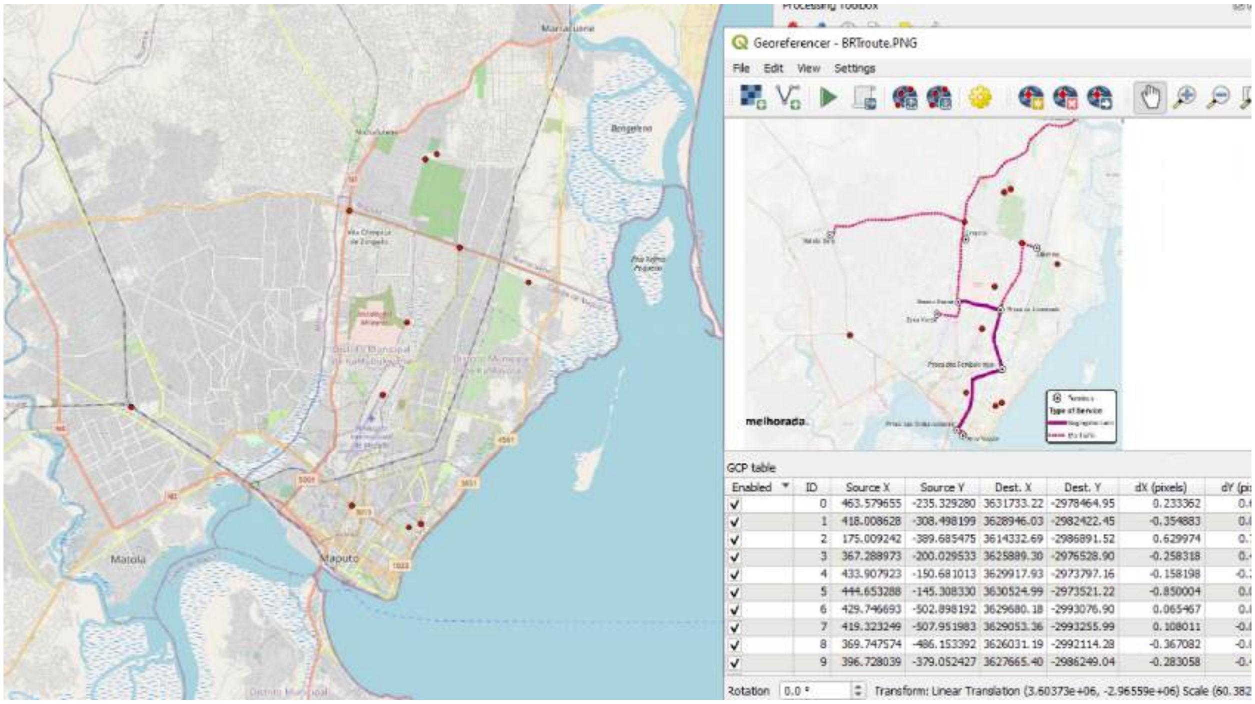

Figure 12. Georeferencing the proposed BRT layer. Source: MoveMaputo (2025), OpenStreetMap (2025)

Through visual inspection and spatial matching with the Mapas Dos Chapas, five Chapas routes (shown in Table 5) were identified as broadly aligning with the proposed BRT corridor:

Table 5. Chapas routes that align with the BRT Network

Aligning Chapas Routes
X05 A. Voador – Malhanzine
X21 Pc. Combatentes – T3
X04 A. Voador – Albazine
X22 Pc. Combatentes – Zimpeto
32-0 and **506**: Zimpeto – Matola Gare & Marracuene – Tchumene

To digitise the BRT Network, the identified Chapas routes are selected from the network using the "Select by Expression" tool in QGIS and are then exported to an independent layer as seen in Figure 13c. For greater precision, the exact extents of the BRT layer was clipped by a drawn polygon after to trim off the irrelevant extents of the selected Chapas network. This approach allowed for more accurate segmentation of the BRT alignment ensuring proper alignment with existing roads and terminals, building a better representation of what the final BRT network could look like.

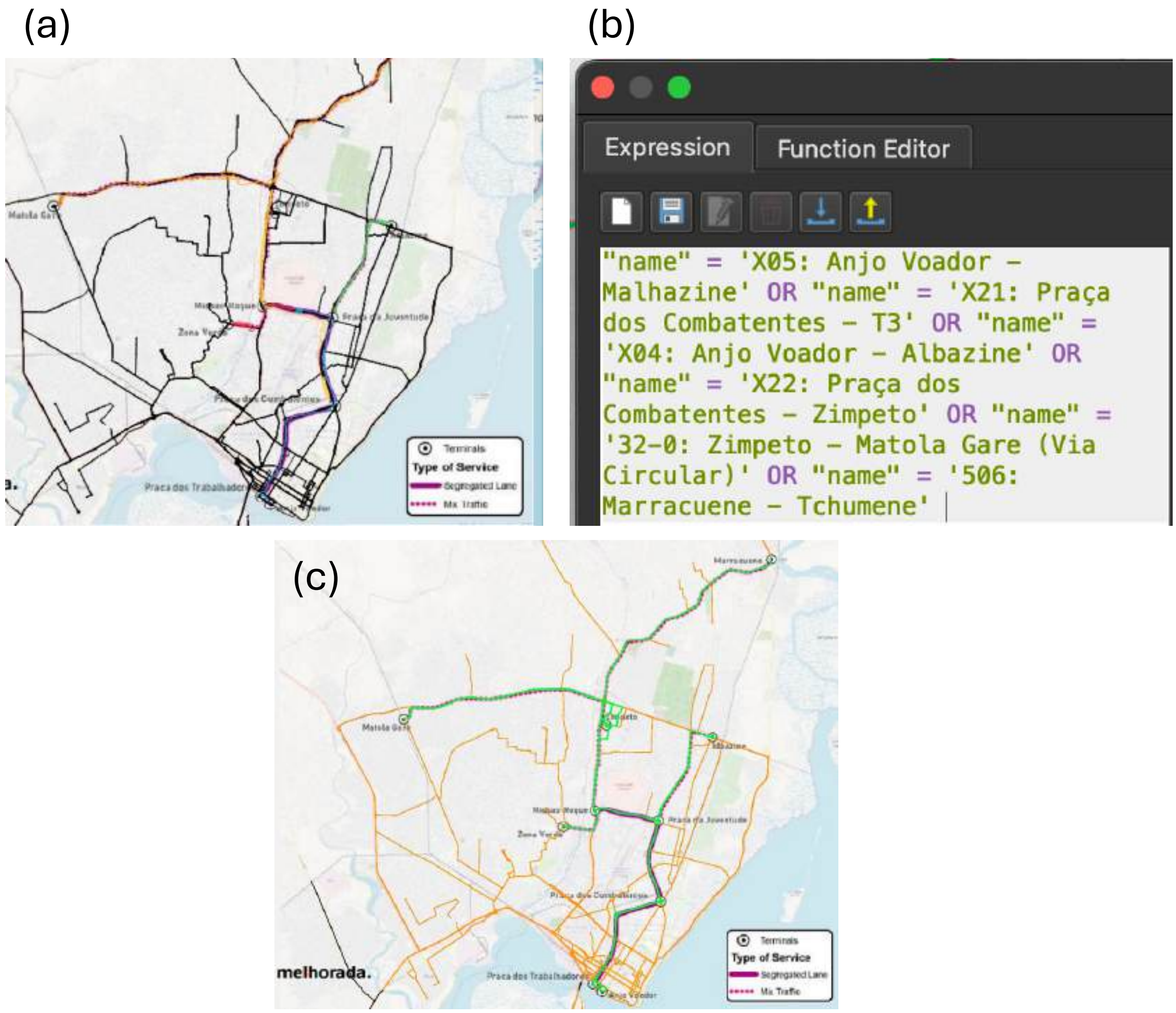

Figure 13. (a) Visual Inspection of aligning Chapas routes with the BRT corridors, (b) Select by expression function, (c) Exported BRT layer digitised

The resulting BRT layer was further processed by using the same methodology shown in Section 3.5.1, Table 4.

The "speed_kmh" field was determined depending on the type of service the BRT was operating, in a segregated lane or mixed traffic. This was differentiated within the layer by creating a new attribute field called "seg_type" as shown in Figure 14b.

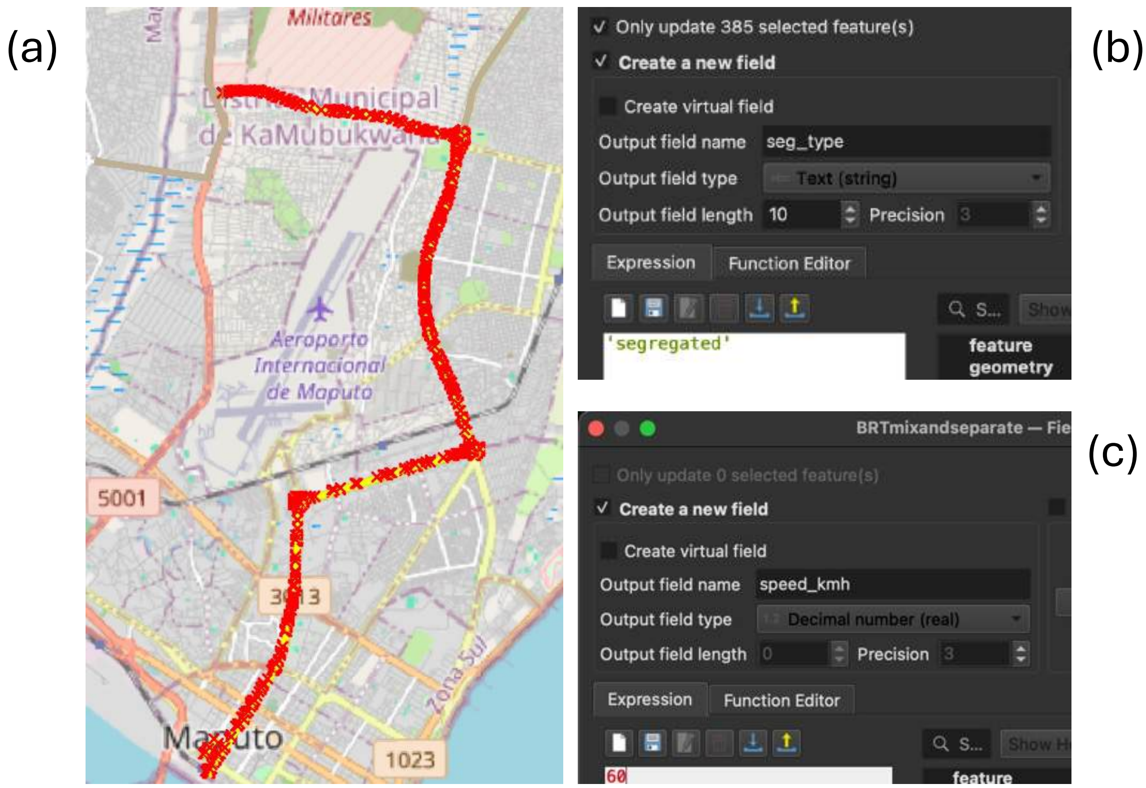

Figure 14. (a) Selected section of the BRT layer to label as segregated lanes, (b) "seg_type" field creation, (c) "speed_kmh" attributed to the 60 km/h speed

Segregated lane sections were assigned a fixed speed of 60 km/h, based on the JICA 2014 feasibility report (Durant et al., 2023b). For mixed traffic sections, segment-specific (Terminal to Terminal) average speeds were derived from Google Maps API queries run during peak hours across the week, yielding values between 19.41 km/h and 46.76 km/h. The average of these speeds, 30.88 km/h were used as the default speeds for the Chapas routes without a set duration.

*Table 6. Speeds assigned to each service type within the BRT layer. *Mixed traffic average speed was determined by calculating the trave time for each section over 1 week (14/4/25-20/4/25) using the API excel sheet*

Section Name	Type of Service	Average Speed (km/h)	Reference
Missão Roque – Zona Verde	Mixed traffic	19.41*	Google's API
Praça da Juventude – Albazine	Mixed traffic	23.37*	Google's API
Zimpeto – Missão Roque	Mixed traffic	25.62*	Google's API
Matola Gare – Zimpeto	Mixed traffic	39.19*	Google's API
Zimpeto – Marracuene	Mixed traffic	46.76*	Google's API
Segregated Lane	Segregated traffic	60.00	JICA 2014

This cleaned and segmented BRT layer was then merged with the Chapas and highway networks for integrated analysis.

3.6 Network Analysis Methods

Accessibility was modelled using QGIS network analysis tools to generate isochrones, travel time-based catchment areas, from each amenity point for each network type, Chapas and Integrated.

3.6.1 Defining Accessibility

In this study, accessibility is defined as the ability for individuals to reach key amenities within a reasonable travel time via the available public transport network. This interpretation aligns with established accessibility literature, which considers both travel time and spatial proximity as key indicators of transport equity (Luke, 2025; Oviedo et al., 2024).

A 60-minute travel time threshold was adopted as the primary benchmark for acceptable access. This threshold is widely used in transport planning to represent a reasonable one-way journey for low-income populations dependent on public or informal modes of transport (Behrens et al., 2021). To provide a more detailed understanding of spatial and temporal accessibility, additional isochrones were generated at 15-minute intervals (15, 30, 45, and 60 minutes).

3.6.2 Network for Accessibility Analysis

A complete transport network was built by merging the layers stated in Table 7 and is visualised in Figure 15:

Table 7. Network types and connected layers. Highway network represents the walking involved to reach a bus stop. The walking speed was set as 5km/h

Network Type	Layers Used
Chapas Network	*Highway + Chapas
Integrated Network	*Highway + Chapas + BRT

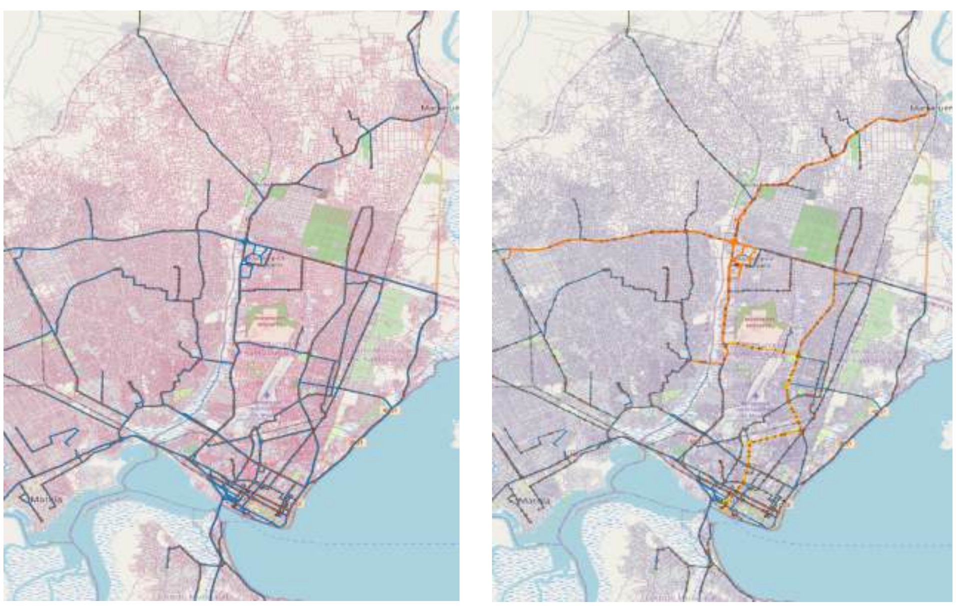

Figure 15. Completed networks. Left: Chapas Network, Right: Integrated Network

QGIS topology tools were used to validate the network structure. The integrity of the network is visualised with a fastest path origin and destination test illustrated in Figure 16

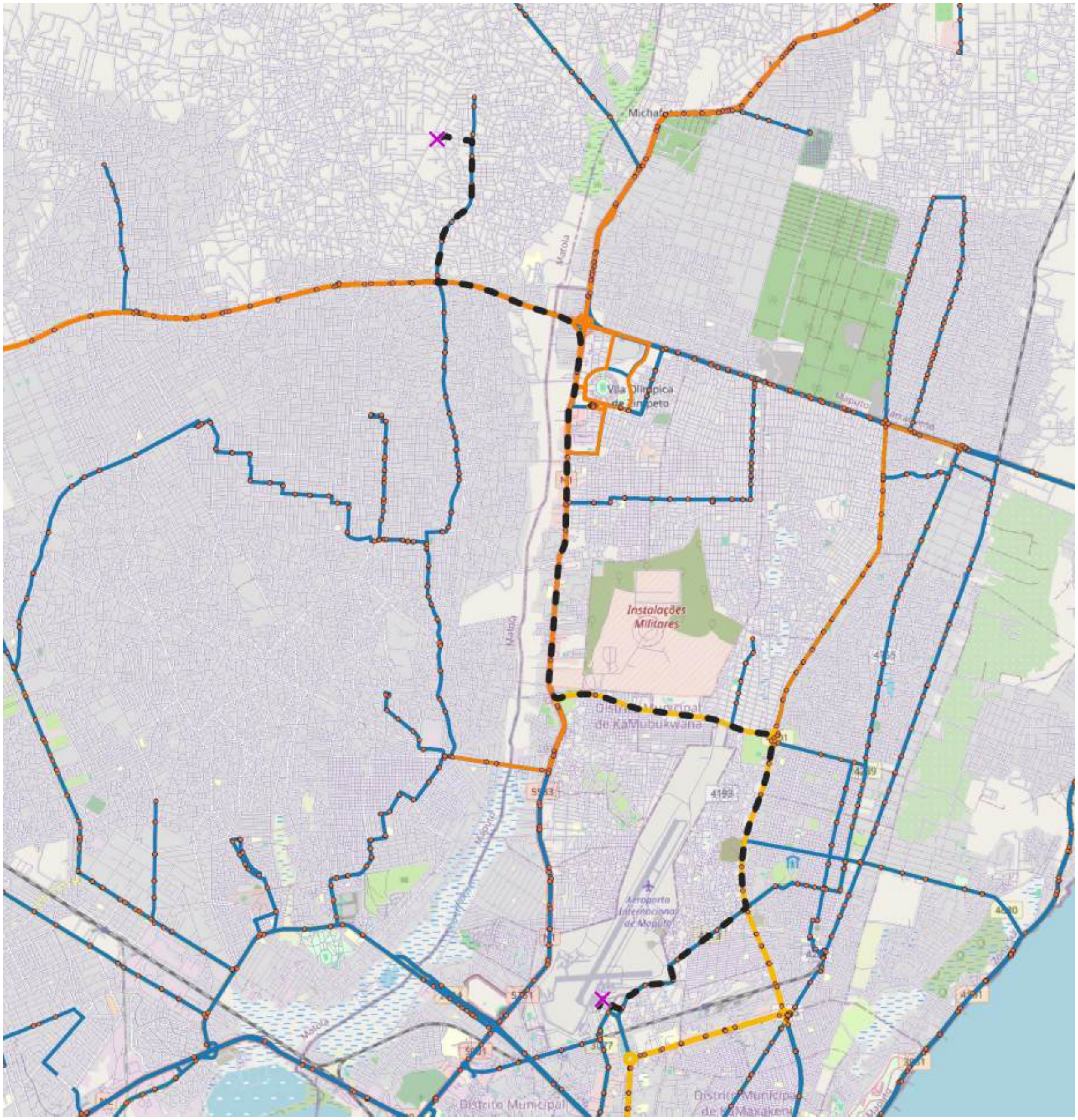

Figure 16. Fastest path Origin and destination analysis performed using QNEAT3.

3.6.3 Isochrone Generation and Catchment Modelling

Isochrones were generated using the QNEAT3 plugin in QGIS, with each amenity type (as outlined in Section 3.4.2) serving as the starting point for the analysis. This was done to understand how accessible key amenities are to the surrounding population within the defined travel time bands using the two transport networks.

To simplify the analysis in dense areas like central Maputo, all amenities within each 1,000m x 1,000m grid cell were grouped and represented by a single centroid. Each centroid was assigned two attributes: “weight_count” (number of amenities) and “weight_sum” (their combined importance). Weighting was applied using a 1–5 scale to reflect the significance of each amenity, based on the idea that accessibility should consider not just quantity, but the presence of diverse and essential services (SA Massingue, 2021). Table 8 showcases the classification style used for each amenity type. Full weighting classification of each amenity type is available in Appendix C-F.

Table 8. Categorisation scoring for amenity types

Score	Category	Description
5	Critical	High frequency, limited substitutes (e.g. hospitals, primary schools)
4	High	Very important but slightly less frequent (e.g. clinics, secondary schools)
3	Moderate	Useful and moderately accessed (e.g. shops, libraries)
2	Low	Nice-to-have, infrequent use (e.g. theatres, parks)
1	Very Low	Niche or irregular access (e.g. planetariums)

After the metrics "weight_count" and "weight_sum" are computed, zonal statistics was used to analyse the range of values. The upper percentile (Q3), seen in Table 9, was used to focus the analysis on high-priority zones with the most significant amenity concentrations. This approach avoids skewing results with low-density or low-weighted areas and aligns with best practices in sustainable indicator studies (Pakzad et al., 2017). It ensures the analysis targets meaningful accessibility rather than nominal service presence. The difference pre and post processing is visualised in Figure 17.

Table 9. Upper percentile values used as minimum criteria for origin POI's

Category	Metric	Q3
Education	weight_sum	15
	weight_count	3
Employment	weight_sum	20
	weight_count	10
Healthcare	weight_sum	9
	weight_count	2
Social & Recreational	weight_sum	14
	weight_count	9

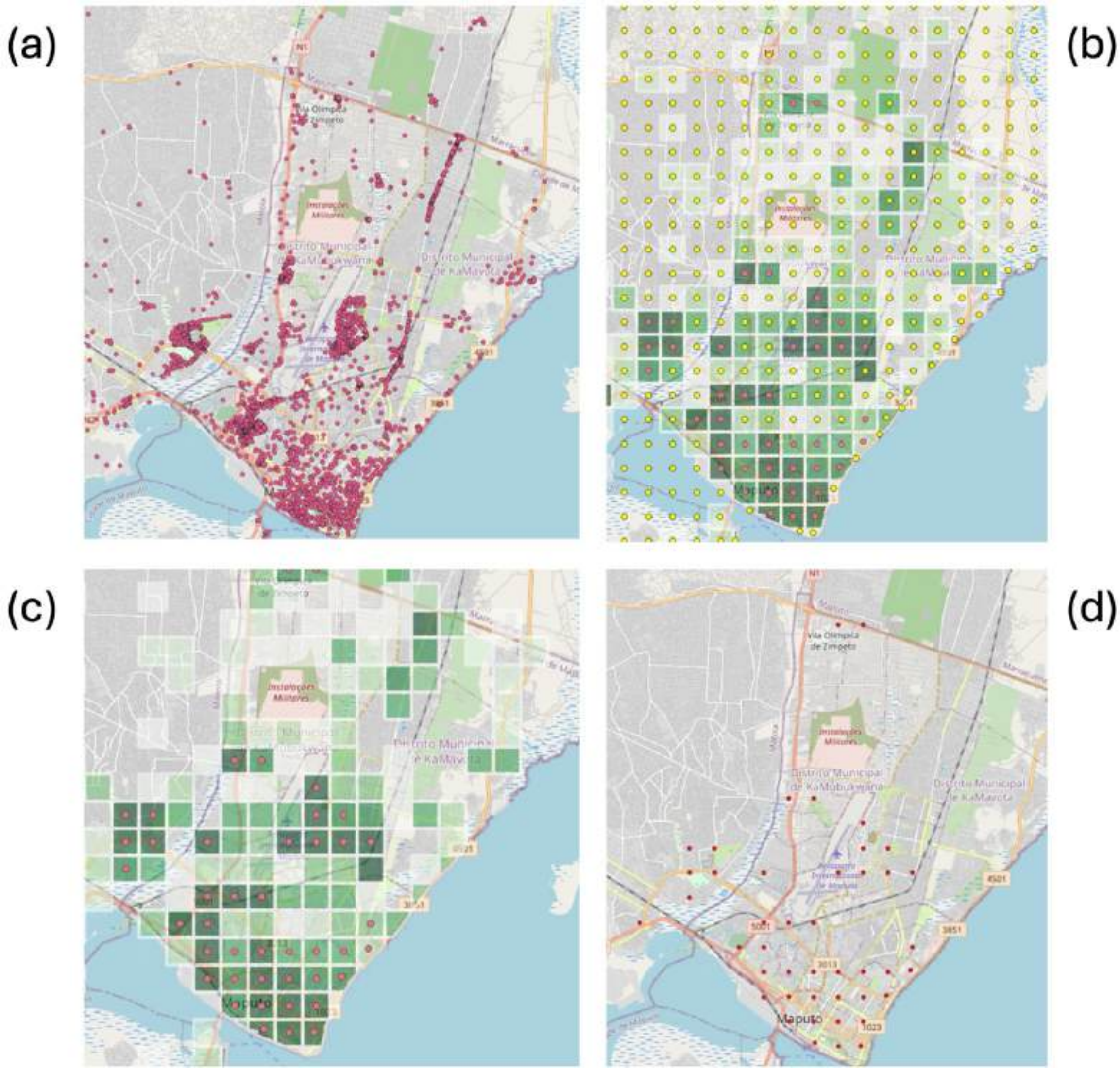

Figure 17. (a) All amenity points, (b) Amenity points grouped into centroids, (c-d) Weighted amenities filtered ready for isochrone analysis

From each weighted centroid, isochrones were generated at 15-minute intervals up to 60 minutes for both the Chapas and Integrated networks. These were based on the speed_kmh attribute for each segment, capturing realistic operating speeds across BRT and mixed-traffic routes. This ensured that catchment areas reflected actual travel conditions rather than idealised shortest paths.

Isochrones were then overlaid with 2023 and 2028 WorldPop raster data to estimate the number of people within each time band per amenity type. The analysis also calculated the percentage of the population with access to each amenity, enabling comparisons across services and timeframes. These outputs, visualised through maps and statistical charts, highlight spatial inequalities and how accessibility improves under different network scenarios.

3.7 Limitations and Assumptions

While this study presents a robust framework for modelling accessibility in Greater Maputo, several limitations and assumptions must be acknowledged.

1. Traffic Conditions and API Data
Travel times for mixed traffic segments were estimated using Google Maps API, which provides generalised averages based on historical and real-time data. However, local traffic in Maputo is highly variable, with informal activity and congestion affecting accuracy. Peak periods (6–9 AM and 4–7 PM) were assumed to be broadly representative.

2. BRT Network Design
The BRT network model reflects the planned end-state integration from the MoveMaputo project. Although phased implementation is expected, this study assumes full rollout for comparison purposes. Future work could test partial rollouts to assess transitional impacts.

3. Stop Locations and Integration Assumptions
BRT stops were assumed to be akin to Chapas's bus stops and terminals. Their exact locations remain unknown, which introduces some spatial uncertainty. The study also assumes seamless operational integration between the Chapas and BRT systems, although real-world coordination, particularly in SSA contexts, can be complex and politically sensitive (Durant et al., 2023b).

4. Service Frequency and Capacity
BRT service frequency and ridership capacity were not modelled, as formal schedules are unavailable. The analysis is based purely on spatial and time-based accessibility, omitting service reliability and vehicle capacity, which are critical for user experience.

5. Chapas and MyLuvs
The model assumes coexistence between the Chapas and BRT system, though in practice, the Chapas network may be rerouted or phased out along BRT corridors. The impact of such restructuring is not assessed here but warrants future sensitivity testing. Similarly, MyLuvs were excluded due to a lack of consistent operational data despite their role in peripheral transport.

6. Population Projections
Population data from WorldPop (2023, 2028) form the basis for catchment analysis, but actual future demographic changes may be influenced by unpredictable socio-economic trends.

4. Results

This chapter presents the results of the accessibility analysis across key amenity types. Healthcare was selected to illustrate density-based disparities due to its clear spatial contrasts in both unweighted and weighted maps (Figures 18 and 19), while Employment was used as the representative example for accessibility improvements observed in the isochrone analysis (Figures A and B). Similar trends were identified for Education and Social & Recreational amenities and are included in Appendix B.

4.1 Amenity Distribution and Density

The unweighted density map shows a clear spatial clustering of amenities in Cement City and south Matola. Peripheral areas such as Katembe and Marracuene had sparse amenity representation across all categories.

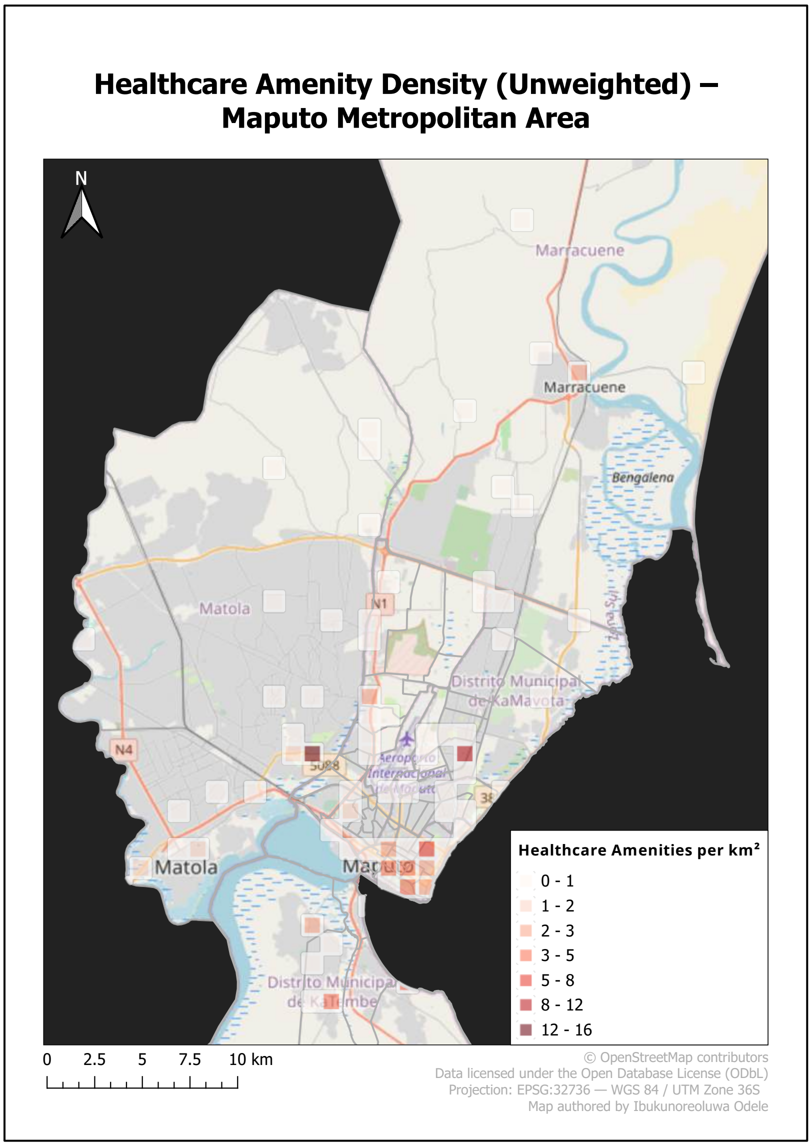

Figure 18. Unweighted Amenity Density (Healthcare example)

The weighted density map further concentrated high-priority amenities in central urban zones. Key services such as secondary schools and hospitals scored higher and were predominantly located in the inner city.

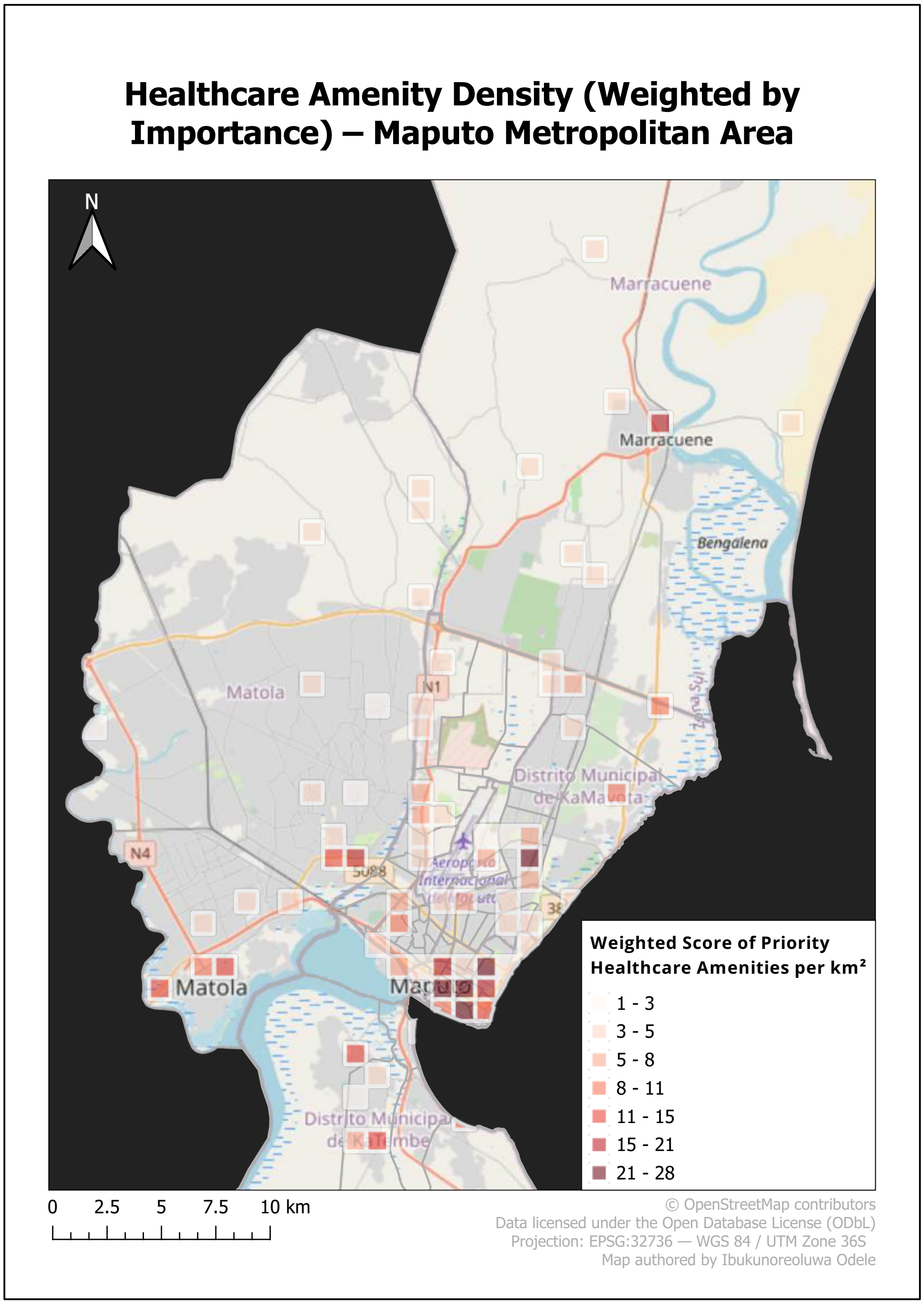

Figure 19. Weighted Amenity Map (Healthcare example)

4.2 Isochrone-Based Accessibility

Isochrone maps were generated at 15-minute intervals up to 60 minutes for both the Chapas-only and Integrated networks. Under the Chapas-only scenario, coverage was largely limited to central Maputo and southern Matola, with reduced reach in the northern and western districts shown in Figure 20.

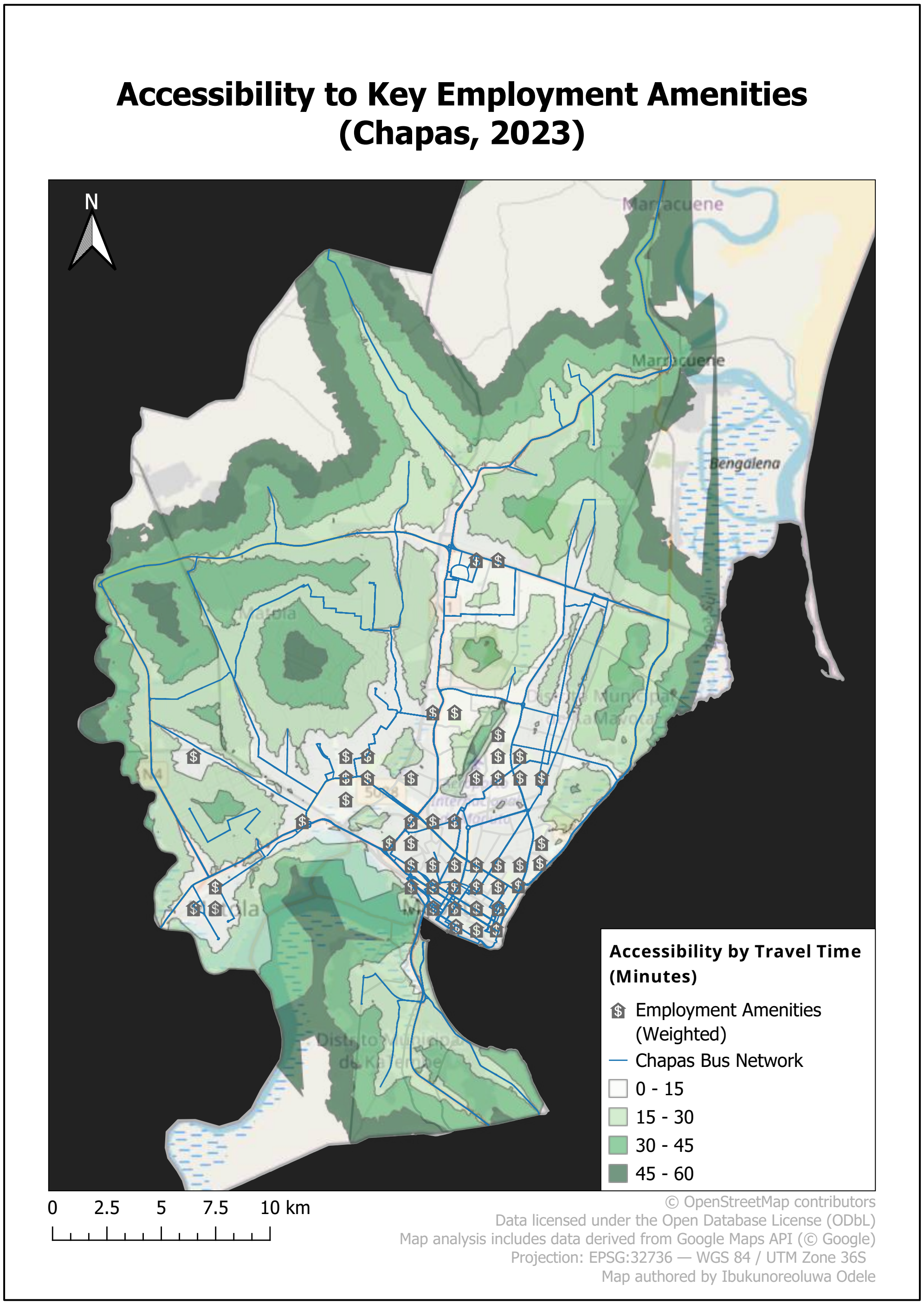

Figure 20. Chapas network isochrone catchment bands (Employment example)

The Integrated network expanded accessibility, particularly within the 15–30 minute travel time bands. Healthcare and employment services showed the most pronounced increases in spatial reach. Reach in the northern and western districts showed a notable increased illustrated in Figure 21. In this analysis, the accessibility rate refers to the percentage of the total population within the study area that can reach a given amenity within a specified travel time threshold (e.g., 15, 30, 45, or 60 minutes).

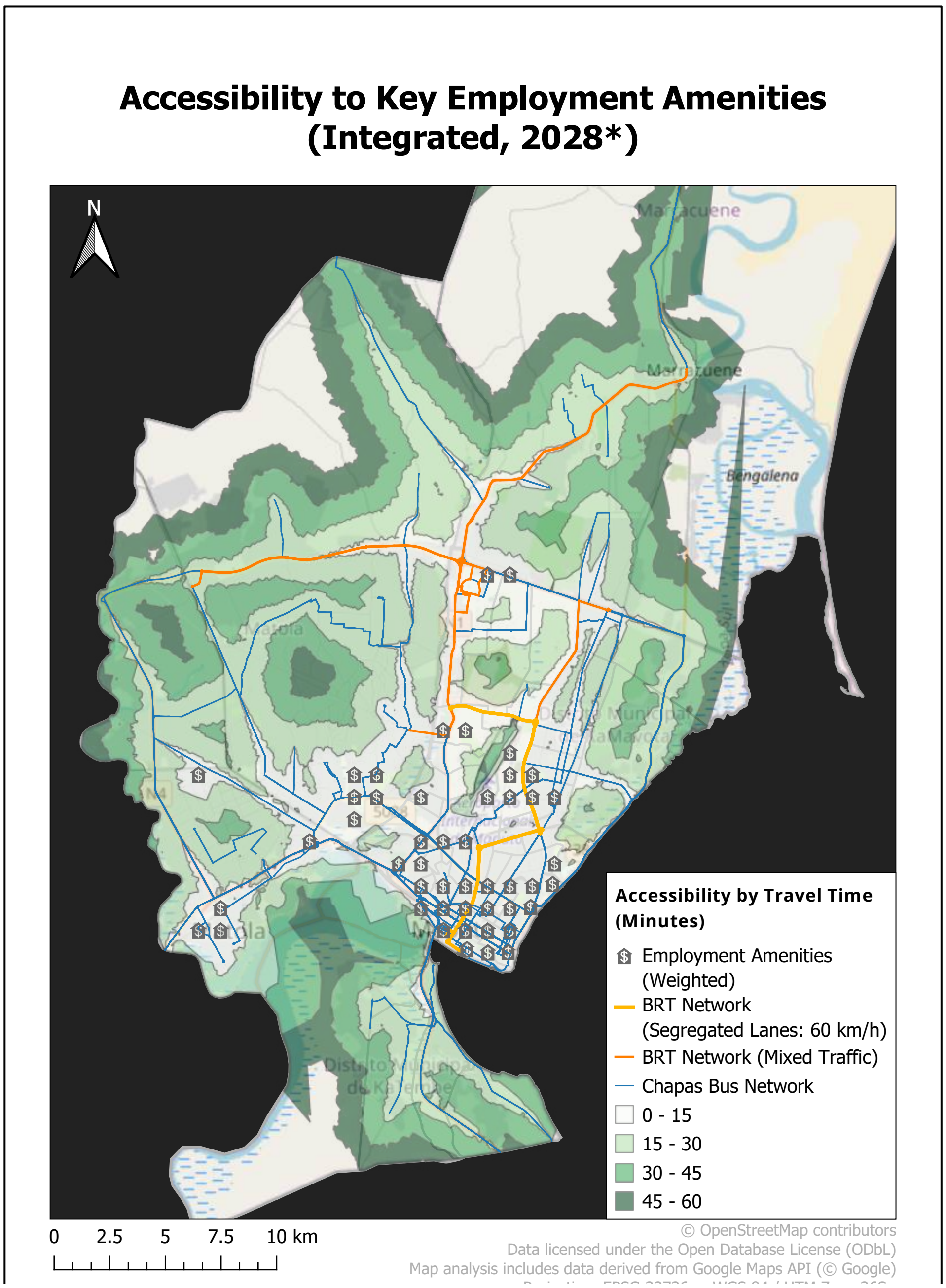

Figure 21. Integrated network isochrone catchment bands (Employment example)

4.3 Population Accessibility Catchment Analysis

The Integrated Network (2028) consistently enabled a greater number of people to access key amenities across all travel time bands compared to the Chapas only Network (2023). These gains reflect the enhanced accessibility created by the BRT system and its integration with the Chapas network. However, population growth seems to offset the overall percentage of the population benefiting from this improve accessibility. For instance, as shown in Figure 22a the number of people with access to healthcare within 60 minutes increased by approximately 330,952 people, from 2.5 million to 2.82 million. Comparable gains were observed across other amenity types. On the other hand, Figure 22b the percentage of the population with accessibility within 15 and 30 minutes notably decreased by 2.4% and 2.7% respectively.

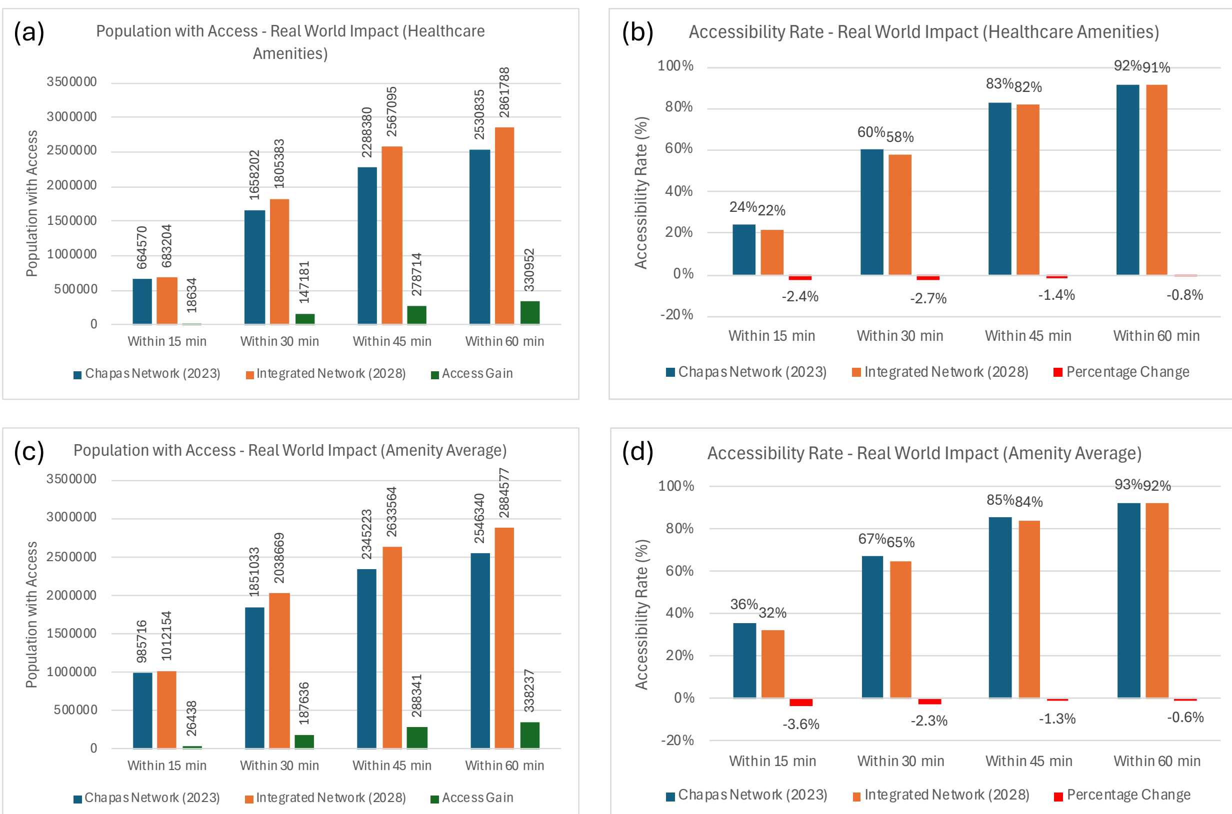

Figure 22. (a) Population with access – Real world Impact (Healthcare), (b) Accessibility Rate – Real world Impact (Healthcare), (c) Population with access – Real world Impact,), (d) Accessibility Rate – Real world Impact.

The average population gains and percentage change in accessibility across all amenities as shown in Figure 22c and 22d are summarised in Table 10:

Table 10. Population Gained in accessibility.

Travel Time Band	Population Gained (People)	Percentage Change (%)
15 minutes	26,438	-3.6%
30 minutes	187,636	-2.3%
45 minutes	288,341	-1.3%

Travel Time Band	Population Gained (People)	Percentage Change (%)
60 minutes	328,577	-0.6%

4.4 Sensitivity Analysis

4.4.1 Impact of Population Growth

The effect of population growth on the accessibility rate of the integrated network was analysed by applying both the 2023 and 2028 projected population counts, excluding the baseline Chapas only network. This approach isolates the impact of demographic change by assuming the integrated network is operational across both population scenarios, thereby simulating the effect of implementing the network earlier than scheduled.

Despite the overall population increase between 2023 and 2028, the accessibility rate decreased across all travel time bands for every amenity type. This decline can be attributed to decentralised urban growth, with new residents settling in peripheral areas less effectively served by the integrated transport network. For instance, Figure 23a demonstrates that accessibility to education amenities fell across all travel time bands, with values ranging from -2.9% to -4.7%.

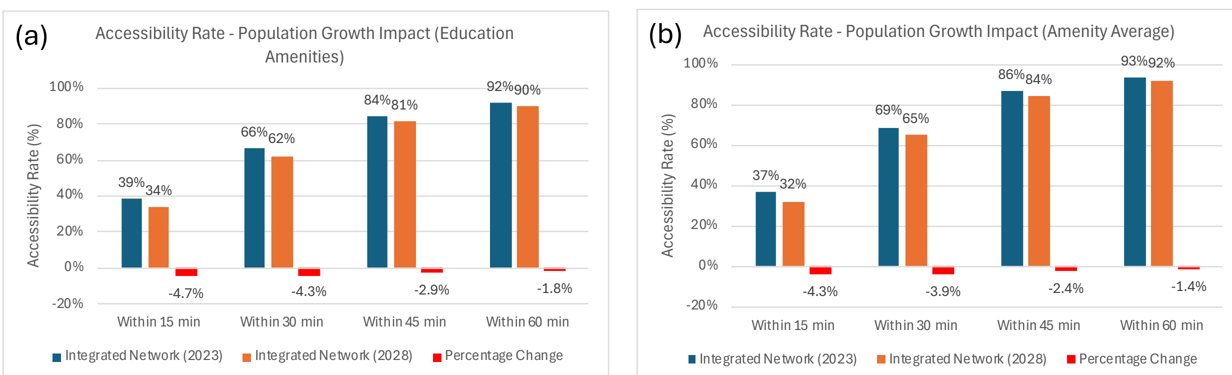

Figure 23. Accessibility Rate – Population growth impact, (a) Education Amenities, (b) Amenity Average.

The average accessibility rate across all amenity groups, illustrated in Figure 22b are summarised in Table :

Table 11. Percentage change in accessibility rate (Population Growth scenario).

Travel Time Band	Accessibility Rate (%), Integrated (2023)	Accessibility Rate (%), Integrated (2028)	Percentage Change (%)
15 minutes	37	32	-4.3%
30 minutes	69	65	-3.9%
45 minutes	86	84	-2.4%
60 minutes	93	92	-1.4%

4.4.2 Impact of Network Integration

The impact of network integration, isolated from population growth, was evaluated by comparing the accessibility rates of the Chapas only network and the integrated network, both under 2023 population conditions. This approach isolates the effect of improved infrastructure coverage and speed, reflecting the added value of integrating the BRT system with the existing Chapas network.

Across all amenity types, the integrated network consistently outperformed the Chapas only network scenario. Although the improvements appear modest in relative terms, the gains are consistent across all travel time bands and represent a significant increase in population catchment. These changes highlight the benefit of BRT corridor speeds and enhanced multimodal connectivity, even when applied to existing population distributions. For example, Figure 24a shows the accessibility rate to social and recreational amenities within the 30-minute threshold increase by 2.0%, which translates to approximately 55,000 additional residents gaining access under the integrated network scenario.

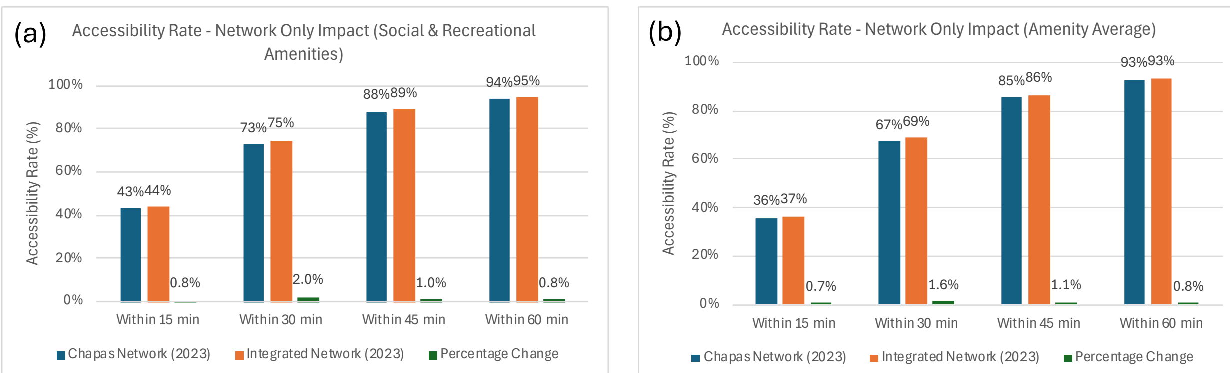

Figure 24. Accessibility Rate – Network only impact, (a) Social & Recreational Amenities, (b) Amenity Average.

The average accessibility rates across all amenities for the 2023 population, as shown in Figure 24b, are summarised in Table 12:

Table 12. Percentage change in accessibility rate (Network Only scenario).

Travel Time Band	Accessibility Rate (%), Chapas (2023)	Accessibility Rate (%), Integrated (2023)	Percentage Change (%)
15 minutes	36	37	+0.7%
30 minutes	67	69	+1.6%
45 minutes	85	86	+1.1%
60 minutes	93	93	+0.8%

5. Analysis and Discussion

5.1 Interpreting Accessibility Gains and Losses

The results presented in Section 4 highlight that integrating formal and informal networks significantly improves overall accessibility to key urban amenities. The most notable gains are in absolute population catchment, with an average of 338,000 additional people gaining access within 60 minutes across all amenity categories (Table 4.3.1). This aligns closely with the World Bank's accessibility target of 344,000 (PROJECT APPRAISAL DOCUMENT ON A PROPOSED GRANT IN THE AMOUNT OF SDR 180.9 MILLION (US$250 MILLION EQUIVALENT) TO THE REPUBLIC OF MOZAMBIQUE FOR A MAPUTO METROPOLITAN AREA URBAN MOBILITY PROJECT, 2022), underscoring the efficacy of the integrated network design.

However, these gains were not uniform across all time bands or spatial areas. The percentage of the population with access within 15 and 30 minutes decreased despite an overall increase in the number of people served. This suggests that while spatial reach has improved, population decentralisation has diluted the share of residents living within shorter-distance catchments. This is consistent with broader patterns of urban sprawl observed in Maputo, where population growth has shifted from central districts to peripheral zones such as Marracuene, Katembe, and Matola-Gare (Mittal et al., 2023).

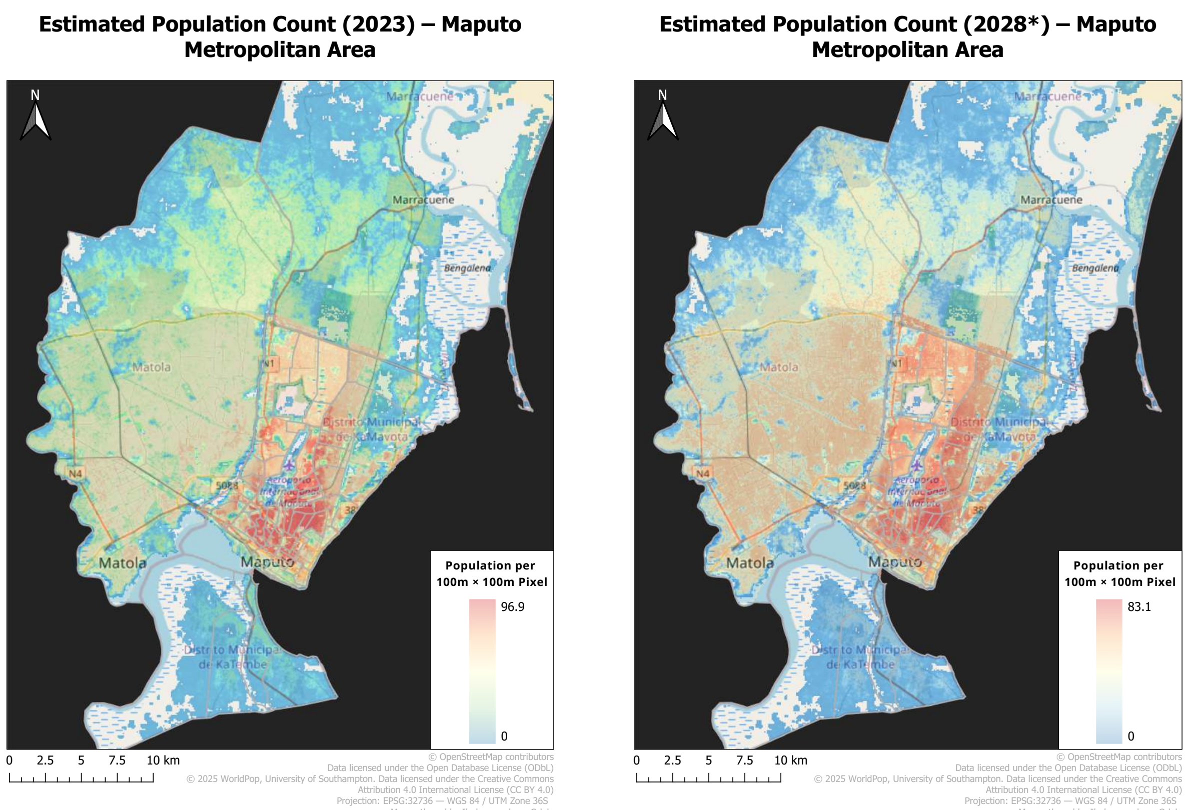

Figure 25. Population Distribution (2023) and (2028), illustrating spatial decentralisation and population growth in Maputo Metropolitan Area

This urban expansion into the peri-urban fringe directly explains why accessibility rates within shorter time bands (e.g., 0–15 or 15–30 minutes) have declined, despite investments in speed and integration. These findings reinforce the importance of linking transport planning with spatial development to avoid future accessibility mismatches (Luke, 2024).

5.2 Network Effects and Infrastructure Constraints

The accessibility improvements attributed to network integration, though relatively modest, reflect meaningful changes in network efficiency, particularly in travel time reductions and corridor-level performance. Rather than extending spatial coverage significantly, the integrated network improved access by leveraging existing infrastructure more effectively.

A key contributor to this efficiency is the segregated BRT lane running through central Maputo, which enables high-speed travel through one of the city's most congested areas. This time advantage produces a knock-on effect, shifting isochrone boundaries outward and allowing areas farther from the centre, such as northern KaMubukwana and Marracuene, to fall within shorter travel-time thresholds. These patterns align with research highlighting BRT's role in improving operational reliability and reducing average travel times in dense urban corridors (World Bank, 2017).

Yet not all peripheral zones benefit equally. For example, Matola Gare, continues to experience poor accessibility. This disparity is likely due to poor road conditions and informal development, which limit the physical feasibility of operating large BRT vehicles. The World Bank notes that underserviced transport infrastructure in peri-urban communities is a major barrier to network extension, particularly when upgrading roads to BRT standards is cost-prohibitive (World Bank, 2017).

Conversely, the current BRT alignment prioritises arterial roads with adequate width and surface quality, improving feasibility and cost-effectiveness. While this benefits areas along these corridors, it reinforces a geographic mismatch in underserved but growing zones such as Matola Gare, highlighting them as priority areas for future expansion.

In this context, the potential realignment of Chapa services into feeder routes becomes particularly relevant. By restructuring existing informal operations to support first and last mile connectivity, the network could reach areas that are currently inaccessible to BRT. This approach is supported by recent literature promoting hybrid transport models as both equitable and operationally efficient in rapidly urbanising cities (Johannes du Preez & Venter, 2022).

5.3 Equity and Policy Implications

The results of this analysis highlight a central equity challenge facing Maputo's transport system: the uneven spatial distribution of accessibility gains. While integration of the BRT and Chapas networks improves overall reach, these benefits are concentrated along well-connected corridors, leaving some growing peripheral areas comparatively excluded. This reflects broader concerns in Sub-Saharan African cities where urban expansion often outpaces infrastructure provision, reinforcing transport-related social exclusion in structurally disadvantaged communities (Luke, 2025).

In this context, the BRT system's alignment with existing arterial roads has improved travel times and network efficiency but also reflects a planning bias toward feasibility over coverage. Areas like Matola Gare remain poorly served, not due to distance, but due to infrastructural limitations that constrain BRT operation. These patterns underline the importance of complementary investment in road infrastructure to expand access in peri-urban zones with rising population density.

To address these gaps, Maputo's transport strategy must go beyond corridor-based planning and adopt a more spatially inclusive approach. Prioritising infrastructure upgrades in underserved regions and designing future BRT phases that align with expected population growth to prevent the exacerbation of existing inequalities.

Ultimately, the case of Maputo reinforces the notion that transport infrastructure should be equitable and allow people to move efficiently with access to multiple opportunities. As the city continues to grow, integrating transport planning with spatial development, while protecting the adaptive role of informal systems, will be essential to ensure that accessibility gains are not only maximised, but equitably distributed.

6. Conclusion

This study evaluated how integrating Maputo's proposed Bus Rapid Transit (BRT) system with the existing Chapas network could improve access to essential services across the city. Accessibility was assessed using travel-time isochrones, weighted amenity scoring, and 2023 and 2028 population projections. Accessibility changes were analysed under different scenarios to understand the combined effects of transport network improvements and population growth. Spatial analysis was used to measure access to healthcare, education, employment, and social amenities. A population catchment framework was developed to quantify gains and losses in access within defined travel-time bands. The analysis also isolated the influence of network layout and demographic change to better interpret spatial disparities in accessibility outcomes.

The application of this framework was demonstrated through a case study of the Greater Maputo Area. Results showed that integrating formal and informal networks could bring approximately 338,000 additional people within 60 minutes of key services by 2028, approaching the World Bank's projected accessibility targets. However, gains were concentrated along the BRT corridors, while peripheral areas like Matola Gare remained poorly connected, largely due to infrastructure constraints. Findings also revealed that while absolute access improved, the proportion of the population within short-range access bands (15–30 minutes) declined, reflecting decentralised urban growth outpacing transport expansion.

The findings contribute to broader debates on equitable urban mobility in Sub-Saharan Africa. They reinforce the role of hybrid transport systems, where informal services like Chapas function as first- and last-mile connectors to formal infrastructure. The study highlights the need for future BRT expansions to account for peri-urban growth trends and emphasises that infrastructure development must be paired with land use planning to prevent spatial mismatch. Limitations included simplified assumptions about service frequencies, travel speeds, and full BRT network rollout. Nonetheless, the framework provides a practical, scalable method for assessing transport integration impacts and can be refined as new data becomes available, including planned feeder routes and service-level information.

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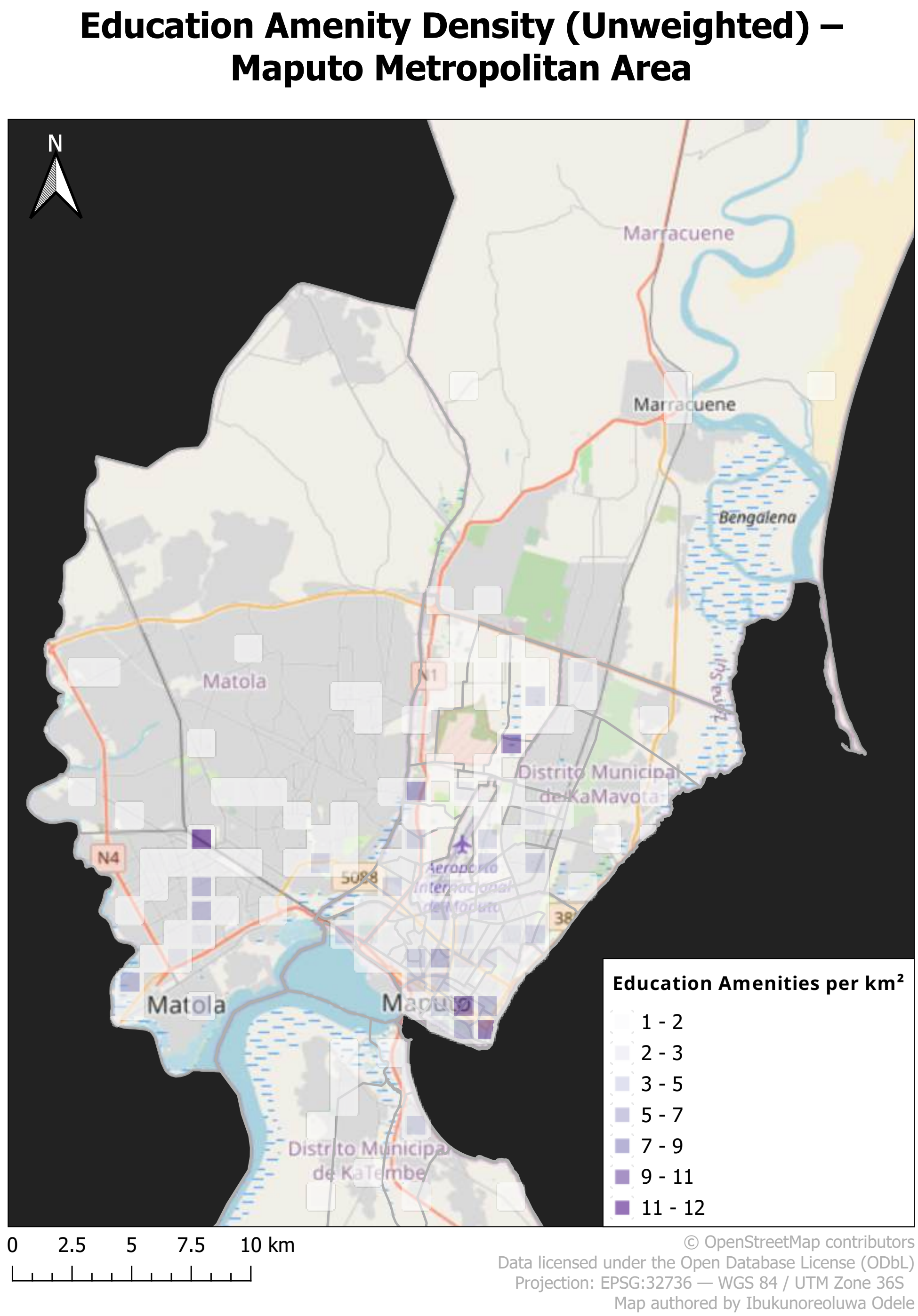
8. Glossary

Term	Definition
Accessibility	The ease with which people can reach desired services and destinations within a given time or cost.
API (Application Programming Interface)	A set of tools and protocols that allow software to communicate, often used to retrieve live travel data.
BRT (Bus Rapid Transit)	A high-capacity public transport system using dedicated lanes, prioritised signalling, and rapid boarding.
Catchment Area	The geographic area from which a service, such as a transport stop or amenity, draws its users.
Centroid	A central point that represents the spatial centre of a polygon or grid cell.
Chapas	Informal minibus taxis widely used in Mozambique, operating without fixed schedules but serving key routes.
CRS (Coordinate Reference System)	A system used to define how the two-dimensional, projected map relates to real places on the Earth.
E-ticketing	Electronic systems used to collect fare payments in public transport, enabling cashless and integrated travel.
Feeder Route	A secondary route that connects users from outlying areas to main transport lines like BRT.
Georeferencing	Aligning map layers or images to real-world coordinates for use in GIS software.
GIS (Geographic Information System)	A system designed to capture, store, manipulate, and analyse spatial or geographic data.
Informal Transport	Transport services like Chapas that operate outside formal regulation, often privately owned and flexible.
Interpolation	A method for estimating unknown values in spatial analysis based on nearby known values.
Isochrone	A map or shape that shows areas reachable from a specific point within a set amount of travel time.
Mixed Traffic	Roads shared by different types of vehicles including private cars, buses, and informal transport.
Multimodal Integration	The coordination of various transport modes into a unified, efficient system.
Multimodal Network	A transport network that includes and connects multiple transport types (e.g. walking, bus, BRT).
OpenStreetMap (OSM)	A collaborative mapping platform where users can freely edit and access geospatial data.
Poverty Index	A statistical measure used to assess poverty levels based on income, access to services, and living conditions.

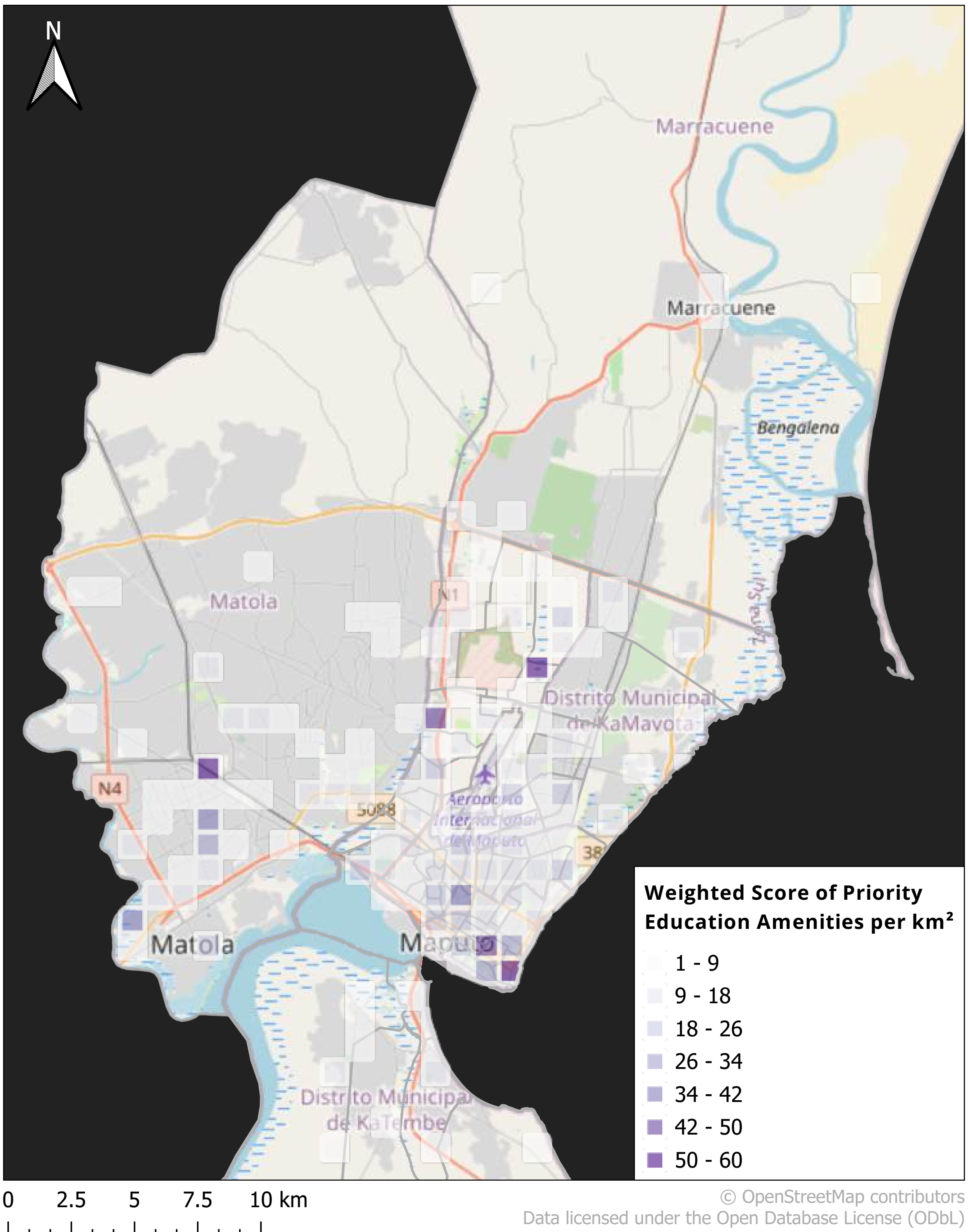
Term	Definition
QGIS	An open-source software used for mapping and spatial data analysis.
QNEAT3	A QGIS plugin for advanced network analysis, such as isochrone and shortest path calculations.
Raster	A grid-based data format used in GIS, often to represent population or elevation.
Relations (in OSM)	A data structure in OpenStreetMap used to represent complex relationships between geographic features.
Segregated Lane	A road lane reserved exclusively for public transport like BRT, separate from mixed traffic.
Shapefile	A widely used file format for storing geometric and attribute data in GIS software.
Spatial Inequality	Unequal access to resources, services, and opportunities based on geographic location.
Spatial Join	A GIS operation that combines attributes from one layer to another based on their spatial relationship.
Urban Sprawl	The uncontrolled expansion of urban areas into surrounding rural or undeveloped land.
Vector	A GIS data format representing features as points, lines, or polygons.

9. Appendices

Appendix A. Density Maps



Education Amenity Density (Weighted by Importance) – Maputo Metropolitan Area



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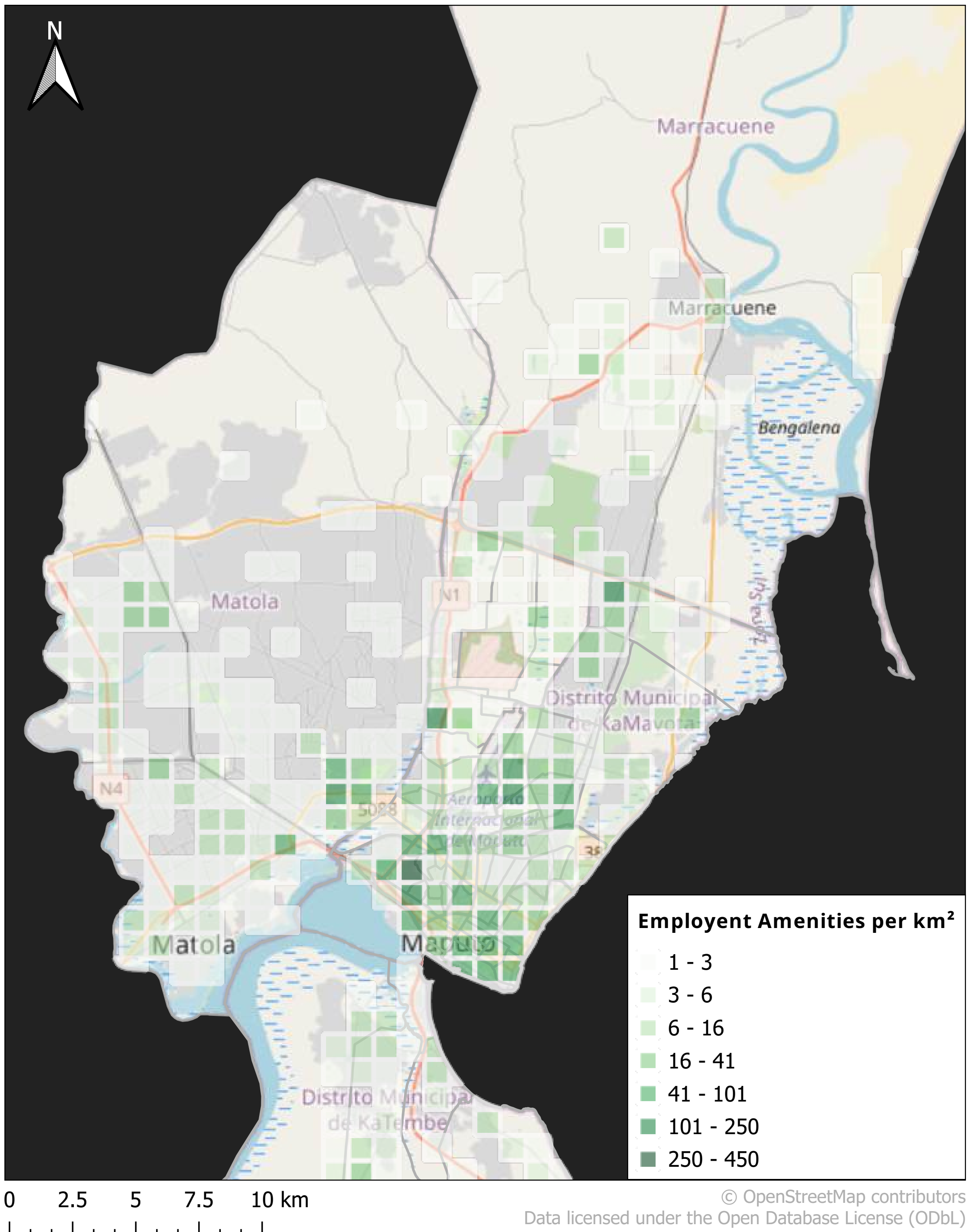
Projection: EPSG:32736 — WGS 84 / UTM Zone 36S
Map authored by Ibukunoreoluwa Odele

Employment Amenity Density (Unweighted) – Maputo Metropolitan Area



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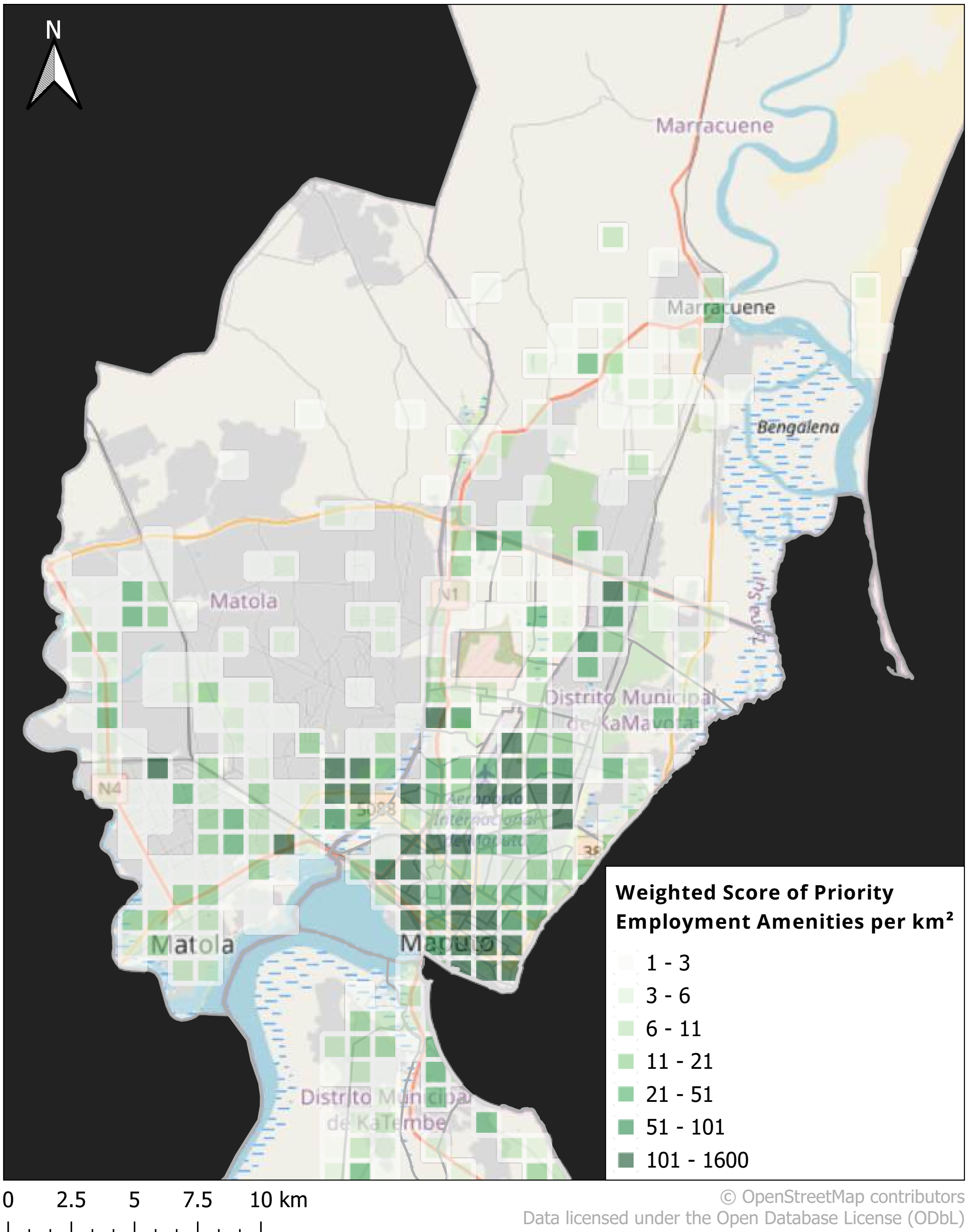
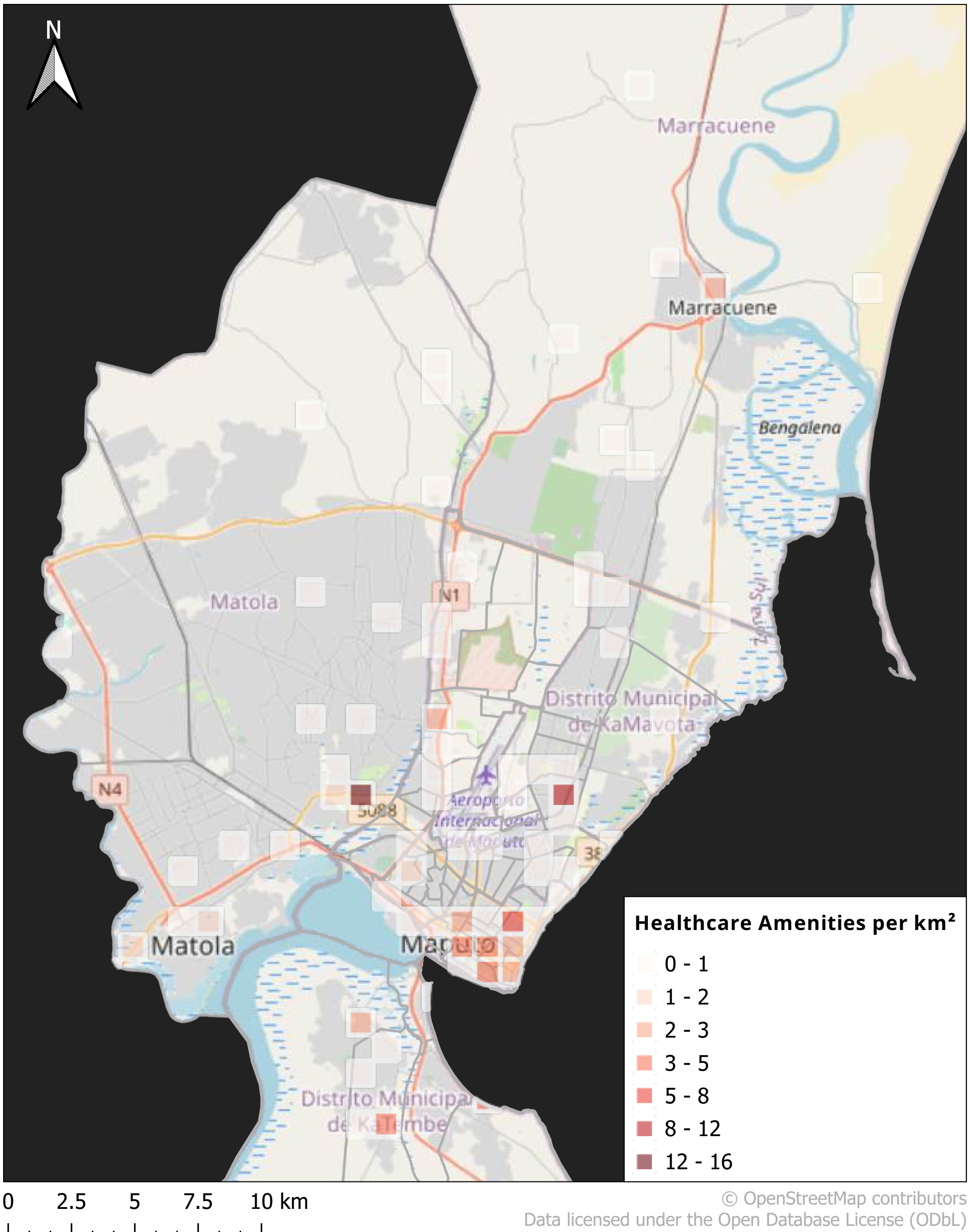
Map authored by Ibukunoreoluwa Odele

Employment Amenity Density (Weighted by Importance) – Maputo Metropolitan Area



Projection: EPSG:32736 — WGS 84 / UTM Zone 36S
Map authored by Ibukunoreoluwa Odele

Healthcare Amenity Density (Unweighted) – Maputo Metropolitan Area



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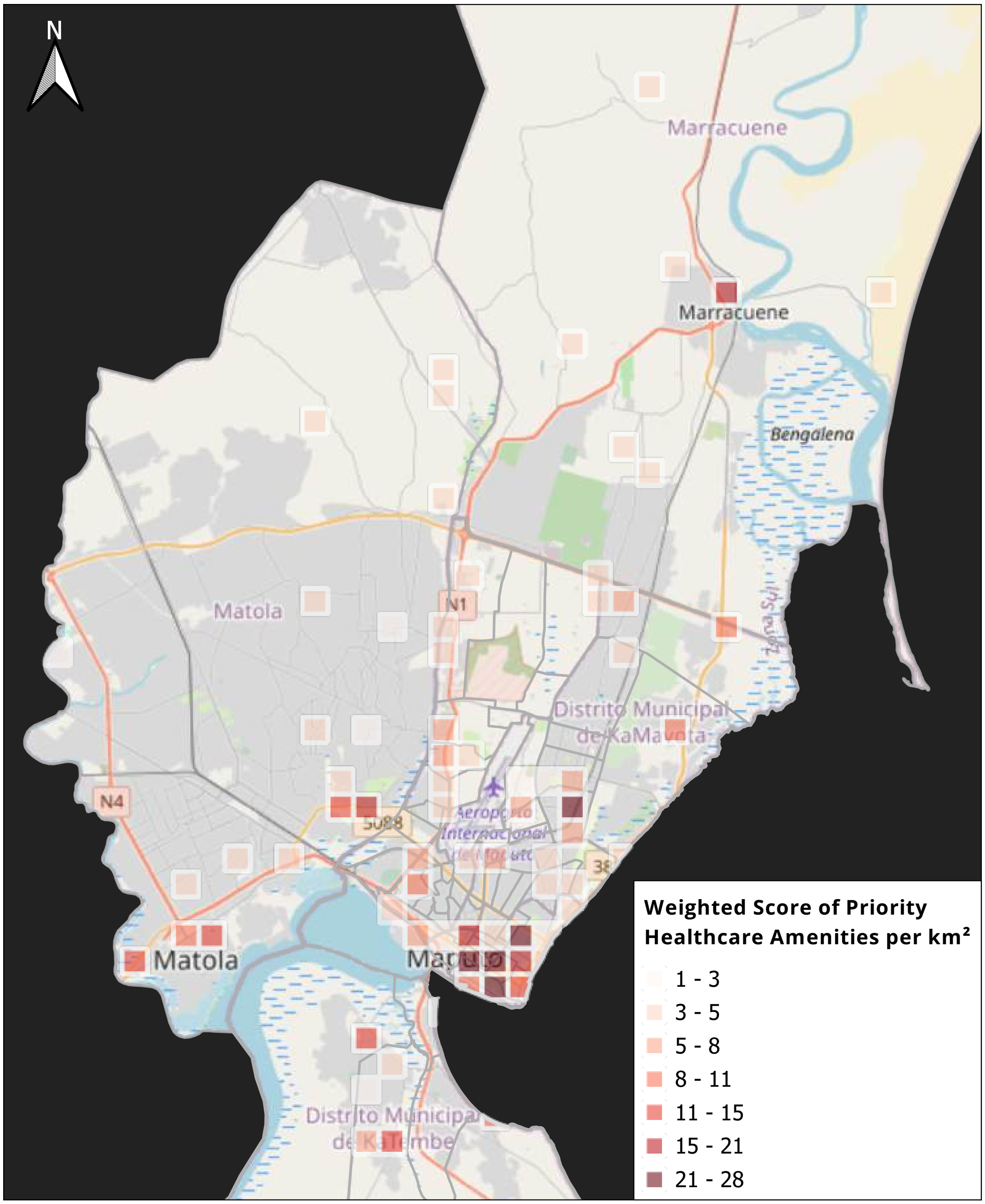
Map authored by Ibukunoreoluwa Odele

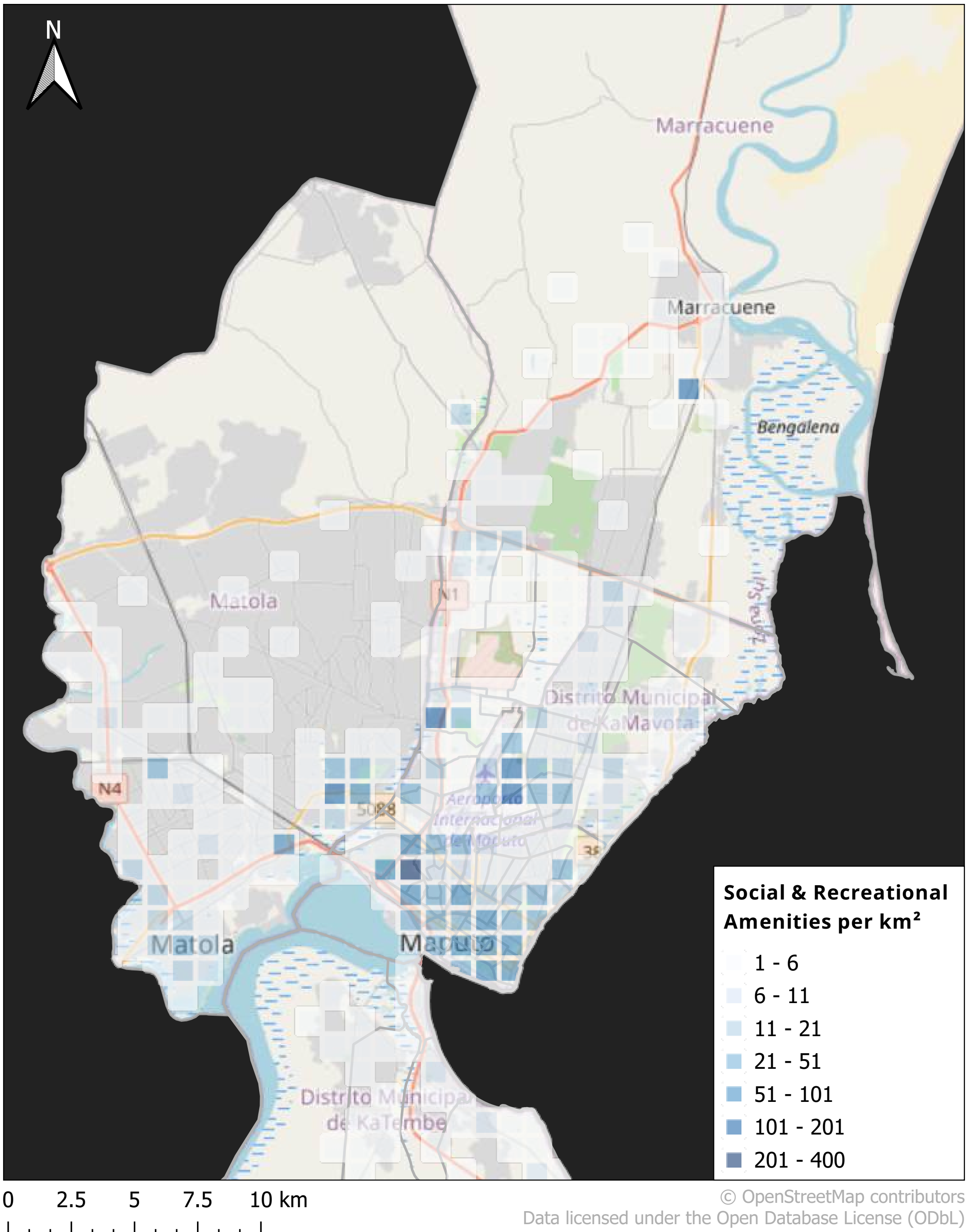
Healthcare Amenity Density (Weighted by Importance) – Maputo Metropolitan Area



0 2.5 5 7.5 10 km

Projection: EPSG:32736 — WGS 84 / UTM Zone 36S
Map authored by Ibukunoreoluwa Odele

Social & Recreational Amenity Density (Unweighted) – Maputo Metropolitan Area



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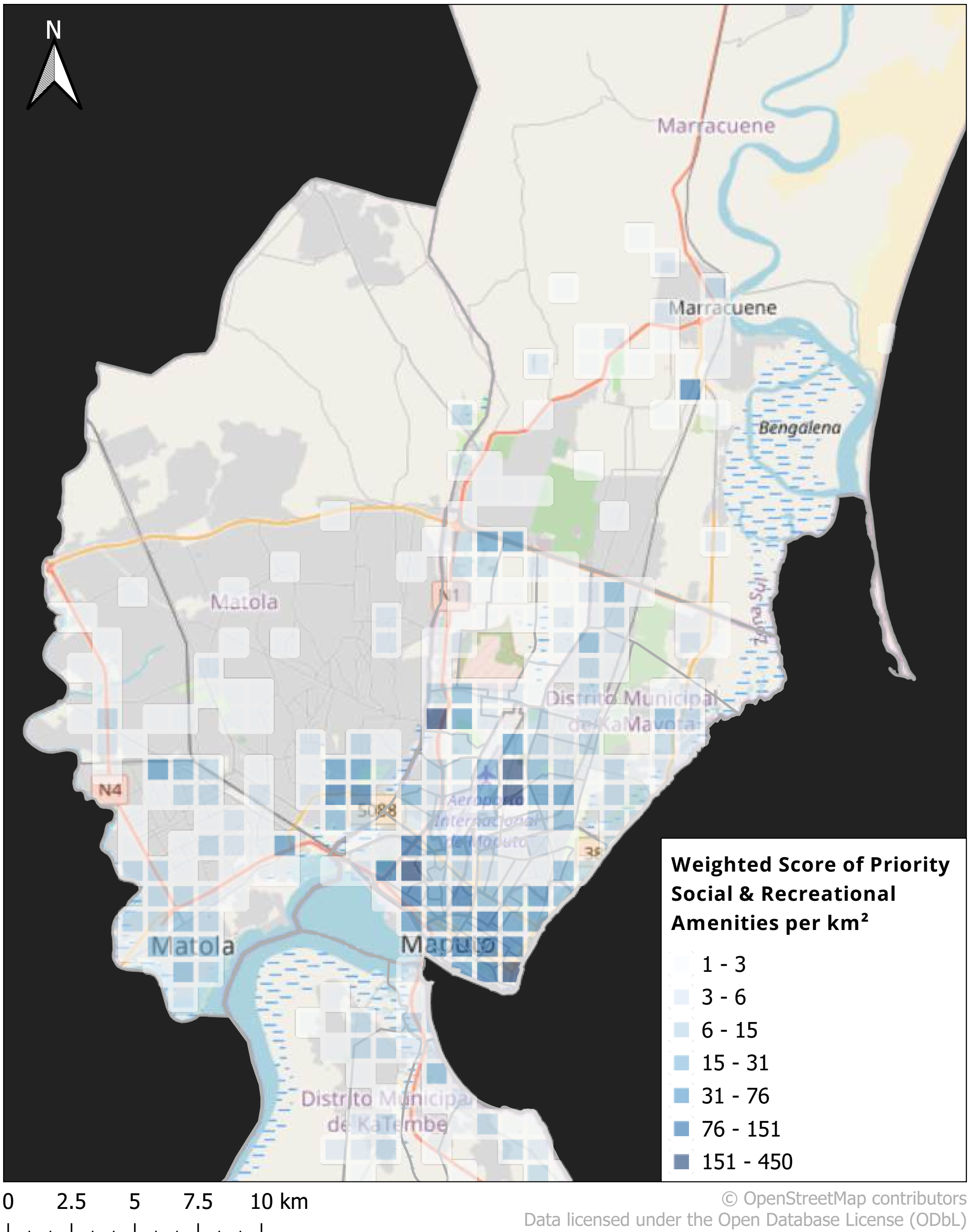
Social & Recreational Amenity Density (Weighted by Importance) – Maputo Metropolitan Area



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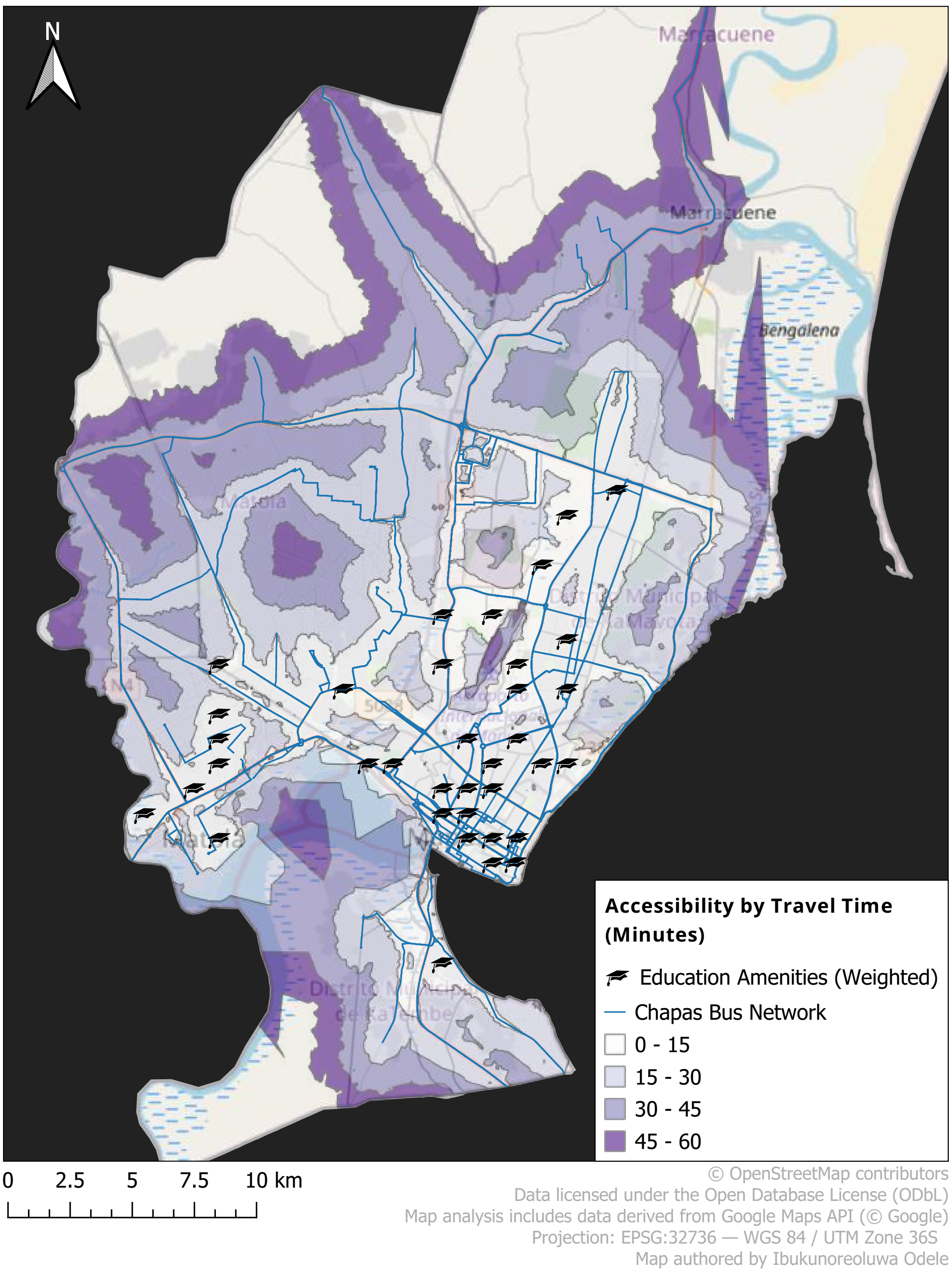
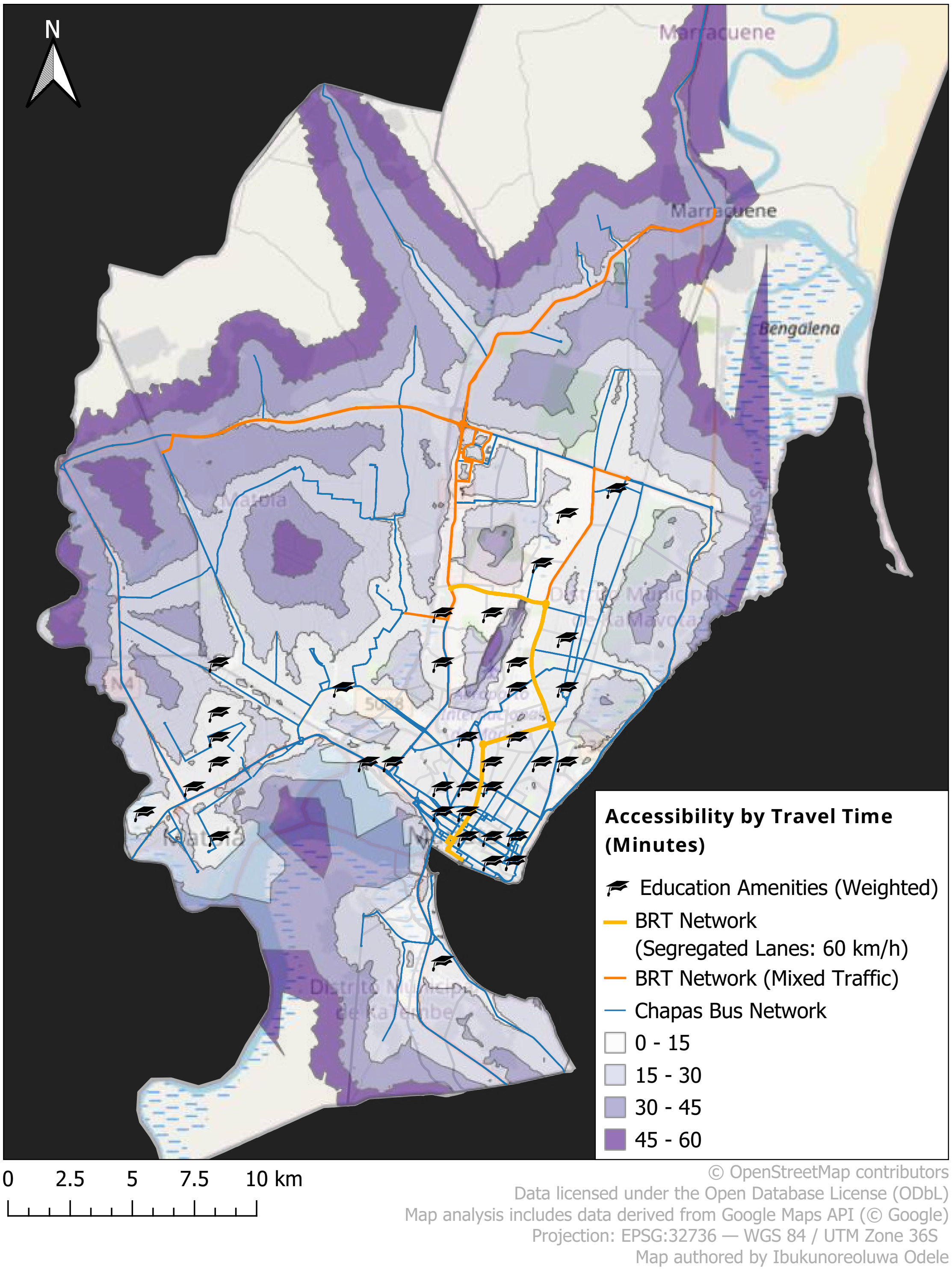
Appendix B. Isochrone Maps

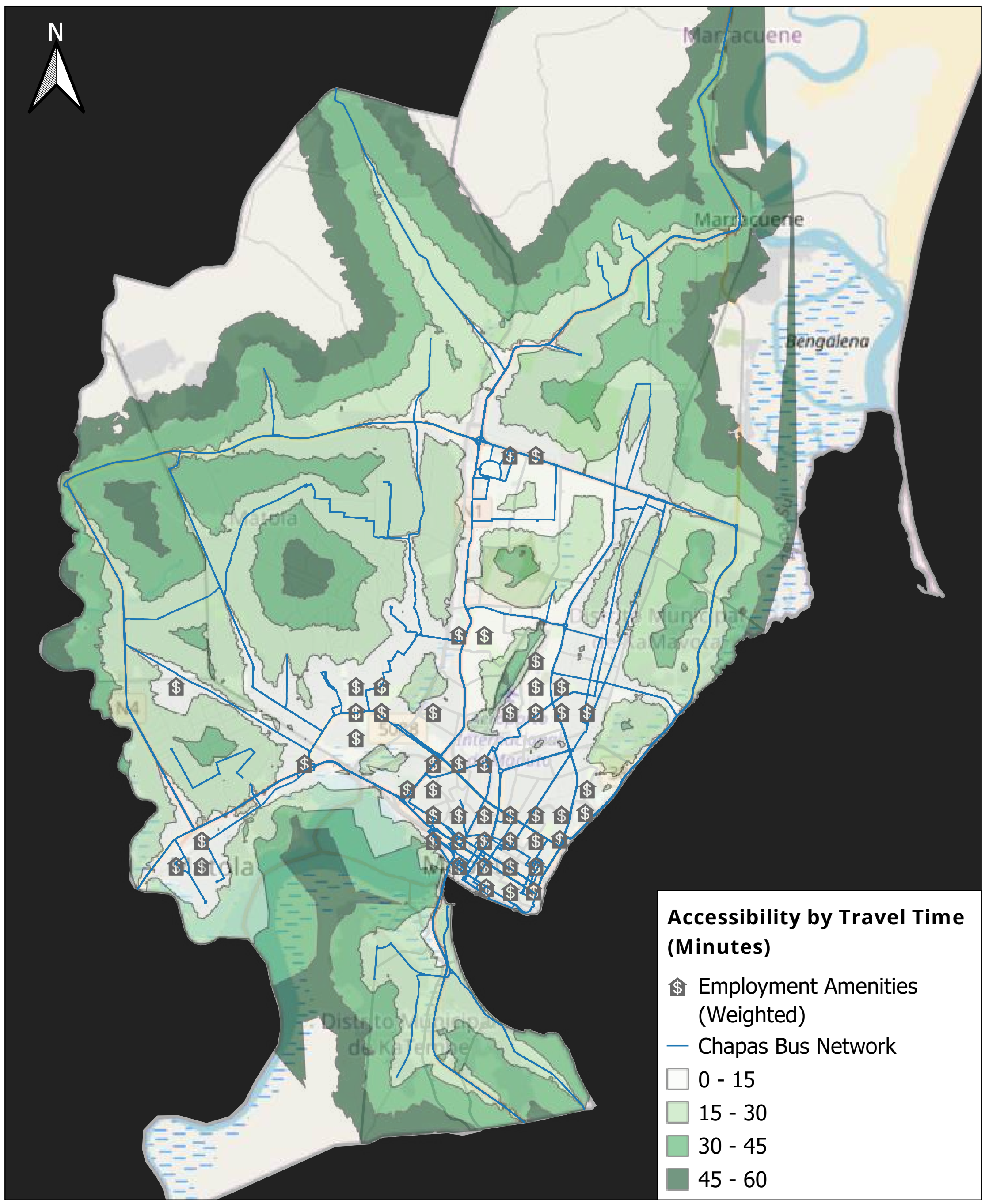
Accessibility to Key Education Amenities (Chapas, 2023)



Accessibility to Key Education Amenities (Integrated, 2028*)



Accessibility to Key Employment Amenities (Chapas, 2023)



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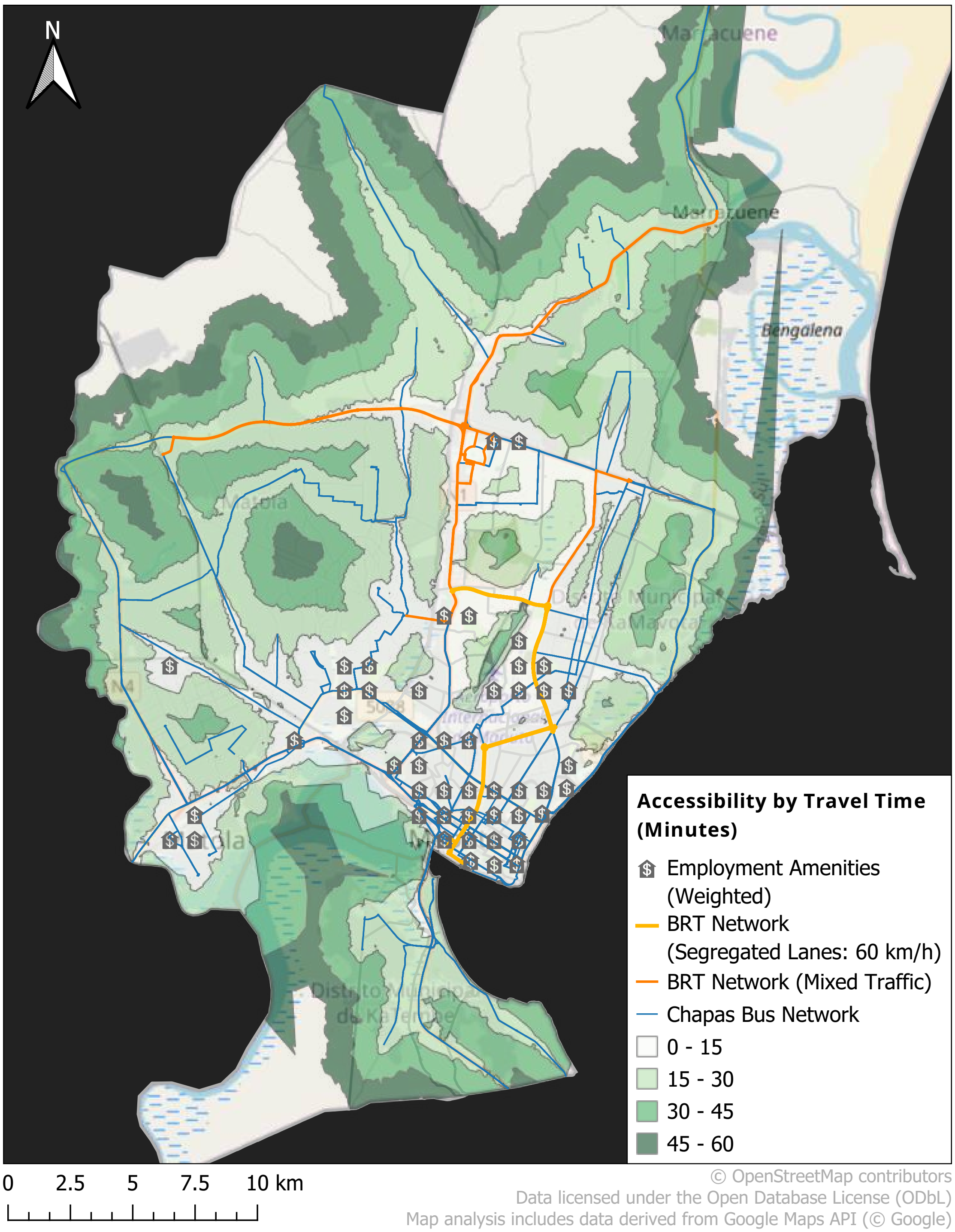

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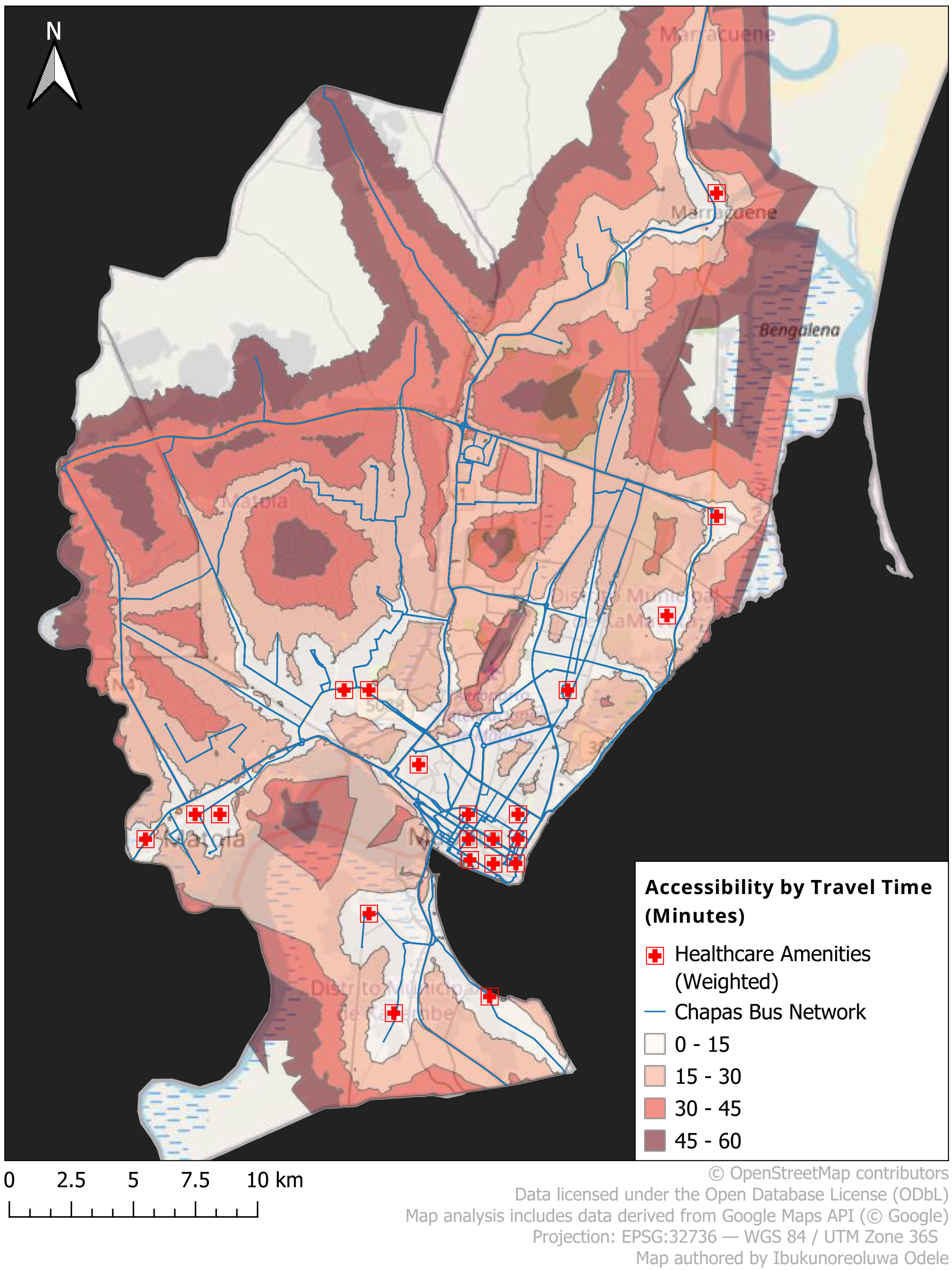
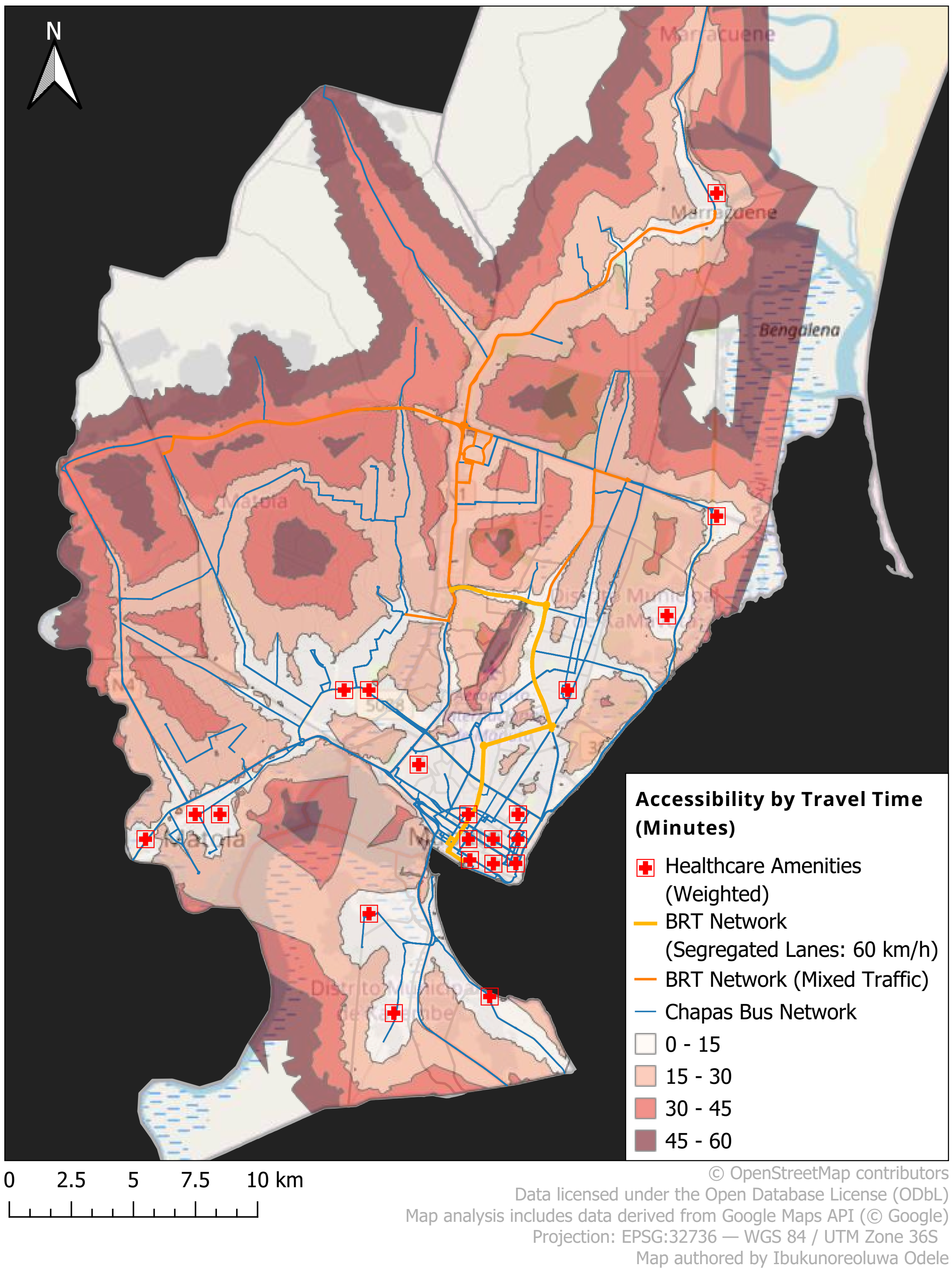
Map authored by Ibukunoreoluwa Odele

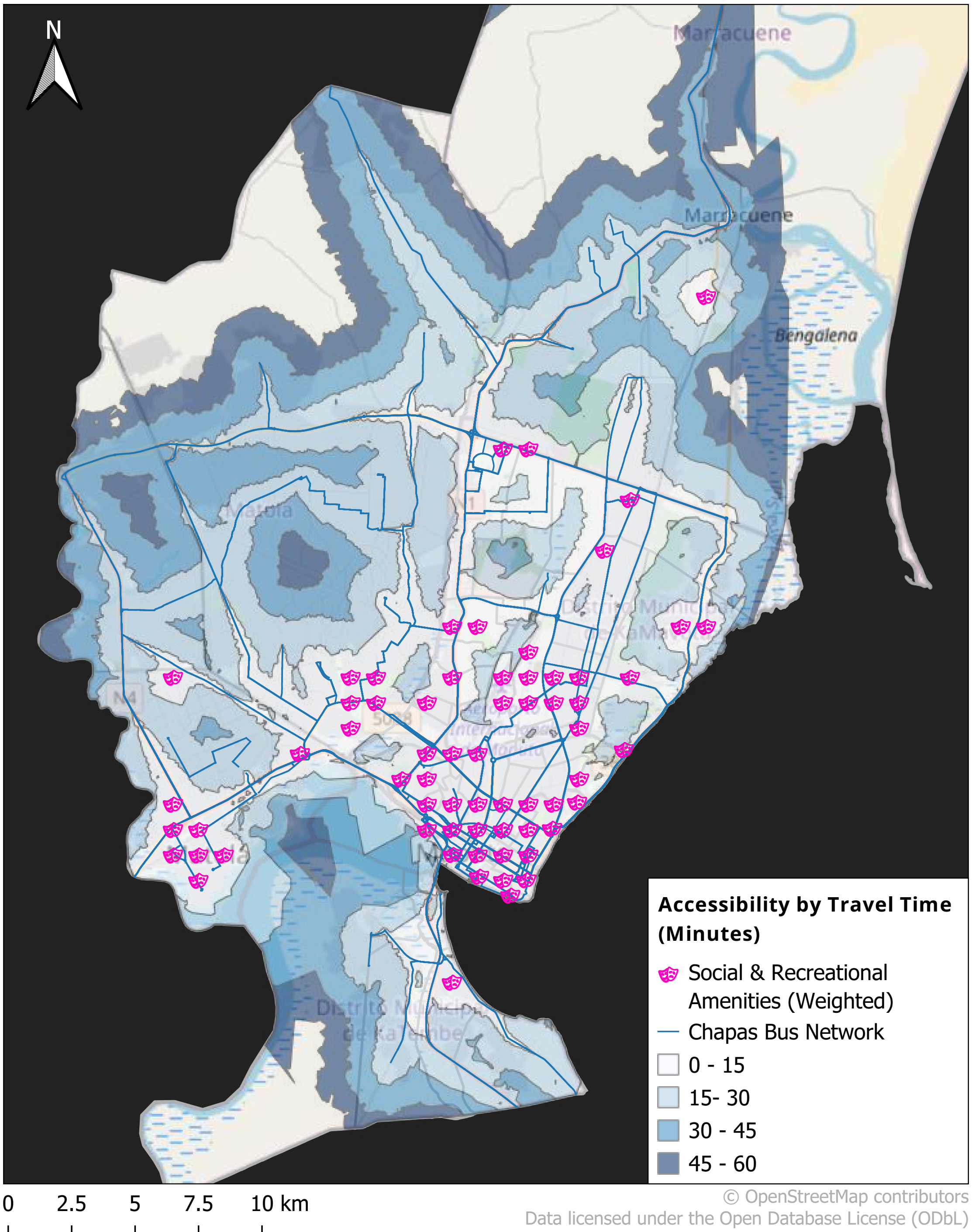
Accessibility to Key Healthcare Amenities (Chapas, 2023)



Accessibility to Key Healthcare Amenities (Integrated, 2028*)



Accessibility to Key Social & Recreational Amenities (Chapas, 2023)



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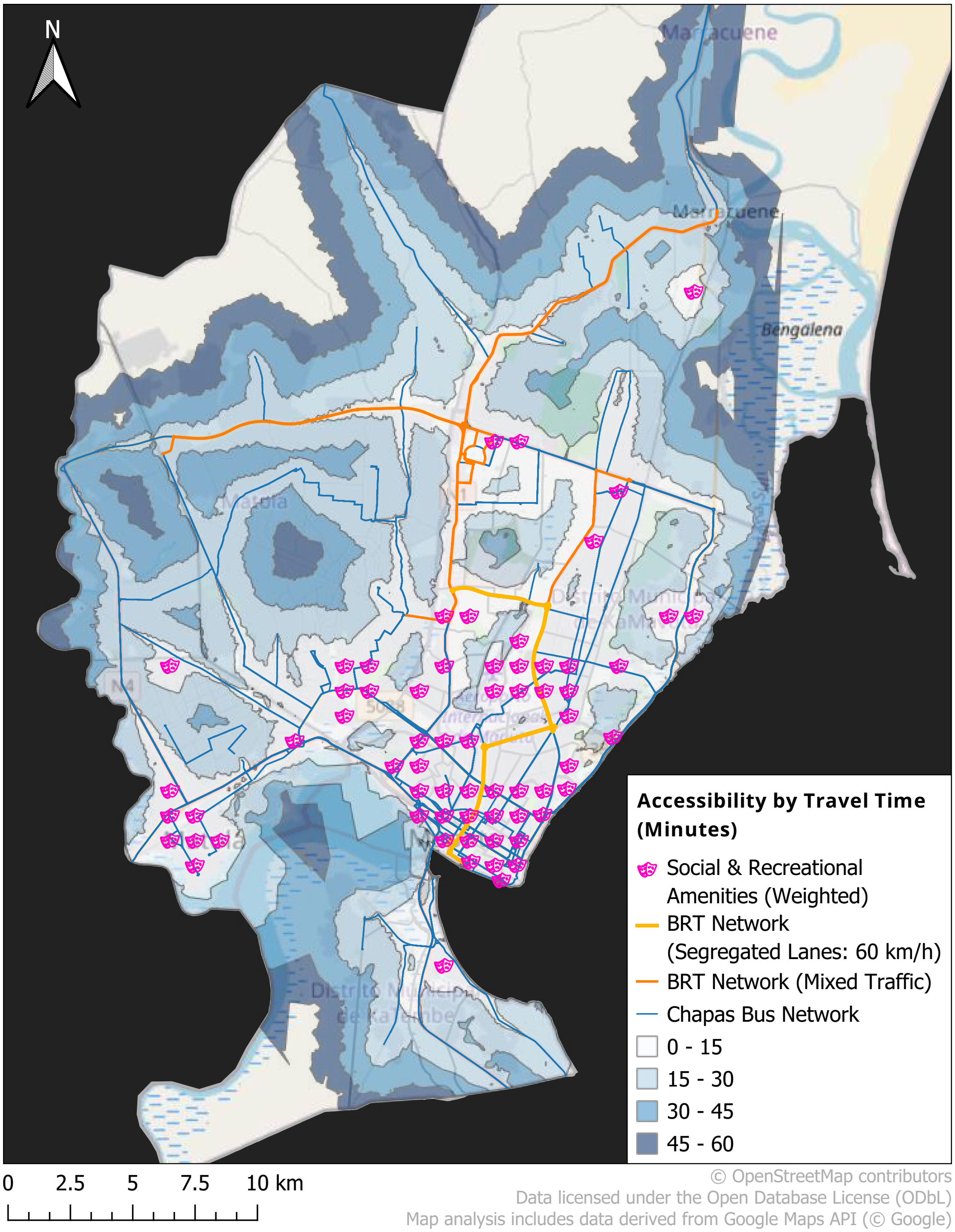
Accessibility to Key Social & Recreational Amenities (Integrated, 2028*)



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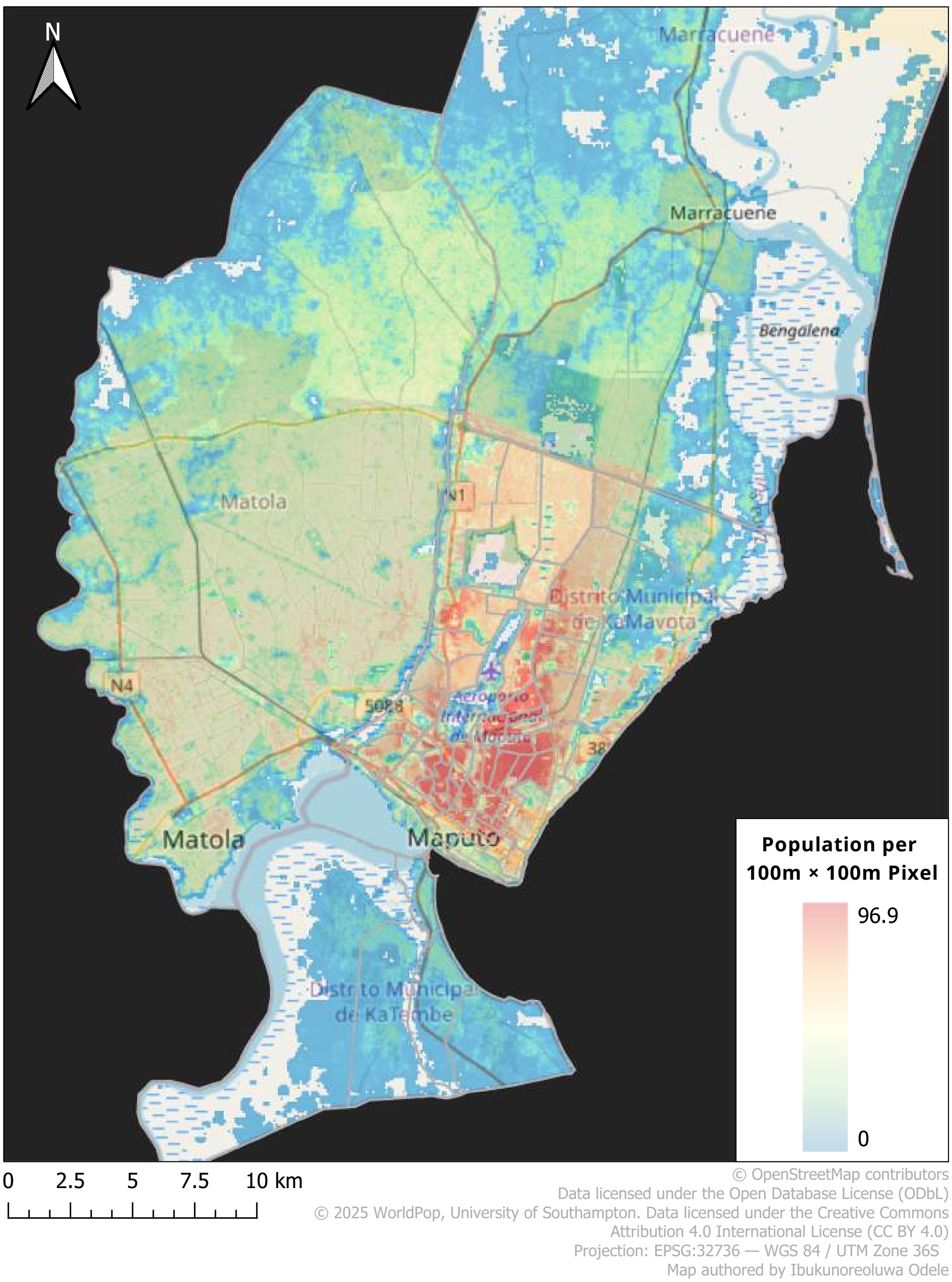
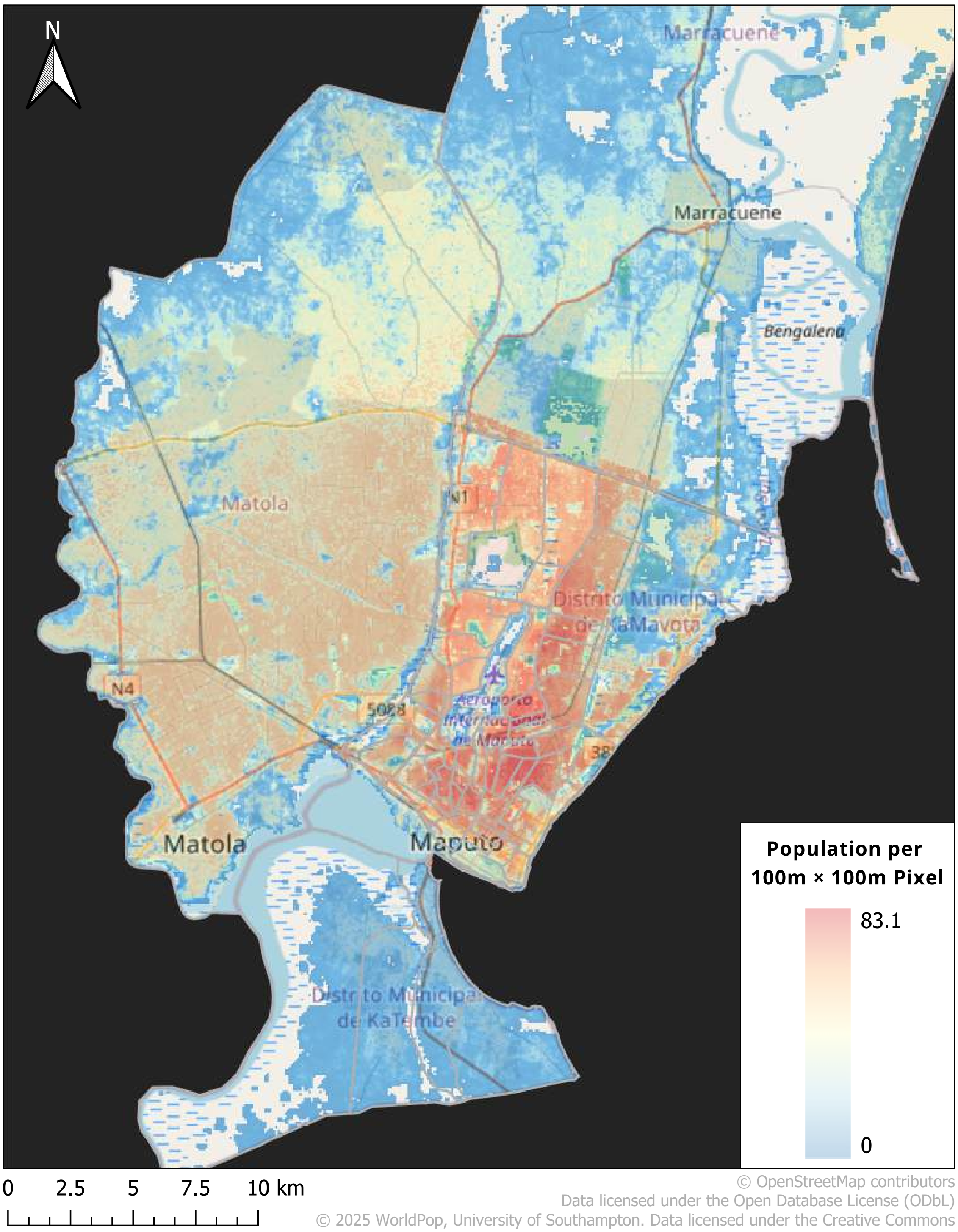
Appendix C. Population Maps

Estimated Population Count (2023) – Maputo Metropolitan Area



Estimated Population Count (2028*) – Maputo Metropolitan Area



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Projection: EPSG:32736 — WGS 84 / UTM Zone 36S
Map authored by Ibukunoreoluwa Odele

Appendix D. Amenity weighting scoring (Education)

Subcategory	OSM Value (Key: "amenity")	Weight	Justification
Primary & Secondary	school, college, university	5	Daily destinations for a wide range of age groups
Early Education	kindergarten, toy_library	4	Frequent destinations for working families
Public Learning	library	3	Valuable but less frequent access
Specialised Schools	music_school, language_school, driving_school, dancing_school	3	Targeted/niche learning

Appendix E. Amenity weighting scoring (Employment)

Subcategory	OSM Value (Key: amenity, shop, office, government, industrial, construction, tourism)	Weight	Justification
Workplace/Office	office, government	5	Major daily employment nodes
Retail & Shops	shop	4	Frequent local commerce
Civic Services	police, post office, bank	4	Public admin, finance, safety
Industry/Trade	industrial, construction	3	Employment-oriented but less accessible
Special Use	tourism	2	Niche and temporary activities

Appendix F. Amenity weighting scoring (Healthcare)

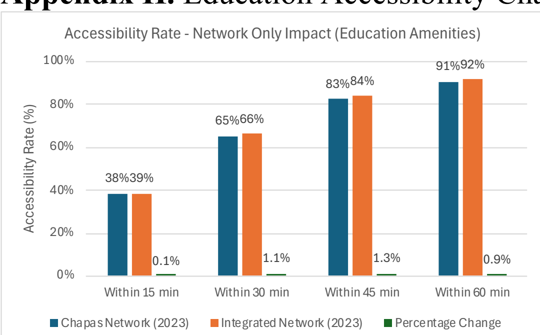
Subcategory	OSM Value (Key: "amenity")	Weight	Justification
Core Health Facilities	hospital, clinic, doctors, dentist	5	Critical daily or emergency access
Pharmacies	pharmacy	4	Routine healthcare supply access

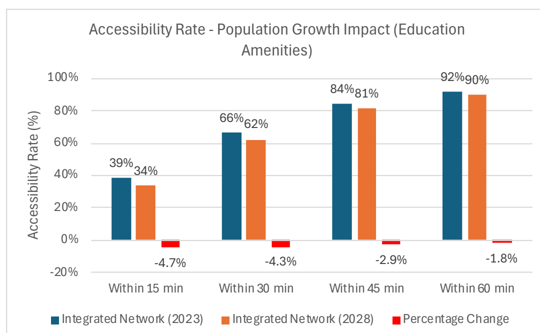
Subcategory	OSM Value (Key: "amenity")	Weight	Justification
Social/Support Care	nursing_home, social_facility, baby_hatch	3	Important but less frequent for most
Alternative/Minor	herbalist, massage, hearing_aids, optician	2	Specialist or non-essential needs
Animal Health	veterinary	1	Rare access need

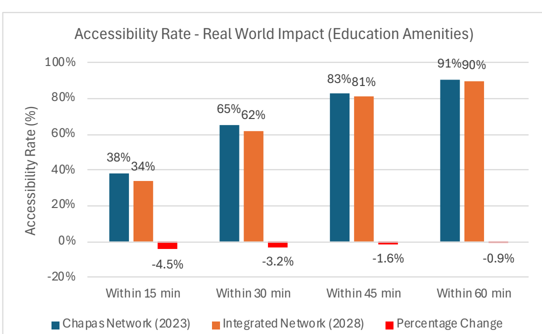
Appendix G. Amenity weighting scoring (Social & Recreational)

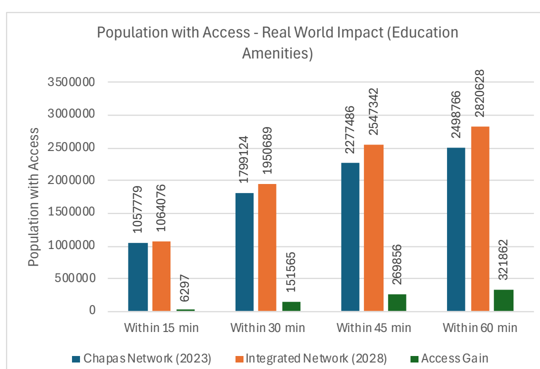
Subcategory	OSM Value (Key: "amenity")	Weight	Justification
Religious Access	place_of_worship	4	Regular and important for many communities
Food & Drink	restaurant, cafe, fast_food, ice_cream	3	Frequently visited but not essential
Community Services	community_centre, public_bookcase	3	Supports inclusion, minor but meaningful
Culture & Leisure	cinema, arts_centre, events_venue, conference_centre, nightclub, planetarium	2	Irregular or occasional recreational use

Appendix H. Education Accessibility Charts

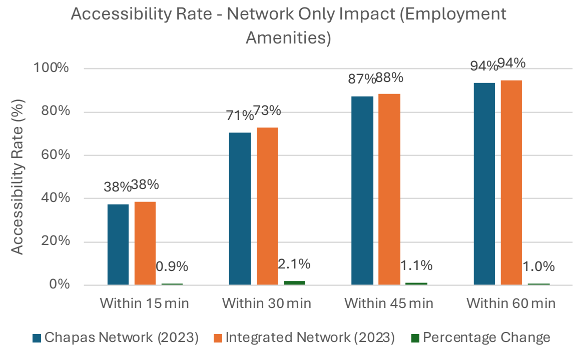


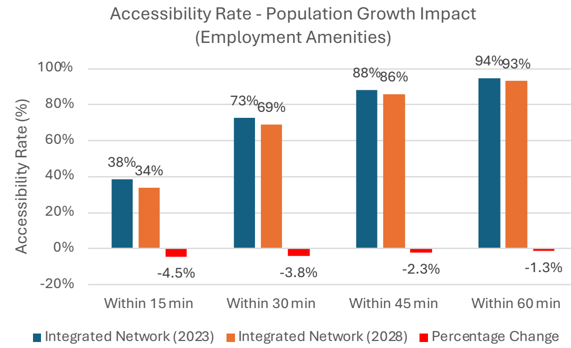


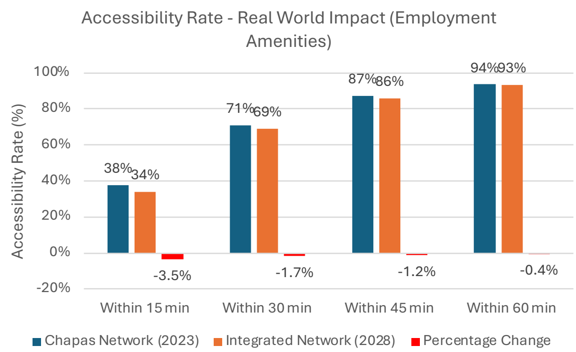


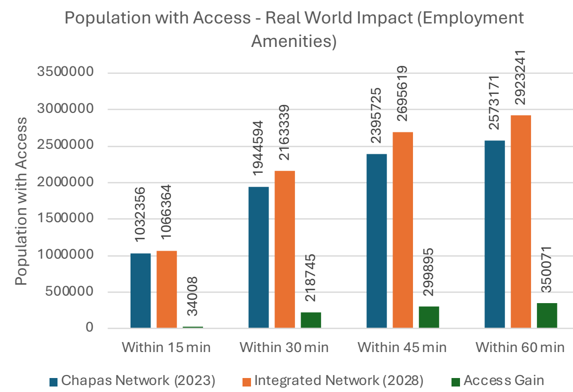


Appendix I. Employment Accessibility Charts

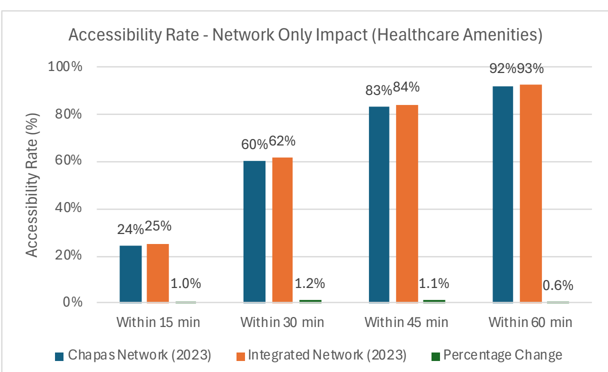


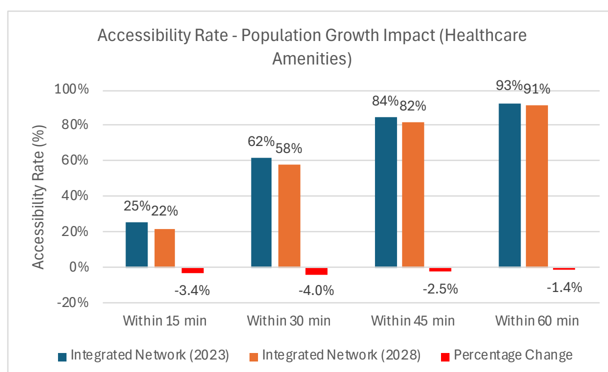


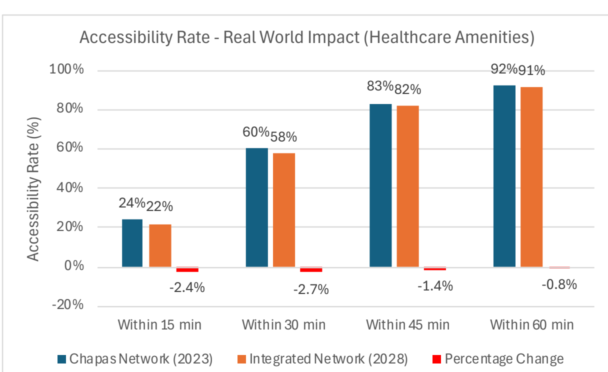


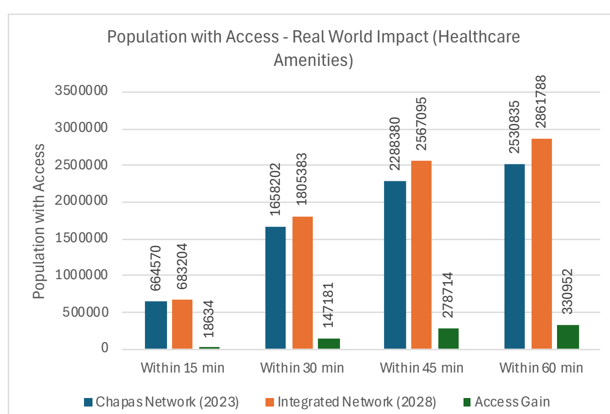


Appendix J. Healthcare Accessibility Charts









Appendix K. Social & Recreational Accessibility Charts