Low carbon transport futures in Zambia

Final Report

Final Report v1

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World Resources Institute

Digital Transport for Africa

Climate Compatible Growth

Title picture: Different modes of mobility competing for road space, Ghada AbdulAziz

Table of Contents

List of Figures

List of Tables

Glossary

Acronym	Term
GTFS	General Transit Feed Specification
WRI	World Resource Institute
TfC	Transport for Cairo
OSM	OpenStreetMap
GIS	Geographic Information Systems
PT	Public Transport
GPS	Global Positioning System
GIS2GTFS	Geographic Information Systems to General Transit Feed Specification
FR	Field Research
FRM	Field Research Manager

AWP	Annual Work Plan
BTOAZ	Bus and Taxi Owners Association of Zambia
CRAZ	Commuters' Right Association of Zambia
LAs	Local Authorities
LCC	Lusaka City Council
MIHUD	Ministry of Infrastructure, Housing and Urban Development
MoFNP	Ministry of Finance and National Planning
MoGEE	Ministry of Green Economy and Environment
MoLG/MLGRD	Ministry of Local Government and Rural Development
MoTL	Ministry of Transport and Logistics
MoWS	Ministry of Works and Supply
NRFA	National Road Fund Agency
NTP	National Transport Policy
PPCA	Passengers, Pedestrians and Cyclists Association
PPTDAZ	Public Passenger Transport Drivers Association of Zambia
PSVs	Public Service Vehicles
RDA	Road Development Agency
RTSA	Road Transport & Safety Agency
TRSF	Talk Road Safety Foundation
ZEMA	Zambia Environmental Management Authority
ZIPAR	Zambia Institute of Policy Analysis and Research
RFL	Road Fitness Licenses

1 Executive Summary

In 2023 Transport for Cairo (TfC) and Smart Solutech (SS) in partnership with the World Resources Institute (WRI) embarked on mapping Lusaka's public transport network to gain data-driven insights and specifically to model GHG emissions from transport services. The research project was funded by the Foreign and Commonwealth Development Office (FCDO) under the Climate Compatible Growth (CCG) programme.

Stakeholder mapping and analysis showed that the main challenges on the policy level are:

a. Cross-organizational gaps, mainly between the Ministry of Transport & Logistics developing transport policies and the other entities implementing the policies, including Lusaka City Council.
b. Lack of incentive to upgrade transport fleets given Zambia Revenue Authority's defined duty rates on used motor vehicles. (i.e. The newer the vehicle the higher the tax)
c. Lack of sustainable mobility transition frameworks in the National Transport Policy in public transit.

Digital data collection (i.e. Mapping) was done comprehensively for the public transport network in Lusaka resulting in a digital database comprising of **sixty-seven (67) routes**, **fifty (50) terminals**, **793 stops**, **section counts**, **headway** and **travel time** estimations for three (3) time intervals. (morning peak, morning off-peak, evening peak). Additionally, the Road Transport Safety Authority (RTSA) shared **fleet characteristics** data for licensed public transport vehicles.

Two capacity building sessions were held focusing on the topics of "Digital Transport Data collection" and "Data Analysis and GHG modelling" respectively. The sessions were conducted with participants from the Zambian Government, civil society, and private sector. Main conclusion from both session was that stakeholder ownership of the mapping process is key and can be realistically achieved using open data and open/free software tools.

The "Lusaka Transit Map" is designed with an emphasis on user-oriented interface, aiming to efficiently portray public transportation options within and around the city. It highlights various modes of public transportation and their interchange possibilities to facilitate easy navigation for users. The map is based on the up-to-date information collected from the field and can be used for passenger information at bus stops and main points of interest in the city.

Boarding and alighting data analysis shows large discrepancies on the township-level between female and male ridership. Kanyama has the highest male ridership with evidence suggesting correlation to poor infrastructure preventing women from proper access to mobility; Whereas townships with higher commercial activities, particularly in the professional, service and sales sectors, have the highest female ridership ratios.

The public transport network in Lusaka as it stands is inefficient due to lack of inter-city direct connectivity and low commercial speeds at the city edges; Low speeds are due to drivers loading passengers from sporadic locations due to lack of a centralized bus terminal at those locations.

GHG emissions from public transport were modelled using the software package "gtfs2emis" which relies on two inputs (a) A functioning General Transit Feed Specification (GTFS) feed and (b) Fleet characteristics data. The estimates from the model are at an unprecedented granularity in geographic and temporal aspects. The model had a total of 29,970 trips from 08:00am to 07:00pm; equivalent to 5.6 trips per vehicle per day.

Lumumba Road, Great North Road, Great East Road, and Chilimbulu Road are the most polluted/polluting corridors, whereas pollution is highest at city centre due to both lower commercial speeds and the concentration of virtually all PT routes. High PM10 emissions within high population neighborhoods are concentrated in the northern quarter of the city, namely "Chazanga" and "Kabanana" townships. CBD, Chelstone, Zanimuone and UTH Hospital bus terminals exhibit both the highest demand and PM10 emissions.

The study concludes (a) there are cross-organizational gaps needs addressing between Lusaka's government entities to build bridges between policy making and implementation, (b) Current laws and taxes do not incentivize the upgrade of PT fleets, (c) Lusaka's CBD congestion is due to the PT network's efficiency, and not simply PT demand.

Several routes can be upgraded to higher capacity vehicles based on measured level of service; While the same polluting corridors (Lumumba, Great North, and Great East Road) exhibit high passenger flow and can host a potential public transport infrastructure (PPTI). Key recommendations also include the direct connectivity between Lusaka's city edges based on the metrics made available by this research and complemented by passenger Origin-Destination surveys.

Using open data and open software tools, the government of Zambia along with academic and private sector partners may easily replicate this research to enable better decision making and informed regulation. The mapping and hosting of a digital database for PT services are recommended to be carried out by a newly established Public Transport Authority (PTA) within Lusaka City Council (LCC).

2 Introduction

The World Resources Institute (WRI) and Transport for Cairo (TfC) were granted the "Flexible Research Fund" in 2023 through the Climate Compatible Growth (CCG) programme, funded by the Foreign and Commonwealth Development Office (FCDO), to implement research revolving around the mapping of **public transport** (PT) and **Non-motorized Transport audits** (NMT) in Lusaka, Zambia. This report focuses on the **PT components** of the research.

2.1 Background on Lusaka

2.1.1 Lusaka's Road Network and Transit Routes

The road network in Lusaka has a radial nature, and the geographic location of the city of Lusaka accentuates this network, the city lies at the intersection of the north-south and east-west corridors. This illustrates why through traffic (traffic passing through Lusaka to reach origin and destinations on the north and south of the city) represents almost 15% of the traffic on main roads such as Kafue Road and Great North Road. (Japan International Cooperation Agency (JICA), March 2009)

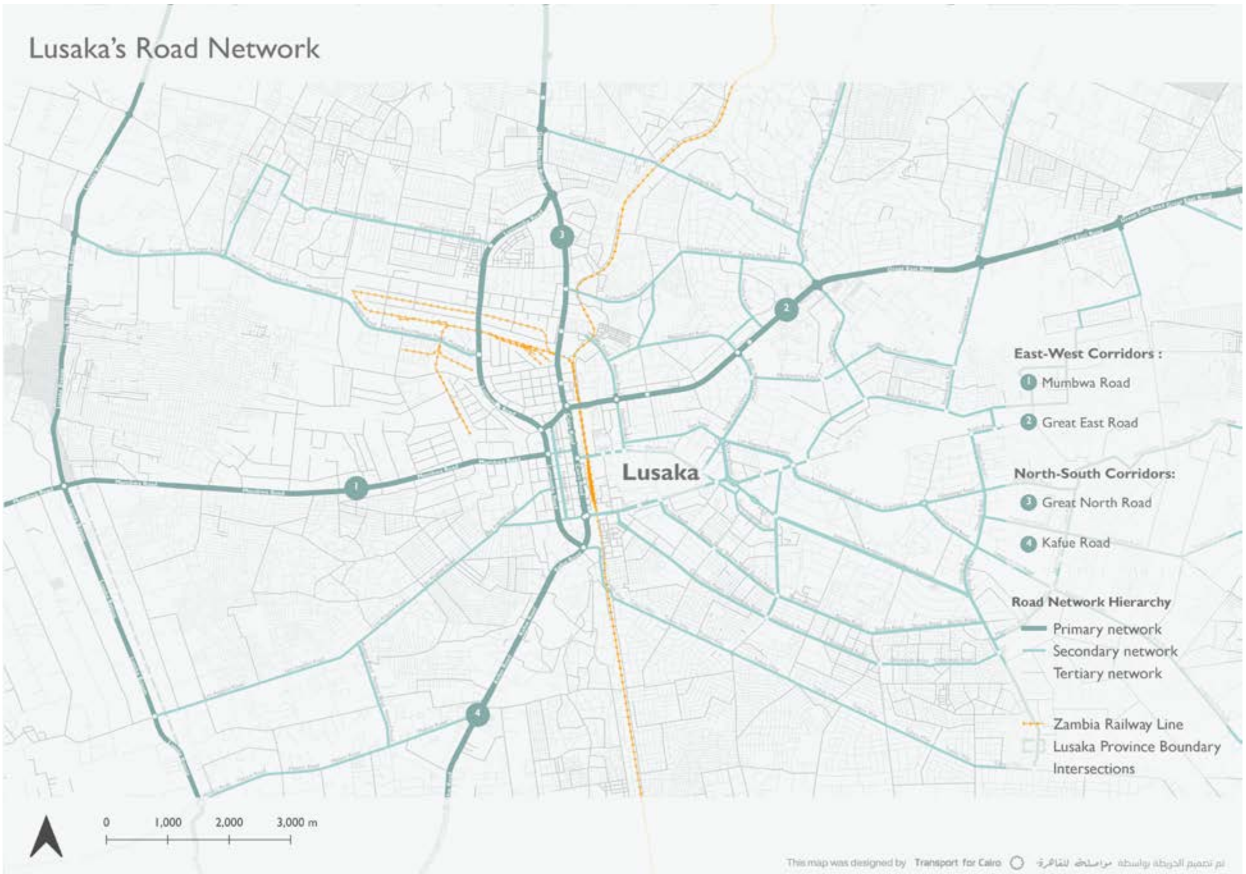


Figure 2-1 Lusaka's Road Network

There are five main bus terminals in Lusaka, four of the five terminals operate on intracity level, while the Lusaka Intercity Terminal provides intercity trips. The terminals are located within the Central Business District (CBD) which is considered the main intermediary location that feeds transportation to different destinations. This radial network connects the different locations through the CBD, and this impacts the extent of the geographic coverage of public transport in Lusaka. To reach any destination in the periphery of Lusaka, commuters have to reach the CBD and commute to their destinations, this increases the congestion in the city centre, and increases the trip length for the commuters.

2.1.2 Economic Reforms Impact on Transportation Services in Lusaka

The transportation services in Lusaka underwent several economic and institutional changes which evidently shaped the provision of PT services in intercity and intracity levels. These changes are summarized in the following points based on the Zambia Case Study Report published by the International Transport Workers' Federation in 2006.[1]

[1] International Transport Workers' Federation. (June 2006). *Organisaing Informal Transport Workers: A case study of Zambia.*

The changes are chronologically highlighted in Figure 2-2.

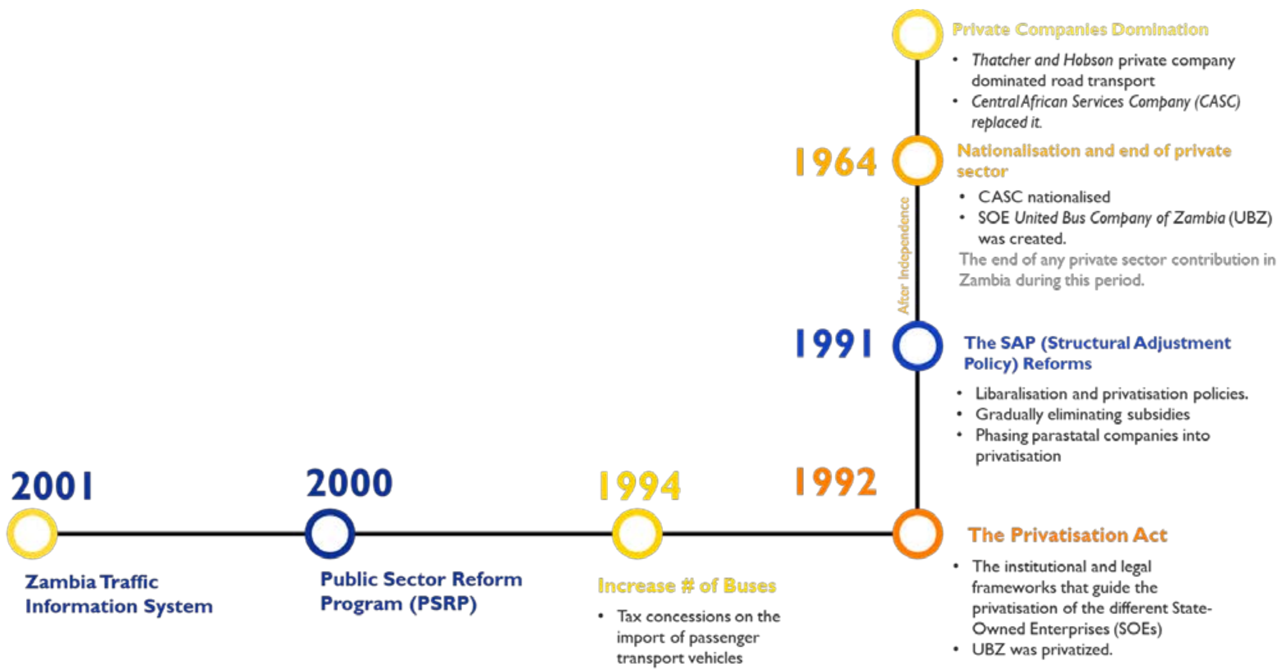


Figure 2-2 Chronological reforms that affected the provision of transport services in Zambia.

The policies had a clear impact on the public transport services in Zambia, the privatisation policies led to an increase in the number of bus operators as well as buses. (ZIPAR, 2013) The initial intent of the liberalization was to make PT services less dependent on the government and to increase the competition between operators to improve the level of service. While this was partially attained since the gap between supply and demand decreased due to the increase in the number of buses, unregulated operations led to a decrease in the level of service. Anyone could buy a vehicle, license, and operate it on any route, without any restraints. (ZIPAR, 2013)

2.2 Project Objectives

Lusaka's PT is dominantly operated by paratransit with two main modes: minibuses (14-18 seaters) and bigger "Rosa" buses (30-seaters). Those modes, similar to other African cities with similar paratransit services, are dynamic and demand driven. This makes paratransit more challenging to "digitize"; meaning to comprehensively map and quantify the network to its actual volume.

With this challenge in mind, activities for the project and the city of Lusaka can be summarized as follows:

- Create a comprehensive, digital database for Lusaka's paratransit network.
- Build a GHG emissions Model for the network.
- Build the local capacity for Zambia's local stakeholders (mapping community, government, civil society) to do the mapping themselves in the future.

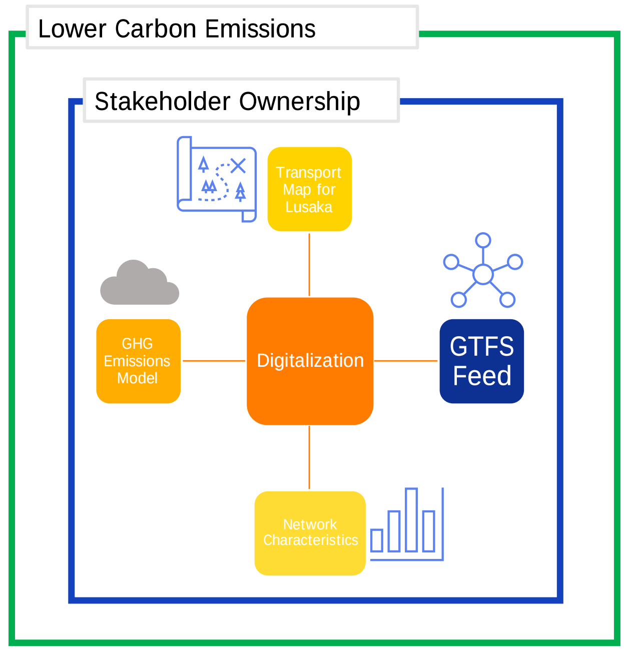


Figure 2-3: Project Objectives

These activities should achieve the three targeted objectives:

1. Digitalization: Of public transport network and characteristics.
2. Stakeholder Ownership: of the process from A to Z.
3. Lower Carbon Emissions: By creating a sustainable digitalization workflow within local stakeholders allowing for better decision-making tools and enacting of existing policies.

3 Methodology

To create proper, data driven insights for Lusaka's PT network, a meticulous data collection process has to be performed to create a digital database for the network that is comprehensive and accurate. This process was divided into three phases:

1. **Stakeholders Mapping & Consultation**: To identify who are the main and primary stakeholders for the different project outputs, as well as to comprehend the underlying policy challenges for sustainable public transport in Lusaka.
2. **Mapping** (i.e. Data collection)
3. **Data Processing**
4. **Data Analysis** & Findings

Data collection relied mainly on **field research**, in addition to minor desk-based research from online sources to get existing information about the network; as well as data collection from local government to get information about the PT fleet characteristics.

To ensure a context-aware field research, "Smart Solutech" (SS) a Zambian company with mapping experts from the local OpenStreetMap (OSM) and Humanitarian OSM Team (HOT) took on the responsibility of implementing the field research with management and software tools provided by TfC.

The SS team would hire field researchers and provide TfC with insights from the field to direct the mapping activities.

The overall approach is to maximize benefit by producing **reusable data outputs** with **digital tools** that optimize every step of the process. Starting with desk research, preliminary input data is used to draw a field research plan. The field research will be done using an in-built software suite developed by TfC called "RouteLab" of which the "Observer" mobile app captures geographic, temporal, and additional attributes tailored for the assignment of paratransit mapping.

The data outputs from the field research are mostly in Geographic Information systems (GIS) file formats, which when supplemented by the temporal data, are converted into accurate General Transit Feed Specification (GTFS) feed. The GTFS format can be used for multiple purposes including as a **passenger information system** (i.e. Trip planning) and for analyses such as **passenger flow** and **accessibility** measurements.

Further for the purpose of passenger information, a **stylized map** is created based on the GIS data collected from the field.

Additionally, another open-source software tool "gtfs2emis" is used to **model emissions** from the PT network daily and during different time intervals using the same GTFS output.

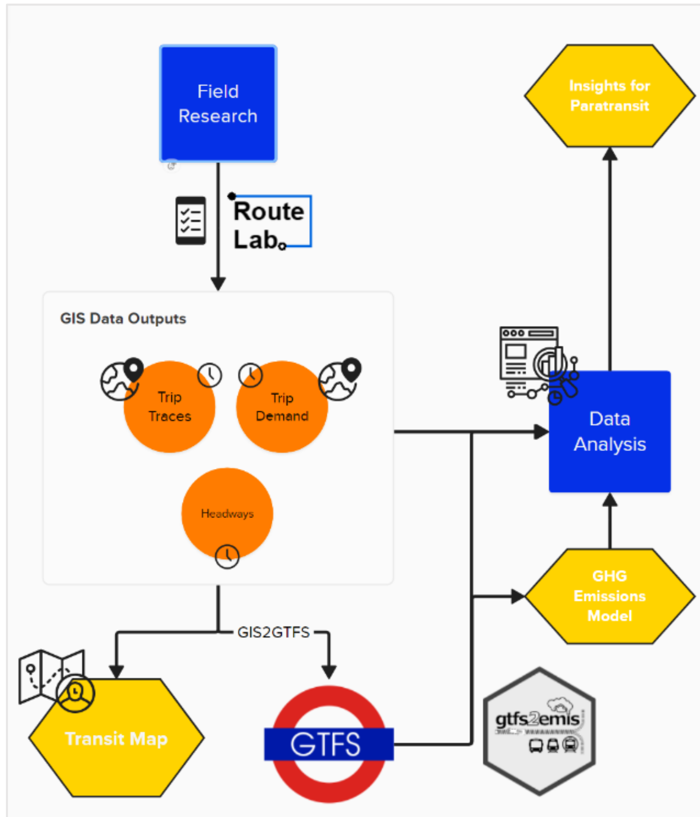


Figure 2-4 Lusaka's Paratransit Mapping Approach

In tandem with the project's production activities, capacity building sessions with local government and civil society stakeholders are conducted to ensure the sustainability of the data collection and management. Given the use of open technologies and straight-forward processes, the sessions facilitated the ownership of local stakeholders to the mapping process.

4 Stakeholders Identification and Analysis

The main objective of this section is to understand the roles of different stakeholders which are relevant to the provision of public transit in Lusaka, and to position the capacity of the current institutional system on creating a shift towards a more sustainable and efficient transport system.

The section begins by [1] mapping the stakeholders according to their mandate and their actual roles, [2] analyzing the capacity of the current institutional system in providing quality transport system, and [3] Identifying areas of development.

4.1 Key Stakeholder Groups

The Stakeholders are categorized according to their governmental role into five levels: [1] National Level Governance [2] Ministries [2] Local Authorities, [3] Civil Society Organisations and Co-operatives, [4] Bus Owners and [5] Institutions. This categorization, and the role of each will be developed and further investigated based on the consultations with the stakeholders.

The following section describes the roles and responsibilities of the stakeholders in relevance to the transport services. Each of these entities have a holistic organisational structure, but only the relevant departments to the provision of transport are reviewed and discussed.

4.1.1 National Level Governance - Agencies

- *Road Transport & Safety Agency (RTSA)*

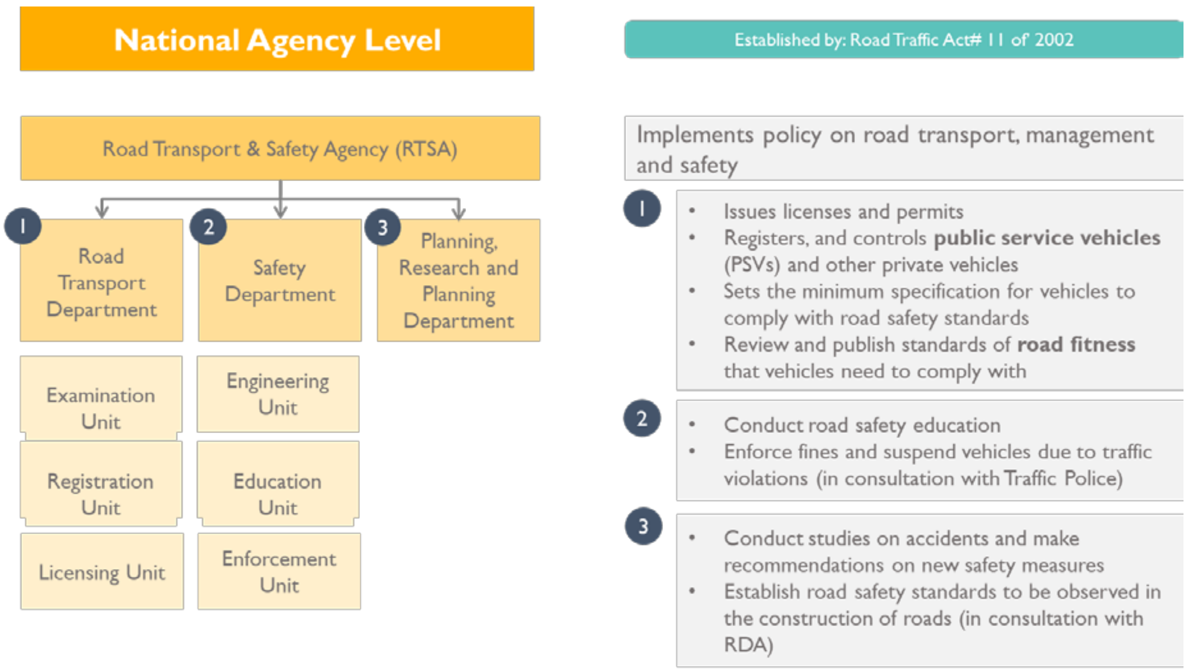
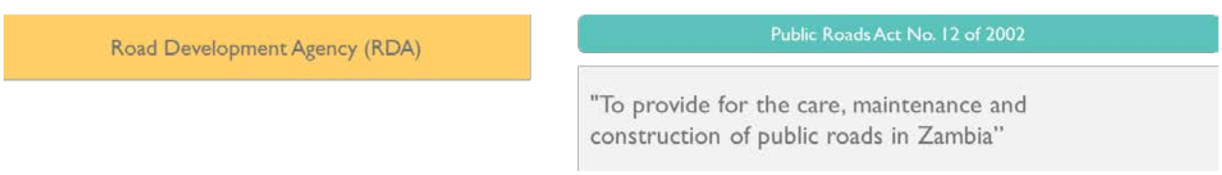


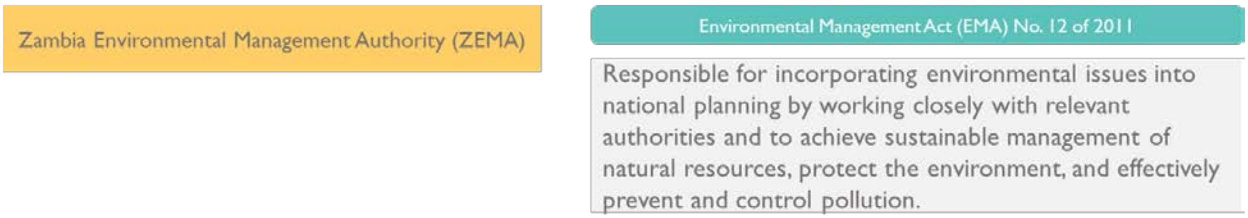
Figure 4-1 RTSA's Departments and Roles Relevant to the Provision of Transit

- *Road Development Agency (RDA)*



- *National Road Fund Agency (NRFA)*

- *Zambia Environmental Management Authority (ZEMA)*



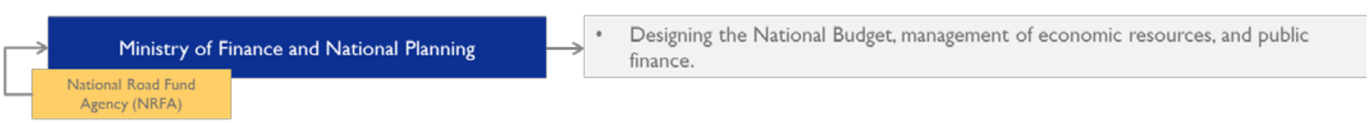
4.1.2 Ministries

In the following section, the role of each ministry in relevance to the transport sector is highlighted, and the agency or local authority affiliated to each ministry is indicated under each Ministry. The following is the list of ministries involved with the planning, funding, or the provision of transport across Zambia as well as ministries (such as the MoGEE) whose involvement could improve the environmental impact of the transport sector.

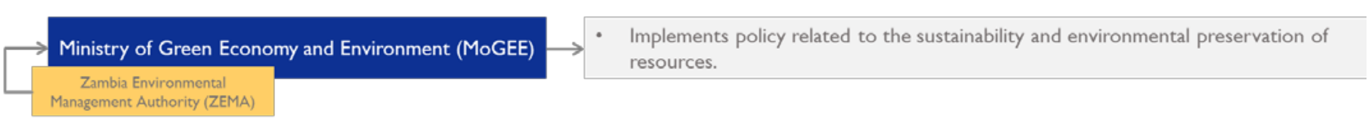
- The Ministry of Transport and Logistics (MoTL)

- The Ministry of Works and Supply

- Ministry of Finance and National Planning

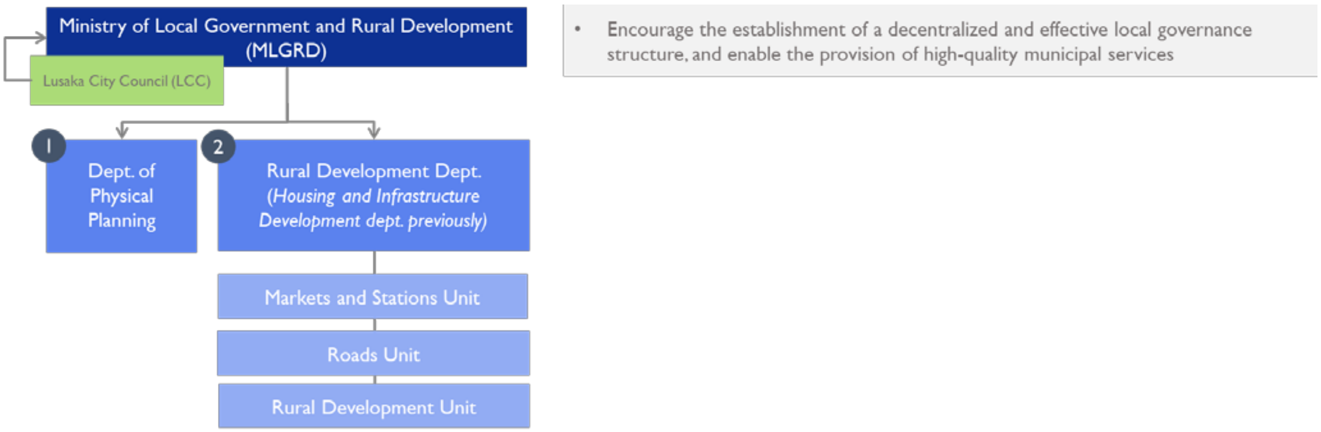


- Ministry of Green Economy and Environment (MoGEE)



- Ministry of Infrastructure, Housing and Urban Development (MIHUD)

- Ministry of Local Government and Rural Development (MLGRD)



4.1.3 Local Authorities

- *Lusaka City Council* (LCC)

Most bus owners depend on importing used vehicles and fitting seats for the imported buses. After the buses are bought, the owners register the Vehicles as PSVs and drivers must update their licenses to Road Service License (RSL), both processes are done through RTSA. During the registration of PSVs, operators choose which concession zone to operate in.

During the registration process, applicants have the flexibility to choose the areas that they want to operate in. These areas are usually 50 km radius zones and although these areas are mentioned in the registration details, they do not confine the drivers to operating in other areas. Routes are not specified in the registration of vehicles.

The role of LCC is related to planning the route and regulating the demand of the buses on the different routes. While this role is currently managed by the bus stations management, assessing the whole network, and planning future changes for the change in the service, should be done through LCC.

Local Government Act, Cap 281

The council is responsible for the construction, maintenance and management of roads and infrastructure in Lusaka, in collaboration with other stakeholders such as RDA, NRFA, & RTSA.

1
- Urban Planning
- Landuse management
- Infrastructure Planning

2
- Building and Road construction including the construction of bus stops and road infrastructure of local township roads.

3
- Planning commissions
- Occupation Certificates
- Document for safe habilitation
- Ensure buildings follow building codes
- Bus stations Unit (communicates with engineering and planning departments for the construction of bus stops)

4.1.4 Civil Society Organisations and Co-operatives

Associations are the key structure that helps government govern and communicate with private sector, such as transport. These associations attend monthly meetings with RTSA to discuss monthly fuel adjustments and discuss the impact of these changes on the fare. RTSA represents MoTL in these meetings which is eventually the main ministry responsible for administering these changes.

It's easier for regulators such as RTSA to follow standards and administrative requirements related to taxes and insurance when dealing with companies or cooperatives rather than individual owners.

Associations & Cooperatives

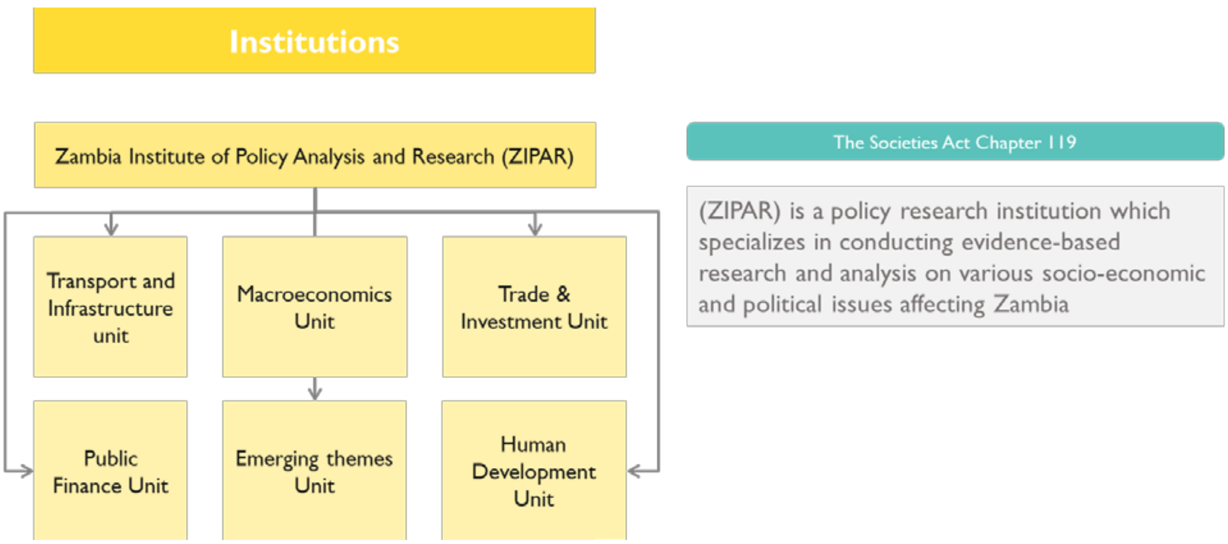
Law Association of Zambia Act, 1973

- Cooperatives are the key structure that helps governments administer its economic objectives with private sectors such as transport which is a liberalized market for the public service.
- Cooperatives also ease the communication channel between the members and governmental bodies.

Public Passenger Transport Drivers Association of Zambia (PPTDAZ)	Eases the communication channel between government and transport drivers regarding insurance, pension scheme, loans, and currently developing a concept note on transitioning to a single fleet management plan
Commuters' Right Association of Zambia (CRAZ)	Represent the commuters in maintaining fares and attends the consultations with RTSA and other associations regarding any increase or reductions in fares based on monthly fuel adjustments
Bus and Taxi Owners Association of Zambia (BTOAZ)	BTOAZ main objective is to advocate for the rights and welfare of its members, as well as to promote the development of the transport business.

4.1.5 Institutions

- *Zambia Institute of Policy Analysis and Research (ZIPAR)*

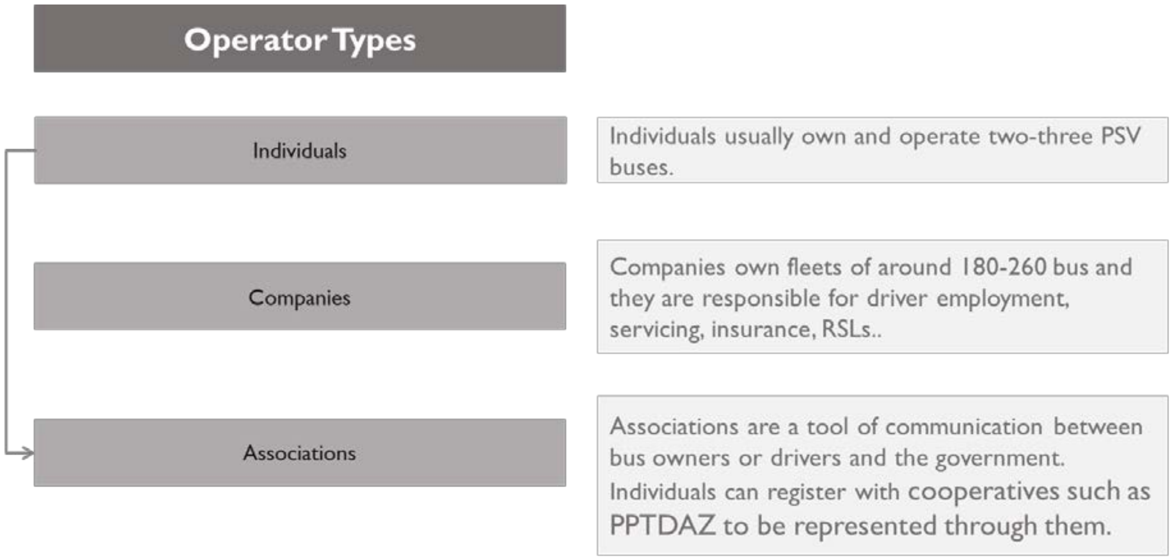


4.1.6 Bus Ownership Representation

Due to the liberalized nature of the provision of transport services in Lusaka, the ownership of buses is represented differently:

- **Individuals** who buy less than five buses, and this form of ownership is considered a form of subsistence living for the owners.
- **Companies** such as Flash operators, have a fleet of around 270 buses and they are also the only private company that own a station for operations in the CBD (Millennium Bus Station).

Bus owners can also register with **associations** to support them in processes related to licensing, pension, and loans.



4.2 Stakeholder Engagement Plan

The engagement of the stakeholders is implemented through Capacity Building Trainings and Consultation Interviews.

- **Capacity building trainings:** The capacity building is held to introduce stakeholders to the impact of digitizing and mapping transit systems and its application on improving the transit systems.
- **Consultation interviews:** Different stakeholders have diverse experiences and engagements with the public transit system. Consultations were conducted with the stakeholders with the main objective to:
  - Identify their institutional challenges and needs.
  - Understand their roles in the provision of transit services.
  - Identify gaps between policy and implementation.

4.2.1 First Visit

The first visit to Lusaka that was scheduled during early July 2023 started with the official launch event of the project with the attendance of different stakeholder groups. The project objectives and timeline were shared with the attendees. During the visit, TfC's team facilitated a capacity building session on "Data Collection in transit systems" for governmental stakeholders with an interest and knowledge in managing data systems in their respective institutions.

4.2.2 Second Visit

During the second visit to Lusaka in August 2023, a series of consultations were held with stakeholders. Table 4-1 shows the different stakeholder groups who were interviewed during the visit. The results and discussion points of these consultations are documented in section 10.1.

Table 4-1 Consultations conducted during the second visit to Lusaka for Stakeholder Engagements

#	Entity	Consultation Attendees	Job Title	Date
Agencies				
1	Road Transport & Safety Agency (RTSA)	Mr.CHNUNKY KANCHELE	Head Planning, R&D	Tuesday 8TH August 2023
2		Eng.ALINANI MSISYA	Deputy Director - Road Safety	
3		Ms.LINDA MUWOWO	Principal Education & Publicity Officer	
4		Mr.JOSEPH MUMBA	Deputy Director - Transport	
5		Mr.MIOKO	Head of Examination Unit	
Ministries				
6	Ministry of Local Government and Rural Development (MLGRD)	o Mr.RICHARD KANGWA o Mr.STEPHEN MALUBILA	o Principal Engineer o Technical Advisor	Thursday 10 August 2023
Local Authorities				
7	Lusaka City Council (LCC)	o Mr.FERGUSON SIMUSAMBA, o Mr.SABBSON PHIRI, o Mr.EVANS KAMBOLE	o Town Planner o Assistant Director of City Planning o Bus Stations Manager	Thursday 10 August 2023
Civil Society Organisations and Co-operatives				
8	Public Passenger Transport Drivers Association of Zambia (PPTDAZ)	Mr. SIDNEY MBEWE	Executive Chairman	Tuesday 8TH August 2023
9	Passengers, pedestrians, and cyclists' association of Zambia	Ms. FOSTER CHILESHE Ms. SHUPIWE SAKALA	President	Thursday 10 August 2023
Institutions				
10	Zambia Institute of Policy Analysis and Research (ZIPAR)	Mr. JOHN MUTUTWA	Research Fellow - Transport and Infrastructure Development	Friday 11 August 2023
Operators				
11	Flash Buses Operators	Mr. ISMAIL KHANKARA	Owner	Wednesday 9 August 2023

4.3 Stakeholder Engagement Analysis

This section investigates the different roles in the provision of transport in Lusaka. This analysis is based on the [1] desk review of the mandates and functions of the different stakeholders and [2] the consultations held as indicated in Table 4-1. The current structure of transport management in Lusaka is distributed across entities with different power weights. Figure 4-2 Shows the division in roles between implementation and policy making across different bodies according to their mandate and functions.

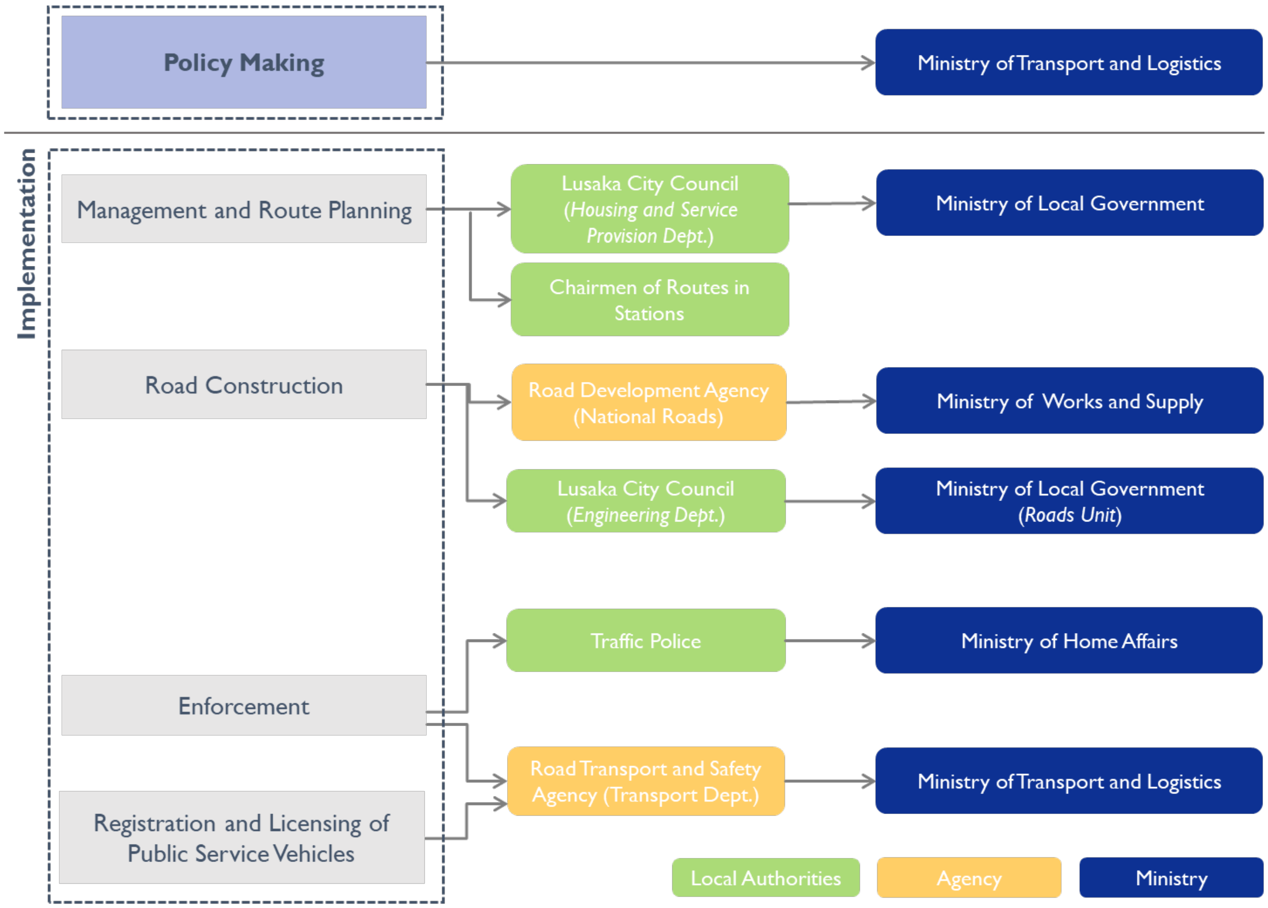


Figure 4-2 Roles of the different stakeholders and their affiliation to the ministries

4.3.1 Active Policies

- *Establishment of PTA in Local Authorities* – *National Transport Policy*

The MoTL is the highest entity that develops policies related to the performance of the transportations sector, including acknowledging fares increases or reductions due to fuel adjustments. The National Transport Policy is a review and update of the National Transport Policy that was developed in 2002. The developed policy also aims at introducing institutional reforms to improve the implementation of the policy.

The implementation framework in the policy reviews the roles across the different ministries and introduces the establishment of the *Public Transport Authority (PTA)* in all local authorities, and in the case of this study, the LCC. The policy doesn't define the specific roles of the PTA within the city councils, but according to the interviews conducted with LCC, this department will regulate, plan and monitor routes and generally work on formalizing the system, which is an organisational gap in the current functions of the LCC.

- *Shift to Sustainable Mobility – Nationally Determined Contribution (NDC) for Zambia*

Zambia has submitted its first NDC to the Paris Agreement on climate change in 2016, where it committed to a pledge of reducing Greenhouse Gases (GHG) emissions by 25% (20,000 Gg CO2 eq.) by 2030, compared to the base year 2010. In this NDC, Zambia broadens the scope of the sectors that can contribute to Zambia's mitigation actions by including the transport sector along with the liquid waste and coal production.

Data from Zambia Transport Data Portal as indicated show that the number of registered vehicles [2] has increased in the course of ten years.

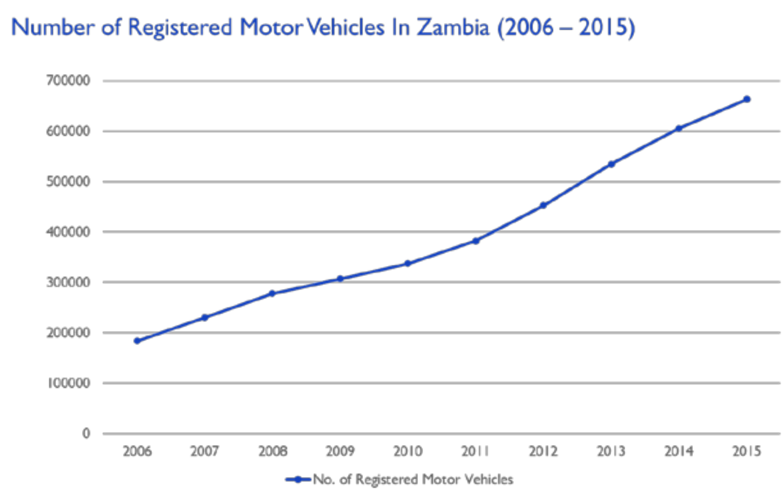
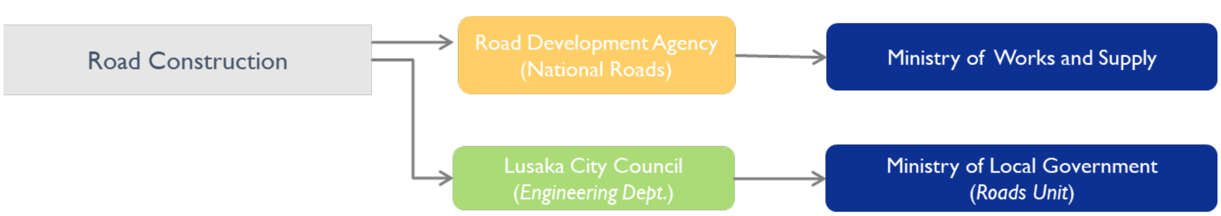


Figure 4-3 Number of registered vehicles in Zambia from 2006-2015. (source: https://zambiamtc.opendataforafrica.org/zadjuh/road-traffic-accident-statistics)

4.3.2 Road and Bus Stops Construction



Road maintenance and construction follow the Road Traffic Act No.11 of 2002. RDA has the overall responsibility for the maintenance and construction of all roads, except township roads which are considered as municipal services that are within the mandate of the local authority, affiliated to MLGRD.

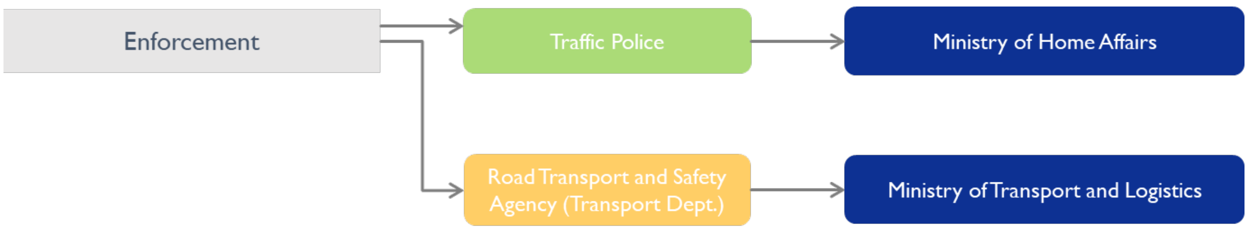
[2] https://zambiamtc.opendataforafrica.org/zadjuh/road-traffic-accident-statistics

According to the stakeholder meetings with LCC, roads are classified into:

- Highways (connecting districts) that are handled by the RDA (MoWS)
- Township roads are handled by Local authorities (MLGRD)

The MLGRD provide technical and financial support to the LCC and depend on a bottom-up demand approach, where the Local authorities (LAs) share their annual work plans (AWPs) with the (MLGRD) regarding their needs in the provision of different services whether related to the construction of bus stops, or the maintenance of township roads.

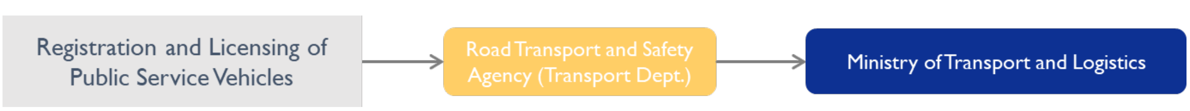
4.3.3 Enforcement



- RTSA consists of the Safety Department that focuses on improving the safety measures in the country and increase the public awareness on street safety, the department consists of three units:
    - Education Unit (Outreach and awareness)
    - Enforcement Unit (Develops enforcement systems for violations)
    - Engineering Unit (Inspects and advises with RDA through road safety audits (RSAs) and inspections (RSIs)
- According to the consultation with the safety department deputy director, the enforcement unit has been installing GPS trackers on PSVs.[3] The unit is planning to increase the number of PSVs with GPS tracking.
    - GPS tracking is not aimed at tracking the routes or understanding the efficiency of the network but rather as an enforcement tool to easily track the locations of accidents, or violations of the PSVs.
    - The aim of the tracking is to regulate the PSVs that violate the road act. These violations include loading and offloading passengers outside their designated stations and integrating the reported accidents with the location of vehicles.

Zambia Traffic Police still maintains the major role in street interception of violating vehicles, along with RTSA's enforcement unit.

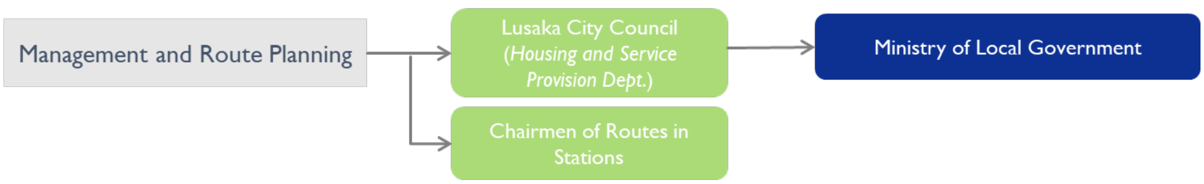
4.3.4 Registration and Licensing



[3] http://www.daily-mail.co.zm/rtsa-installs-gps-on-public-service-vehicles/

- RTSA is the main governmental body responsible for the registration of PSVs and all vehicles according to the Road Traffic Act# 11 of' 2002. After the Privatization Act, the transport services transformed into a profit industry, and this led to the increase in the number of buses on the street. As indicated by several stakeholders, besides the increase in the congestion in the CBD, there is an evident increase in the number of parked buses during off-peak times.
- RTSA's Examination includes ensuring that the buses are in good condition through the examinations unit which focuses on assessing the external condition of the bus and its fitness level for the Road Fitness Licenses (RFL)
    - o RTSA owns a new vehicle examination facility with a mechanized testing unit (MIMOSA) that was previously used by RTSA to issue road fitness licenses but based on the consultations there is only one unit in Zambia, and it is now not part of the process of obtaining the RFL.

4.3.5 Management and Route Planning



- According to the Act No. 2 of 2019[4], its mandated that LCC's responsibility in section 16(2) regarding the functions of local authority in public amenities is to: *Establish and maintain a public transport service.*
- LCC organizational system accommodates several public service amenities, such as city planning, but the functions of planning transport services are being accommodated under the *Housing and Service Provision Dept.*
- During vehicle registration (PSVs) in RTSA the applicant is asked to define the district (50 km radius) in which they'll be operating in, this information is not regulatory and doesn't confine the drivers to operating in specific districts but rather operators assess which area is more profitable. and organize themselves through the stations' chairmen management to decide on the routes.
    - o The operators can change their routes based on a change in demand with no restrictions on route operations from the licensing authority (RTSA) or LCC.

4.4 Conclusions

Cross-Organizational Gaps

Since the MoTL is the main entity responsible for developing transport policies, and other ministries act as the implementation for them. The functions related to transport provision is distributed across entities with different power weights, from agencies to local authorities.

[4] The Local Government Act No. 2 of 2019.pdf

Currently LCC doesn't own the capacity of planning and reinforcing a different operational system, and when a PTA is created within LCC, it will require building capacities related to transport planning and data management.

Carbon Emissions Surtax and the Aging Fleet (incentivizing newer cars)

Lack of incentive to upgrade the PSVs fleet:

- Zambia Revenue Authority which is the main authority responsible for defining the duty rates on used motor vehicles, assigns taxes based on the age of the used motor vehicles. Taxes on motor vehicles aged less than 5 years, are taxed more than vehicles that are aged above 5 years. (ZRA, 2022)
- For example, a motor vehicle with compression-ignition internal combustion piston and a seating capacity not exceeding 14 is taxed 58,763.10 Kwachas as a used vehicle (from 2 – 5 years), but a used vehicle aged above 5 years with the same specifications is taxed 31,873.10 Kwachas.
- Current policies encourage over investment in low-capacity vehicles, and the reuse of older models of vehicles that can be running for almost 20 years. There is no incentive from the government to renew the fleet, and doubling the taxation difference might contribute to an increasingly ageing fleet.

These taxes include custom duty, excise duty, value added tax, motor vehicle fee, processing fee and motor vehicle surtax. There is another type of tax that is not included, which is the carbon emission surtax, and its value depends on the engine capacity of the vehicle. As the engine capacity increases, the tax amount increases.

The National Transport Policy doesn't define the frameworks of transitioning to sustainable mobility in public transit which might be challenging the implementation and operationalization of this shift. The introduction of sustainable transport would require changes in the network, and the fleet characteristics.

5 Phase I: Mapping

Informed by the stakeholder consultations analysis, the **mapping** process was initiated in two stages, Pilot & Full-scale. This two-stage approach is a standard approach to mapping in different cities to ensure there is space to "contextualize" the initial data collection plan and iron out any misunderstandings or challenges faced by specific mappers.

5.1 Pilot Mapping

5.1.1 Training

Training for the pilot mapping phase started with half the field research team (5 field researchers) and the field research manager. The training was conducted on 12th July 2023 and consisted of two halves, where in the morning there is a classroom-format induction training followed by practical demo mapping using RouteLab, and the second half of the day in the afternoon is the actual deployment of field researchers to start identification surveys in the field.

The induction session focused on:

- The importance and relevance of digital mapping of paratransit (i.e. popular transport)
- Different types of surveys definition and explanation
- The uniqueness of context and challenges in mapping paratransit in African cities
- Applications and use-cases of data and analyses for the benefit of planning and passenger information, which helped in motivating field researchers in doing the work responsibly by understanding the greater purpose. Moreover, by appreciating the results that they could reap as citizens of Lusaka, they are more inclined to exceed the limits of performance as opposed to only showing them the powers of RouteLab's dashboard monitoring capabilities.

During the researchers deployment in the field, for a day and a half the field research manager was well introduced to the mapping workflow and received a hands-on training on using the dashboard to monitor the researchers and other activities of validation and data processing. Also shared with the team was the "Field Research Protocol" that documents all the technical, logistical and safety instructions.

Figure 4-4: Pilot Mapping Training - First session

5.1.2 Mobilization

The pilot mapping had several purposes. One was to identify most of the routes that are operating in Lusaka. This was done through Identification surveys, as in knowing of origins and destinations, of PT routes operating within the greater Lusaka region; and this would be the starting point in our mapping by having a list of known assignments and a finetuning of the expected logistical workload that initially assumed existing PT routes through limited older resources. This exercise was done in the CBD terminals (Kulima tower, City Market, Lumamba and Millenium) as most routes are known to originate from there.
The second purpose to the pilot map was to make the researchers and management from SS team test and gain familiarity with the surveys (onboard, and frequency) before going to full scale deployment, and

most importantly to provide feedback on their last pilot mapping day, detailing their experience or any hardship to follow the instructions.
The following chart from the RL dashboard, shows a glimpse on their working KPI during the pilot mapping phase; including the numbers of their initial testing during training.

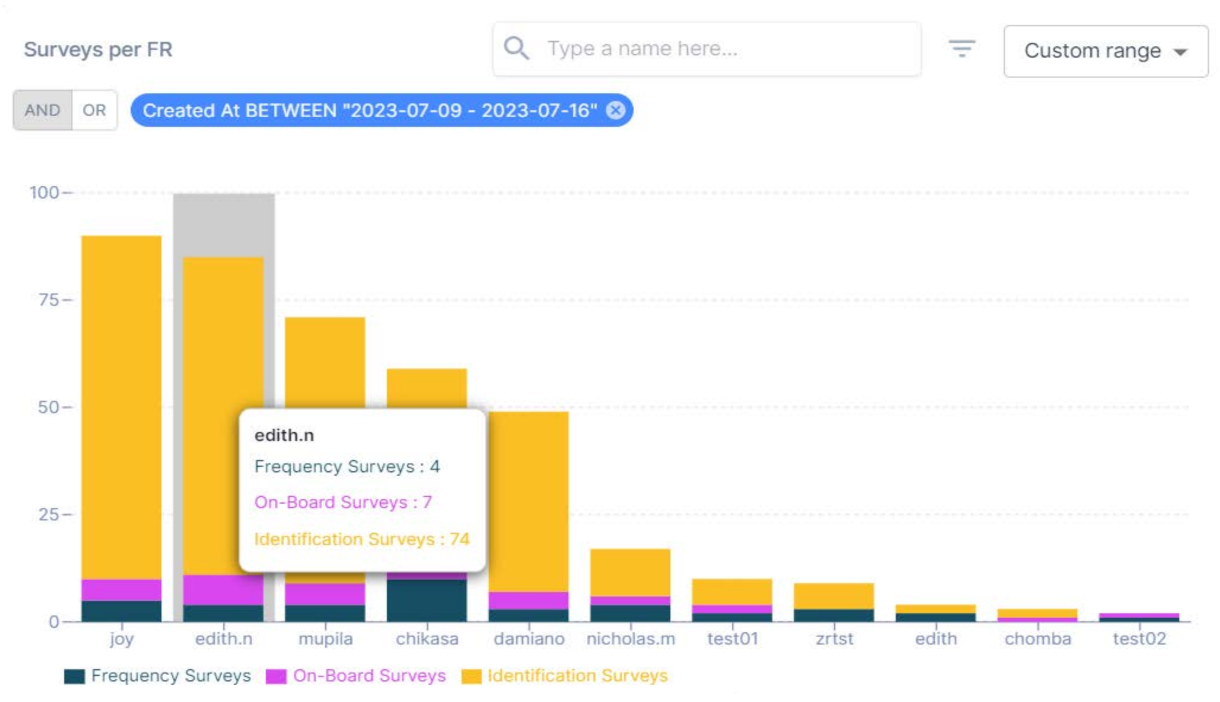


Figure 4-5 Dashboard chart showing researchers' KPIs through each survey type

5.1.3 Summary stats and Feedback

The pilot mapping took 3 days, with 12 person-days, to identify 88 routes, 14 validated Onboard surveys, and 4 validated Frequency surveys, The identifications made, did include some out-of-scope routes for going to destinations far outside the greater Lusaka boundaries; some were duplicates; and other identifications were later rejected when discovered to be just a part of longer routes (i.e. one of its assumed terminals was just a mid-stop).

During the feedback session a peculiarity for the Lusaka PT network was unravelled according to the field researchers team's local knowledge, which is that some buses wouldn't actually start their trips at the assigned origin terminal, they would start boarding passengers at one of the formal bus stops along its route; and since this is an unplanned behaviour, we couldn't have been able to account for this phenomenon magnitude without actually adjusting our rigorous methodology of counting busses frequency just at the start/end terminal. For that reason, we developed an experimental addition to our surveys methodology by adding several mid-routes section counts, to try to make an approximate account for that behaviour.

5.1.4 Validation of Identified Routes

The validation of identified routes is the process of accepting the information from field researchers and adding it to the pool of further mapping assignments for mapping them through onboard and frequency surveys. The process of validation checks several factors such as consistency with local knowledge; operating fully within the scope of the greater Lusaka boundary; and getting assigned an origin terminal and a destination terminal with known location and names and validated through desk work.

By the end of pilot mapping there was a 3-weeks gap till the full-scale deployment. Through that period an extensive validation process for most of the identified routes has been done by the field research manager with the support of others.

5.2 Training Session #1: Public Transit Mapping

First capacity building session was held on 13th July 2023 (during the pilot mapping) and was aimed at Transport planners, Data specialists and civil society members with interest in the intersection of mobility and data. The session's topic was "Public Transit Mapping" and meant to emulate the ongoing mapping that was initiated during the pilot mapping by Smart Solutech mappers. The attendees consisted of representatives from Lusaka City Council (LCC), Zambia Institute for Policy Analysis & Research (ZIPAR), Passengers, Pedestrians, and Cyclists' Association of Zambia (PAPECA), Road Transport & Safety Agency (RTSA), and Zambia Road Safety Trust (ZRST).

Figure 4-6: Practical Mapping Training with Participants

The capacity building session combined the theoretical, managerial aspect of data collection, with the hands-on aspect of collecting data and using digital tools. The day started with a classroom session on data collection planning and description of the different surveys and project management processes, followed by a practical demonstration of the RouteLab software suite used by TfC and Smart Solutech to collect data, and the day was concluded by a trail mapping exercise where participants used their phones to create and submit onboard surveys and going back into the classroom to view and discuss the data results on the RouteLab dashboard.

Table 4-2: Data Collection Training Agenda

Time	Session Title	Objectives
9:00 – 10:00 AM	Digitizing Paratransit	• Introductions • What is Data in Transportation? • What is the Paratransit Context? • What is the composition of a typical Data Collection project? • What are some of the challenges and risks involved? • What is an Identification, Onboard, & Frequency Survey? • What types of data do we collect? • How do we go about collecting each data point?
10:00 – 10:30 AM	RouteLab Demo	• Get to know the software Dashboard and the mobile App
10:30 AM – 12:00 PM	Hands-on Data Collection with RouteLab	• Conduct demo surveys • See the survey results on RouteLab's Dashboard

The concluding feedback session with attendees took more time than intended given the insights that were shared from the attendees. The discussion circled around the limitations of previous mapping projects and the missing data on actual supply and demand in regard to the paratransit services operating in Lusaka. Attendees from government were more focused on data formats and how this data can be integrated in their existing workflows.

In conclusion, the real potential lies in the attendees highlighting the importance of digital transport data in their public discourse, and the effectiveness of using technology in making the data collection process cheaper and more accessible. From the consortium's side, the software tools demonstrated are kept open and accessible, and this was communicated to the attendees during the sessions so that they know they have the tools to do this work themselves.

5.3 Full-scale Mapping

The full deployment of 10 field researchers occurred between August and September 2023 with155.5 person-days spent and a total duration of around 5 weeks; The first half day, a training was held to the rest of the researchers (5 additional field researchers, 10 in total) holding the same content as the pilot mapping training.

5.3.1 Field Challenges

5.3.1.1 Low Frequency Routes

A low frequency route is a highly challenging task to map, since it can rarely be found by field researchers, in the fixed window of time (1 hour) through which they notice any departures of buses on that route. (i.e. noticing a zero/one departure is a hardly useful information, since it doesn't decisively tell whether the bus comes once every hour, or every 3 hours). In this case many of the routes that we noticed that problem with, are in the Millenium Station, that was 10 years ago a more active station, but now is slowly dying. Local investigation shows that it is not atypical for a bus waiting to get full of passengers and start its itinerary from there, to get desperate after more than an hour of waiting and go to another town station to succeed in doing so.

Also, it later becomes a further problem when producing a commercial transit map for the city, for whether these routes should be mentioned or publicized at all, although it is not reliable in any regard.

5.3.1.2 Bus Fare Hike

According to Lusaka-times, on September 8, 2023, "In response to the recent surge in fuel prices, bus fares in Zambia have been officially raised, following approval by the Road Transport and Safety Agency (RTSA). The fare adjustments have been implemented to help transport operators cope with the escalating fuel costs." This put little tension on managing field logistics towards the end of the mapping activity. However, it did end successfully as planned.

5.3.1.3 Routes Detour

Many bus drivers according to our Onboard mapping surveys, and according to local expertise, did have detours along their designated itinerary. It is mostly happening for two specific reasons; One is to avoid traffic, and second is going in a path that is in more accordance with the current patch of passengers and their preferred destinations. Although this is not totally new in African countries and the informal public transportation services; However, the length of detours happening in Lusaka is sometimes unprecedently long as you can see in the example shown in Figure 4-7. This for sure will hugely affect any mid-way passengers that have a dependency for the bus to pass through certain points.

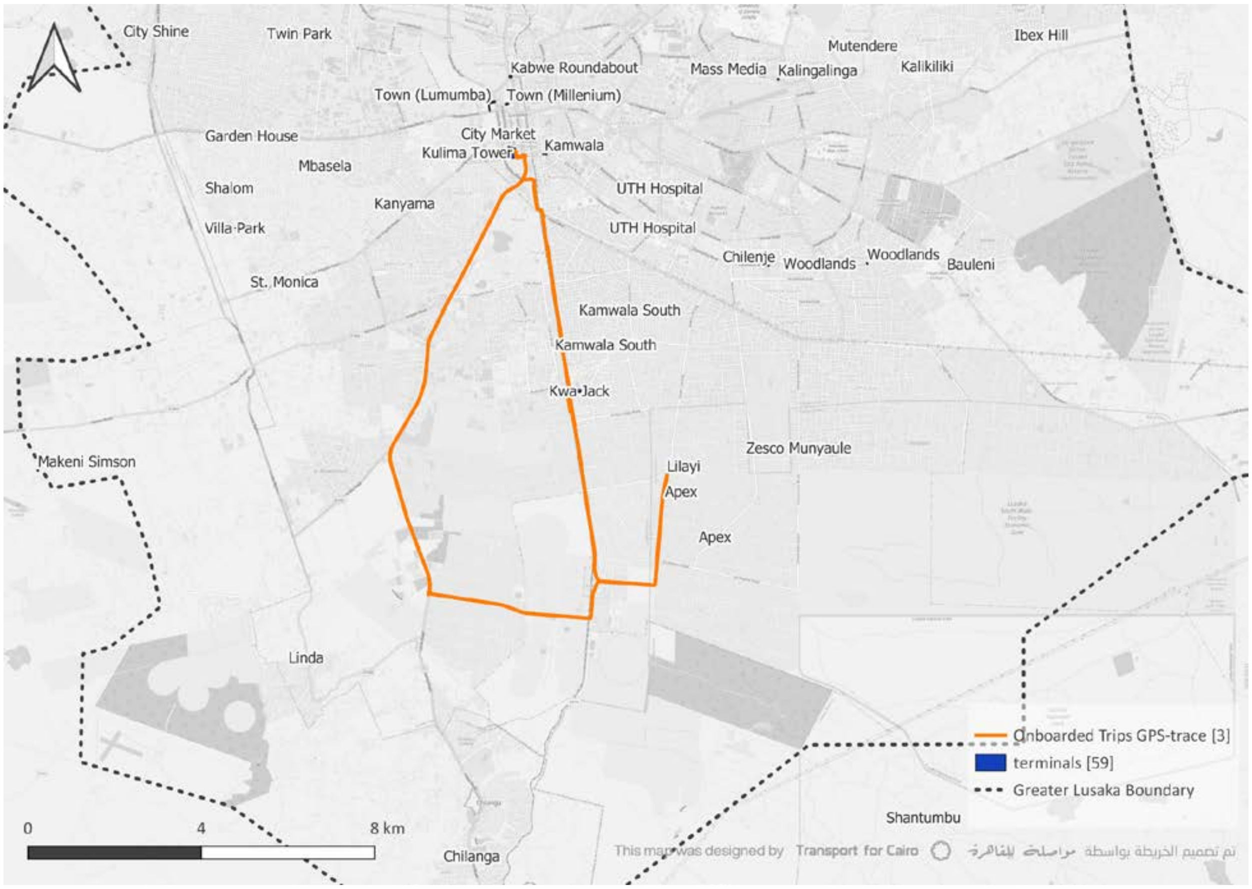


Figure 4-7 Onboard surveys going from Kulima Tower Station to Lilayi Station

5.3.2 Section Counts

Section counts are a novel approach that TfC has added to its mapping strategy. Details about the motivation within the project's context can be found in the project's inception report. Section counts are a means to both validate the frequency surveys conducted at the terminals and calibrate the resulting headway estimates.

Towards the end of completion of onboard and frequency surveys, with a comprehensive picture of the network, TfC's data team started planning the section counts activity.

5.3.2.1 Design

There are major differences between section counts on the street and a frequency survey. The latter can confidently observe a single route, but however can suffer from inaccuracy when a vehicle serving a single route are not organized in one queue that a FR can accurately observer. The former, on the other hand, captures the real flow of PT vehicles, but it cannot reliably observe a specific route due to lack of reliable signals for that. Destination signs are rare, and not all drivers are calling their final destination.

Given the mapped trip itineraries, we know the number of trips that through each link in the network. The smaller the number of trips that pass by the section count location, the more accurate insights can be. Hence, the design criteria were (a) maximizing accuracy of section counts, and (b) maximizing time efficiency by minimizing the number of surveying locations. A trade-off evidently emerged here.

The team arrived at 15 locations, visualized in Figure 4-8. The final set of points was developed iteratively through manual inspection of the spatial layout of the network. Hence, proving that it is optimality of the solution with respect to the trade-off mentioned above is not possible in this case. Further research could potentially go into developing a computational method for selecting survey locations using network theory.

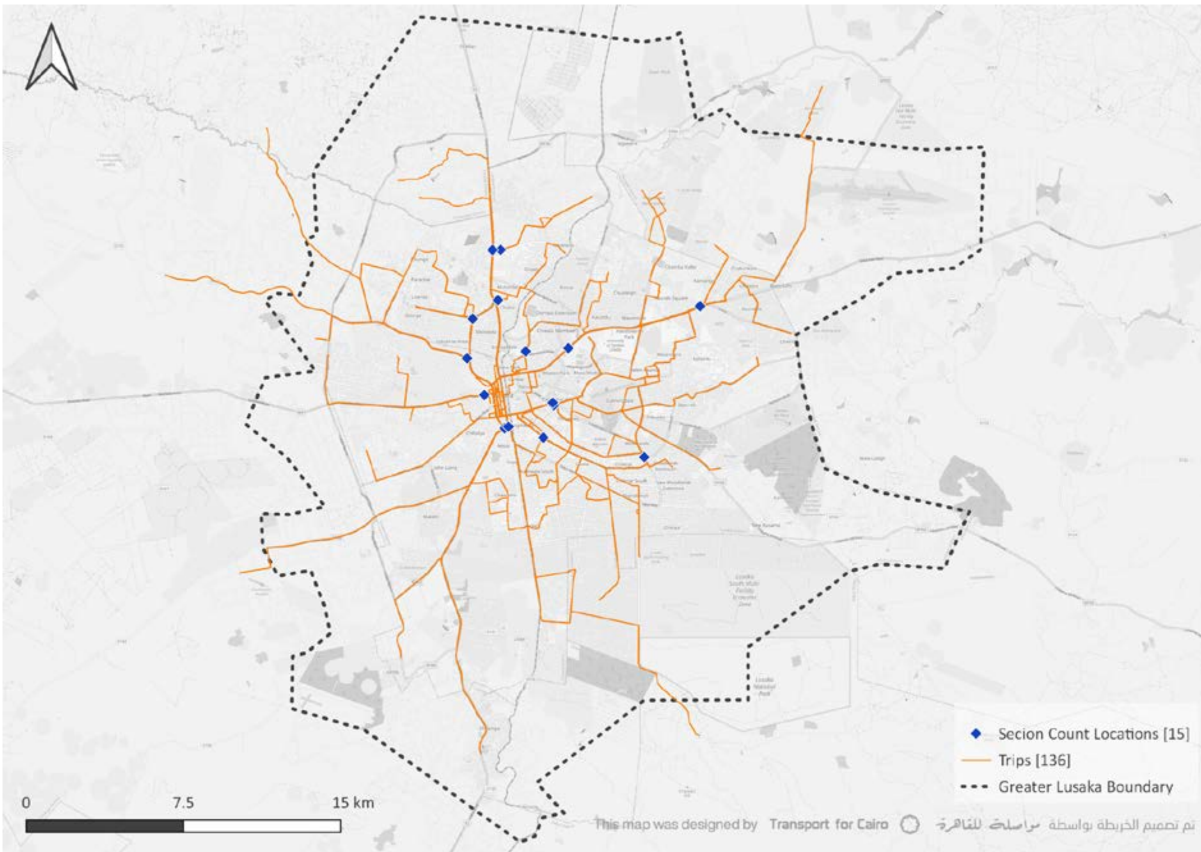


Figure 4-8 section counts location points

Finally, it was also decided to conduct section counts only on one side of the road as shown in Figure 4-9. This decision reduces the person-hours spent per location by makes use of the star-shaped topology of the network, where in each location the side of the street that is directed outward from town centre is the one considered in the survey. The reason is that the terminals in town are the origin terminal for most routes, and frequency surveys are conducted at those origin terminals. Therefore, section counts for vehicles flowing from town is sufficient to achieve the objective of validating frequency surveys.

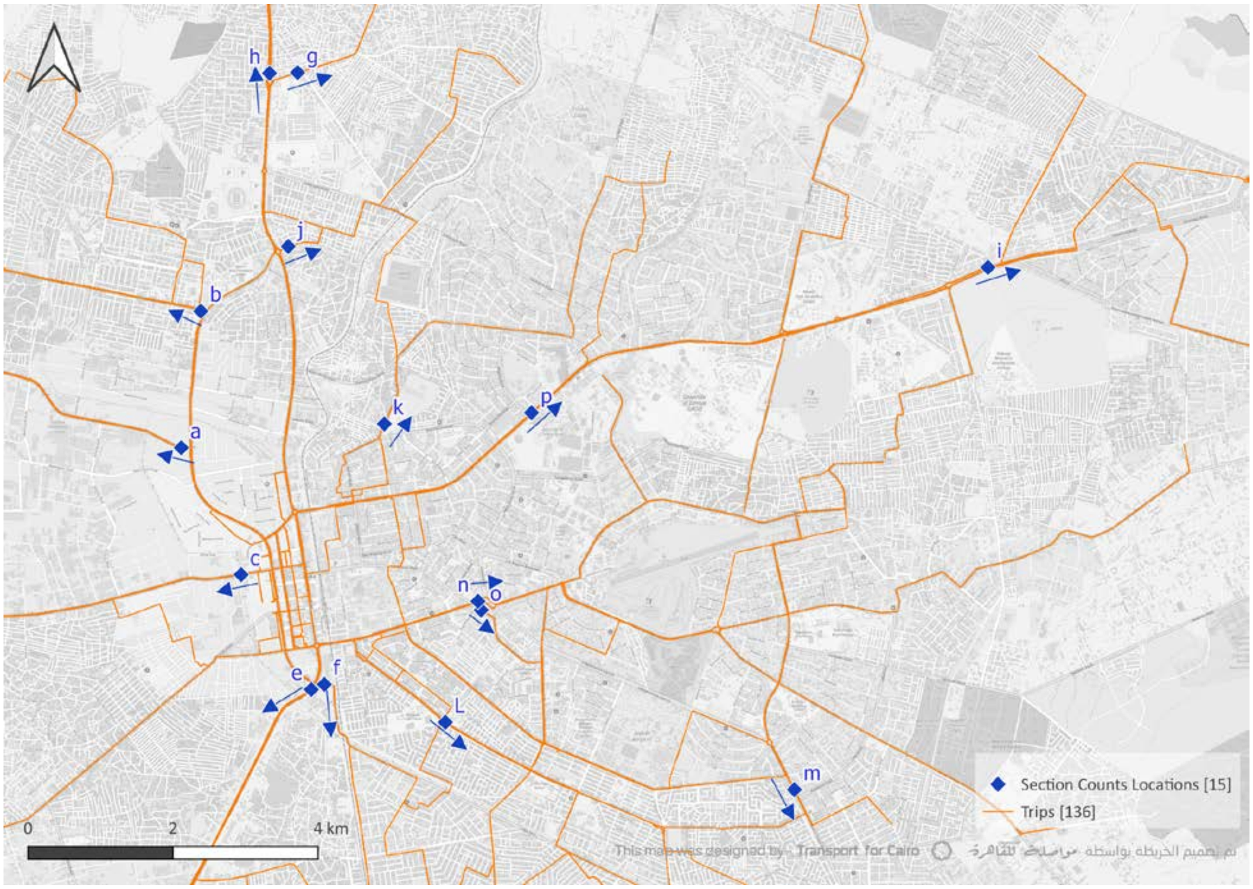


Figure 4-9 Section-counts direction of counting

5.3.2.2 Implementation

A total of 180 surveys were conducted. The duration of one survey session was 20 minutes. 12 surveys were conducted at each of the 15 locations: 6 in the morning peak interval (8:00 – 11:00), and 6 in the morning off-peak interval (11:00 - 15:00). Each FR was assigned a few locations. They were instructed to conduct the 6 surveys per interval back-to-back on the same day, with short breaks in between. Those breaks are necessary to refresh their energy as the survey requires them to stay sharp-eyed for the whole duration of the survey.

Figure 4-10 visualizes all the data collected in section count surveys. Each graph in the figure corresponds to a location from Figure 4-9.

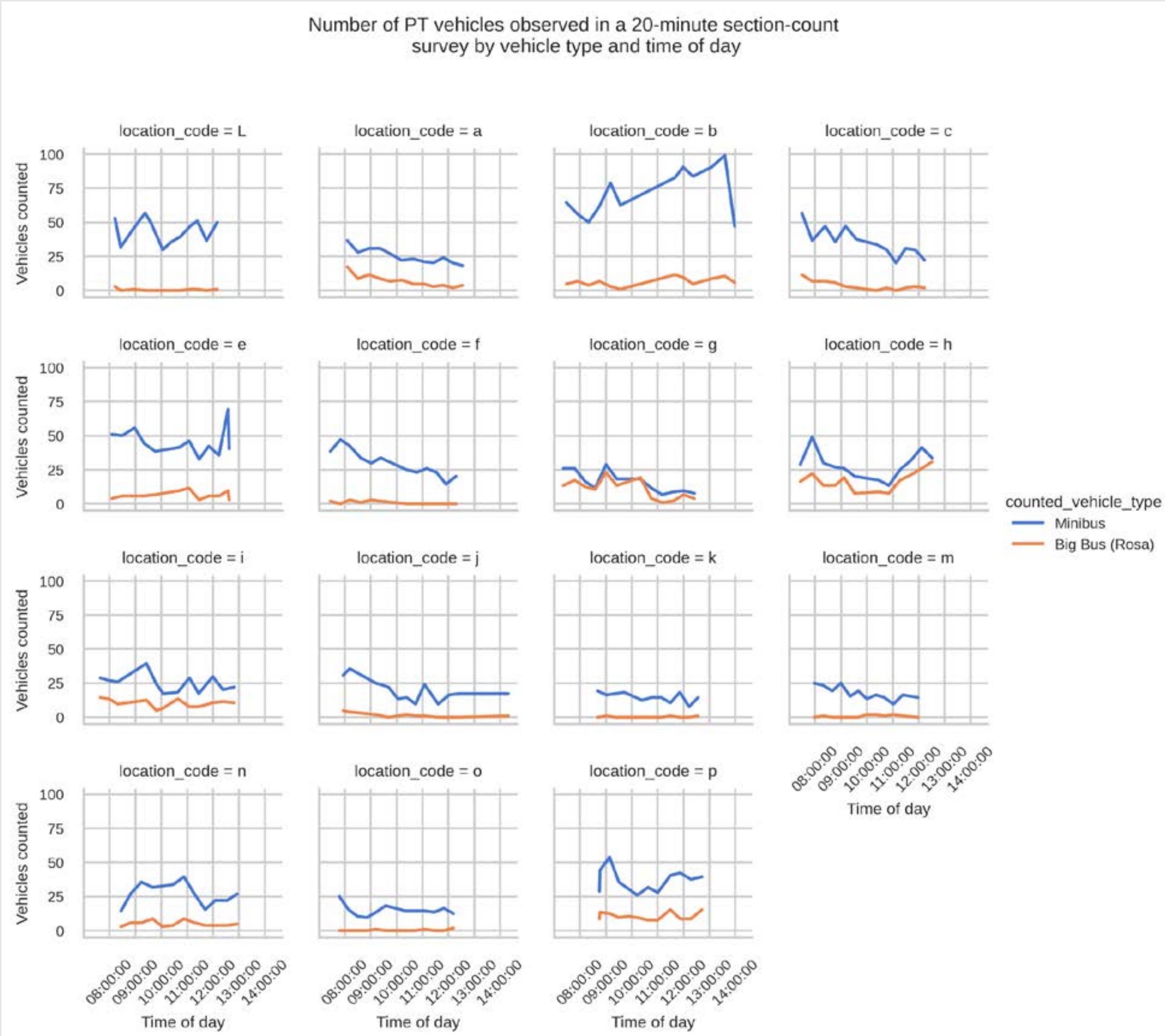


Figure 4-10 Section counts observations across the day

5.3.3 KPIs Management

Several factors affect the management of the mapping activities and the monitoring of the overall efficiency and that for each researcher; some of the factors are quantitative in their nature like number of successful surveys per researcher per day, and this tends to get lower as the project comes near its end as the remaining assignments tends to be hugely dispersed geographically over the city and along the time of day of when they need to be collected, which increase the wasted time daily of chasing the remaining assignments.

Processing data is an intricate part of this process, to judge the validity of the collected surveys and what are the various reasons of invalidity, which includes bad GPS accuracy, circumstantial events as in the cases of the bus breaking down and stopping mid-route, or in rare cases a misjudgment of the researcher when following the field protocol.

Monitoring and management are sometimes qualitative, as some activities are not well numerically represented in the dashboard in its current design state; this is mainly researcher's transportation time between different assignments, and times spent on identifying routes or investigating the peculiarities of some routes. Currently RouteLab tracks the location and time spent for FRs only during performing a survey, while those activities done in-between surveys are communicated manually.

Towards the end of mapping activity, joined tables were used to organize the remaining assignments in a concise list of remaining assignments to forward to the FRs. This is a more manual, targeted approach than the initial approach when more assignments were available.

6 Phase II: Data Quality control and Processing

This section describes the quality control process for managing collected raw data and processing it into outputs in GIS and GTFS formats.

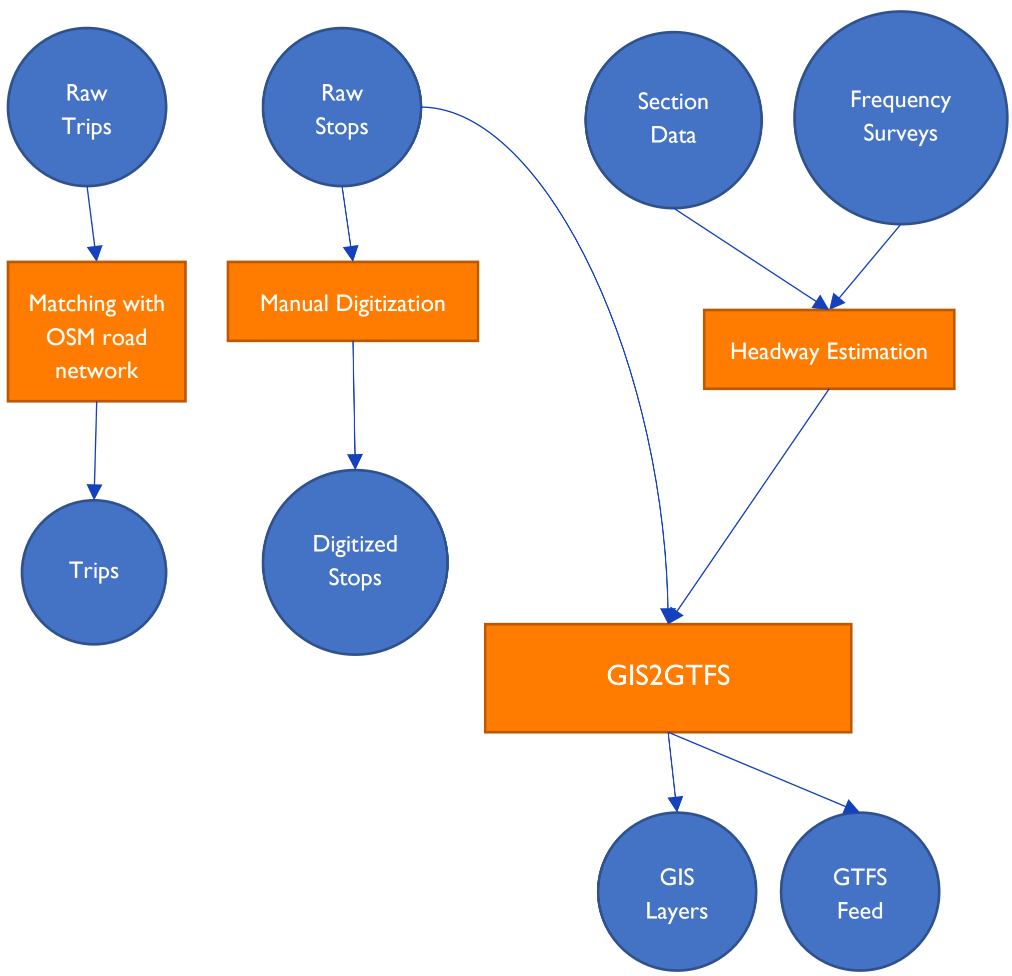


Figure 6-1: Raw data transformation steps

6.1 Map-matching Trips with Road Network

GPS traces from onboard surveys, termed "raw trips" go through a process of manual validation and cleaning. First, the trace is inspected against certain criteria; the GPS trace must (a) match the origin and destination assigned, (b) be readable with as little gaps as possible, and (c) cover the full trip length. Raw trips that don't meet these criteria are deemed invalid and are eliminated from any further processing or cleaning.

Next step is the map-matching of raw trips. Map-matching is the process of snapping the vertices of a GPS trace to a road network. It is required due to GPS errors, which in turn are caused by an array of factors, such as obstructed or weak GPS signal. Map-matching was done using "Snapper", a tool developed by TfC as part of the RouteLab software suite. It offers a user interface for map-matching, backed by the open-source[5] routing and map-matching engine "GraphHopper". GraphHopper is configured to match traces to the road network from OpenStreetMap.

Figure 6-2 shows a screenshot of Snapper in use. The validation and map-matching process, naturally, begins during the mapping activity, as invalid surveys need to be repeated.

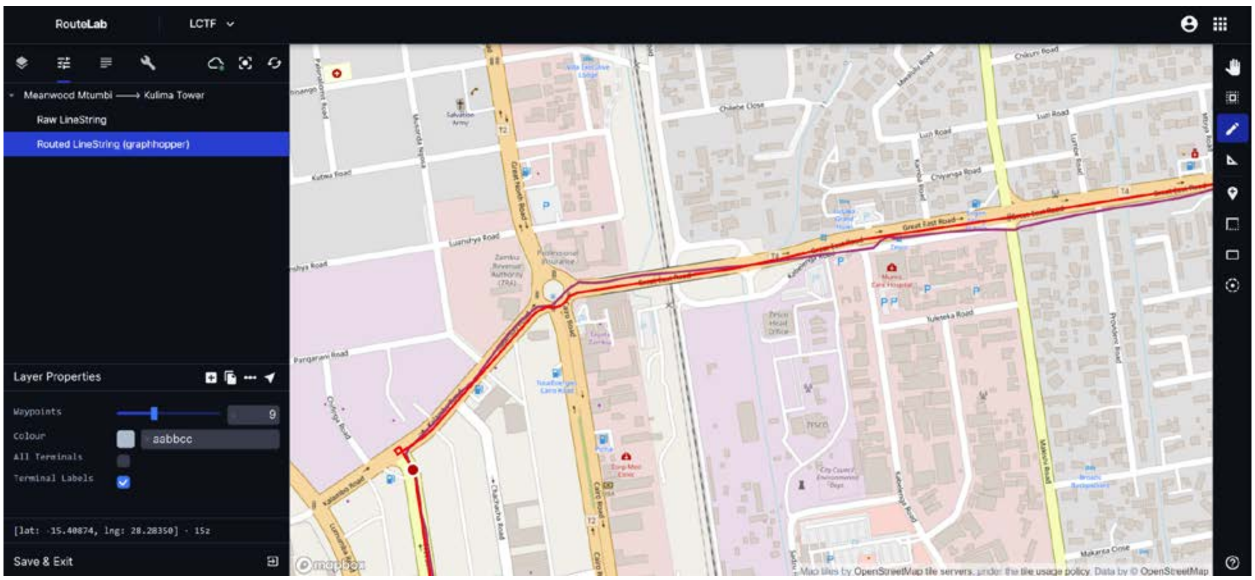


Figure 6-2: Snapper tool in use.

6.2 Stops Digitization

Paratransit services are typically characterised by the absence of a formalized network of stops. They are, however, demand-driven; passengers are allowed to board and alight PT vehicles anywhere along the trip itinerary. On the other hand, the GTFS standard requires the network be defined by a set of stops, which is originally meant to represent formal or built stops in formal transit systems.

Stop digitization is part of TfC's mapping methodology and it's meant to bridge the gap between the two sides mentioned above.

[5] Release under the Apache License 2.0

In this processing step, "raw stops" collected during onboard surveys are consolidated into a *representative* set of stops across the network. Such stops are created to comply with the GTFS specification. The reason that this works well is that raw stops usually form distinct clusters of passenger activity, usually at intersections or entrances of neighborhoods where many people usually board and alight. Such clusters develop as part of local knowledge shared by PT riders and drivers. Mapping raw stops over a large enough sample of onboard surveys could be thought of as reverse engineering this local knowledge.

Stop Digitization is a manual process. Figure 6-3 shows a map of a subset of the raw stops (in green) and processed stops (in red). The output of this processing step is used downstream for (a) GTFS/Routing purposes and (b) spatial analyses such as accessibility analysis.

Every stop created is assigned a location and a name, based on the following approach:

- **Location:**
  - Location of created stops is based on the spatial clusters of raw stops.
  - Stops need to be at least 400 meters apart, with some exceptions in especially dense urban areas.
  - The decision of where to place a stop is made with respect to various factors such as the density of raw stops, proximity between the stops and the passenger activity (boarding/alighting) recorded with raw stops.
  - A stop is mirrored on both sides of the road with the same name. This is necessary for sane routing.
- **Name:**

  Identifying the most frequent name occurring in a cluster is chosen. If no name is identified, the nearest landmark or the team's local knowledge is utilized.

Of 3,343 raw stops received from onboard surveys, a network of 793 virtual stops was created.

Figure 6-3: Green is raw (actual) stops; Red is processed (representative) stops

6.3 Headway Estimation

6.3.1 Initial Approach & Input Data Inspection

In previous mapping projects, TfC's headway estimation method relied only on frequency survey data; headway per route per interval is estimated as the average headway value from the corresponding frequency surveys. Headway from a frequency survey is calculated as the **number of departures divided by survey duration**. Then the average is taken for each trip (trip, not route), which is then clipped at the lower bound of 60 seconds.

In this project, frequency surveys were first validated against the section counts, and a significant gap was found between corresponding numbers in both. For each section count location, the "expected" vehicle count is based on the frequency surveys of the trips that traverse it. Observed numbers of PT vehicles are on average 3x the corresponding expected count.

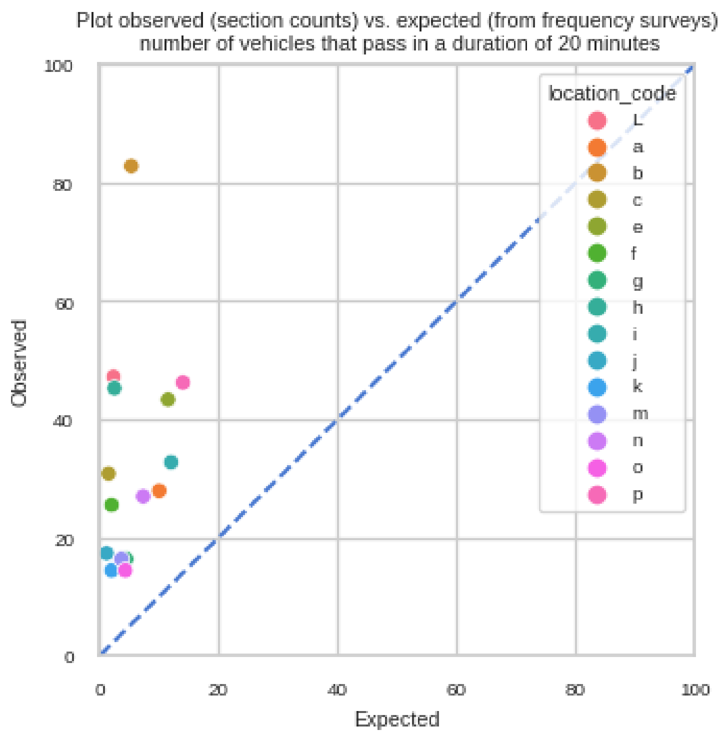


Figure 6-4 Average observed vs. expected PT vehicles counts in by section count location.

Making sense of the gap in Figure 6-4 requires a thorough comparison between both types of surveys. **Frequency surveys** are done at the origin terminal of the route. The FR observes the main queue for vehicles serving the route being surveyed. This entails the assumption of a relatively high degree of formal organization or self-organization in a terminal, where assumption that **all or most** vehicles serving a route would be going through its dedicated queue. The degree to which reality does not match this assumption is the potential source of error in frequency survey data. The said mismatch manifests as either drivers boarding people from places other than the dedicated queues, i.e. disorganization, or as the phenomenon of **pirate taxis** where drivers don't start their trip at the origin terminal as they are supposed to, bypassing queues or fees and picking up passengers near the terminal or along the trip itinerary.

Section counts are conducted at locations along main corridors. They have one advantage and one limitation. Their advantage is that their accuracy is as high as it gets, as they directly measure the desired variable—PT vehicle frequency, which more closely mirrors the end goal of estimating the average headway. However, this accuracy comes with the cost of lower resolution; paratransit vehicles rarely have head-signs or identifiers, so the FR cannot reliably record the route associated with each vehicle passing by. The sources of such information on a passing vehicle are the seldom-found head-signs, or more commonly the driver calling out the destination terminal, which still has uncertainty around whether they are really going to that terminal or maybe they are continuing after that to a farther destination. Such behaviours differ by city.

Based on the comparison, the gap in Figure 6-4 is ascribed to the following:

1. Disorganization in terminals: Multiple boarding spots for the same route exist in the terminals in the city centre. Drivers form spontaneous queues or pick passengers up in the vicinity of the terminals.
2. Pirate Taxi Phenomenon: Minibus drivers bypass the official terminals.

Further field research would be required to investigate the dynamics of those phenomena in more detail.

6.3.2 Final Approach

The final approach for headway estimation primarily used the section counts data. Given the number of routes passing through a section count location, the total observed vehicle count is assumed to belong to those routes, where each route's share corresponds to its frequency survey data. Effectively, numbers from frequency surveys were used as weights. For example, if minibus routes A and B had 10 and 5 observed hourly departures, respectively, and both traverse section count location X, where hourly minibus vehicle count is 30, then the final estimated hourly departures for A and B are 20 and 10 respectively. Hence, estimated headways are 3 minutes and 6 minutes, respectively.

6.4 GTFS Transformation

The output of the data processing step comprises a reduced set of trips and stops that make up the transit network. Using a script "GIS2GTFS", developed by TfC, the data in GIS format is transformed into a valid GTFS feed.

- **Aggregating Temporal Data**

  Onboard survey data include timestamped GPS track points, stop locations and fares. From these inputs, vehicle speeds can be aggregated by time interval. The output layer is termed "commercial speeds".
- **A Virtual Network of Stops**

While GTFS requires a defined set of stops, as explained in 6.2, it also includes the fields "continuous_pickup" and "continuous_dropoff" for the "route" entity, which denote the ability to board or alight anywhere along the trip.

- **Selecting a representative GPS trace for each trip**

  Since multiple onboard surveys are conducted for each trip, some trips exhibit deviations in the itinerary among its onboard surveys. This is expected in a paratransit context. However, the GTFS output represents every trip with a single itinerary. This presents the question of choosing one onboard survey trace that is most representative of the other traces for the same trip.

  The selection is automated. For a given trip, the Fréchet distance[6] is calculated for each pair of onboard surveys. Fréchet distance is a metric that quantifies how similar two linestrings are. Then the average is taken for each onboard survey. The trace that has the highest average is the most similar to the other traces. Said trace is selected as the final geometry for the trip.

- **Stop Times**

  Stop times in a GTFS feed hold order of stops along a trip and the time for each stop. This is also originally meant for schedule-based services. In our case, a trip is associated with every stop from the digitized stops dataset that it spatially passes by. Stop times are *estimated* from the "commercial speeds" layer mentioned in .

  Following from the previous point, the method that we use to create the "Stop Times" is to spatially join the stops and trip geometries. The stops are ordered based on the spatial order, and duration between stop pairs are aggregated from raw track points.

6.5 Outputs

Table 6-1 Index of Datasets

Survey	**Dataset**	Description	# Of Features	Attributes Included
Identification	Identified Routes	Point location of bus queues operating on a specific route, parked within a terminal	67	• Origin Terminal • Destination Terminal • Service Mode
	Terminals	Bus terminals (Stations), any point of origin or destination for bus routes	50	• Name • Raw trip ID
Onboard	Track Points	GPS points for the tracked route	164,041	• Timestamp
	Raw Stops	Point location of boarding and alighting throughout onboard surveys	3,343	• Number of passengers boarding/alighting, disaggregated by gender • Timestamp

[6] https://en.wikipedia.org/wiki/Fr%C3%A9chet_distance

	Raw Trips	Linestring representation of an onboard survey trace	417	• Origin terminal name • Destination terminal name • Time interval • Route main bus type • Timestamps for vehicle's boarding time, departure, and arrival at destination • Trip Fare • Origin, destination, and trip safety
	Processed Trips	Cleaned routes itinerary	136	• Origin • Destination • Direction • Bus Type (Vehicle name) • Fare • Length (km)
	Processed Stops	Manually digitized stops, based on locations of regular boarding and alighting	793	• Name
Frequency	Frequency Instances	Point location of a finished frequency survey	216 hours	• Average headway • Trip origin and destination • Survey creation time and finish
	Frequency Observations	Records of every vehicle's departure for a specific route observed during a survey		• Timestamp of departure • Average passenger load
Section Counts	Section Counts	Point location of a section count survey; the counts were for the main vehicle types heading in the outward direction from town.	60 hours of section count surveys, distributed on 15 points	• End time of counting session • Count of vehicles passing disaggregated by mode: private car / taxi, Minibus, Big bus (Rosa-Coaster)
NA	GTFS	General Transit Feed Specification, based on cleaned data from surveys. Uses raw data to get travel time and headway estimates		
Grid Analysis	H3-hex-res8	An abstraction of the Greater Lusaka into Hexagons, based on H3 hex grid[7] (resolution 8). It contains information on		• Population • Population Accessible in 60min

[7] https://h3geo.org/

		travel demand, GHG emissions, and population per grid unit.		• Boarding and alighting disaggregated by gender • CO2 daily avg emissions • PM10 daily avg emissions • NOX daily avg emissions

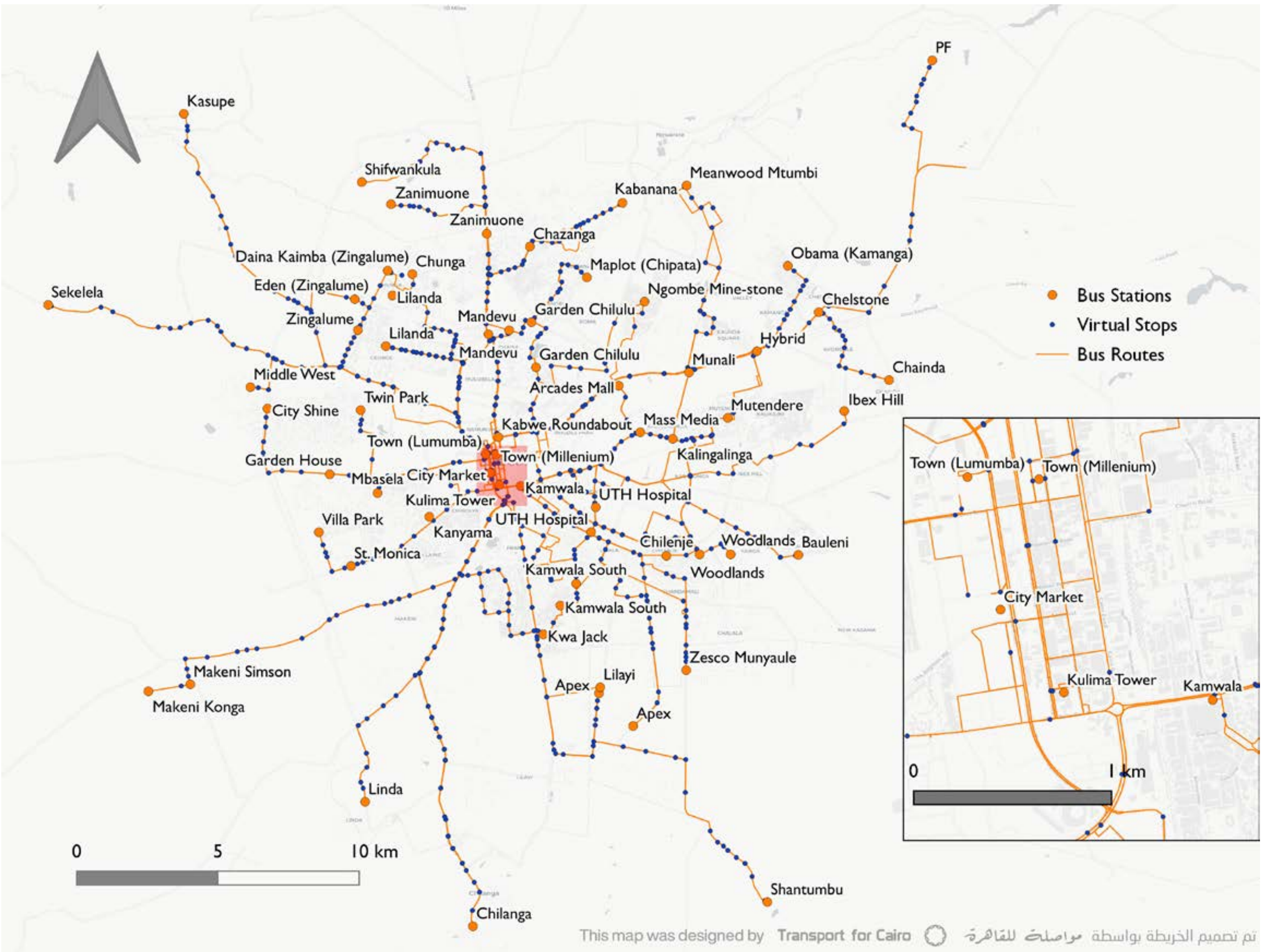


Figure 6-5 A geographic map of Lusaka PT Network

7 Phase III: Data Analysis

The data collection and processing outputs comprise raw data and GTFS. This section presents several network-level analyses that leverage the detailed data collected with RouteLab.

7.1 Passenger Activity

7.1.1 Daily Passenger Activity

When visualized on the network level, the "raw stops" dataset shows the bigger picture of passenger demand across the network, i.e. where do passenger board or alight PT.

Figure 6-6 is a visualization of all the raw stops recorded across the data collection project. This visualization shows the spatial distribution of passenger activity. It can also be observed that boarding activity is more concentrated near or at terminals, while alighting activity is more spatially distributed throughout the network. This suggests that most passengers use the minibuses as "local" and not as express services.

Passenger activity is a proxy for, but not equivalent to, demand for public transit. This is because the spatial distribution of raw stops captured by the mapping activity is influenced by the existing transit network, latent demand wouldn't be fully captured. In PT networks with fast demand-driven feedback loops however, the network adjusts to latent demand, and passenger activity is then a "close" representation of demand.

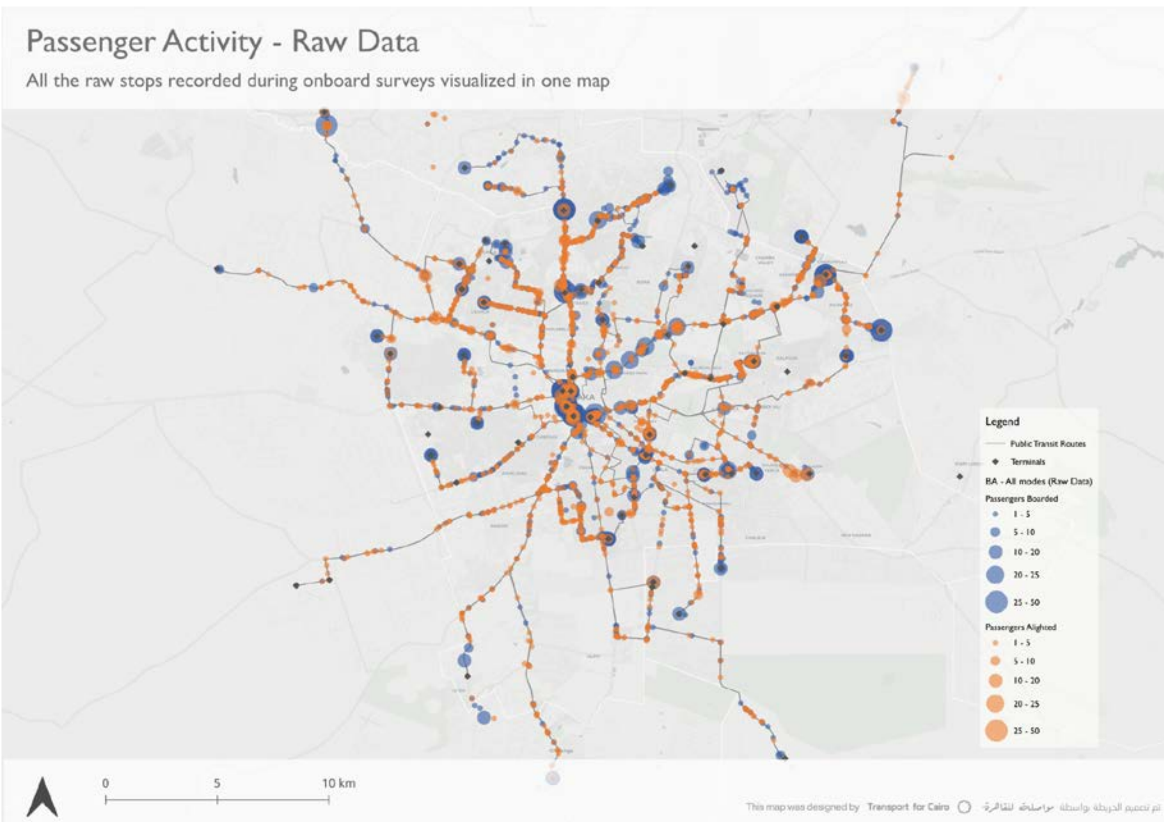


Figure 6-6 Map of passenger activity raw data

When looking at network level percentage of male-female demand, there is almost an even split where 53% percent of recorded boardings were females and the rest males. Aggregating boarding counts by gender on a township level, however, shows some spatial nuances.

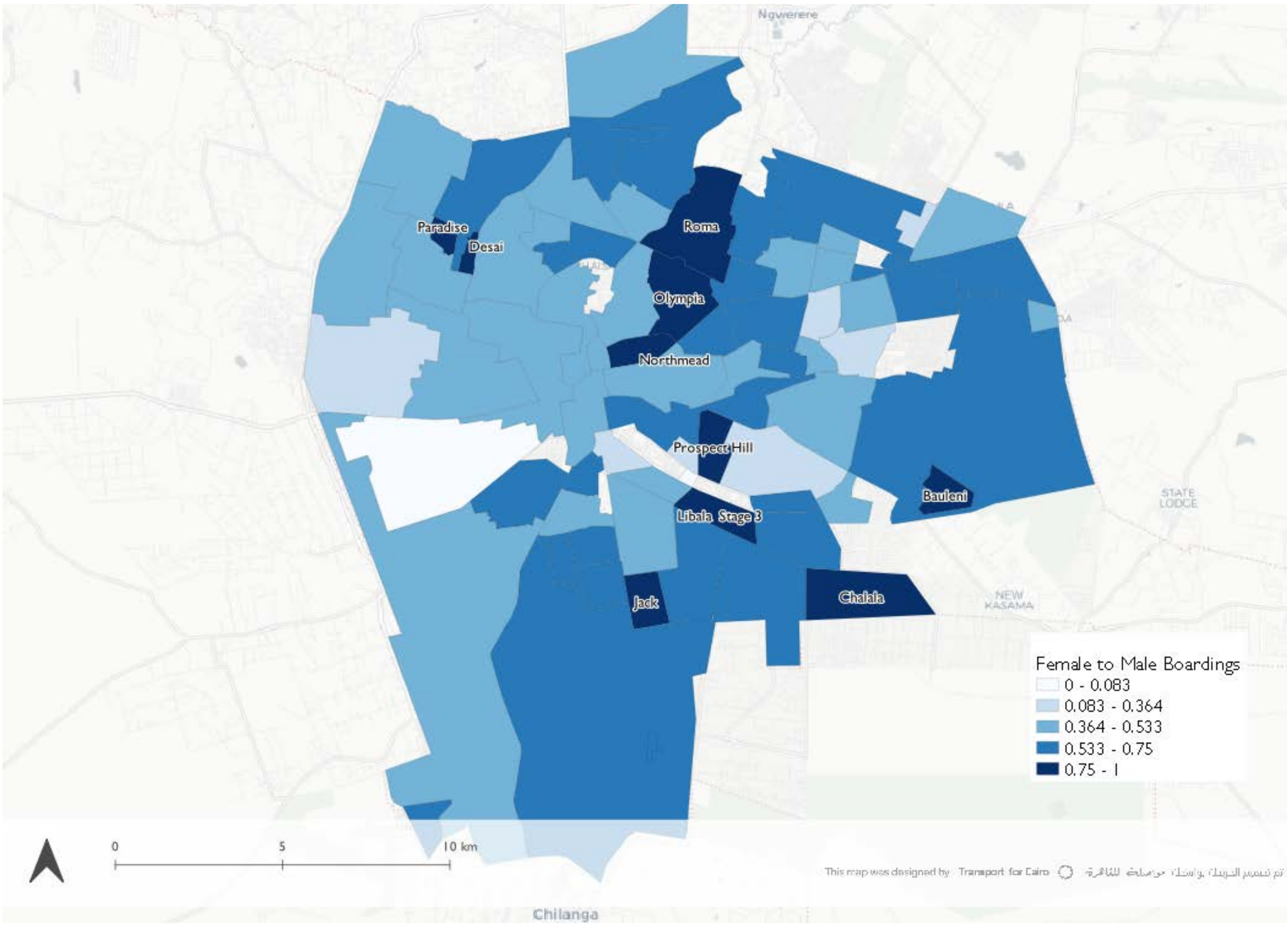


Figure 6-8: Female to Male ratio of boardings from Onboard survey data

Amongst the highest townships with measured boardings of female passengers were: Chalala, Prospect Hill, Roma, Olympia, and Northmead.

Most of those townships are dominated by commercial activities and can be considered upper-scale neighbourhoods. As Figure 6-9 shows, a zoom-in on the satellite imagery of Roma, Olympia and Northmead townships show the clear distinction between the zoning and planning of said townships and the surrounding residential townships such as Ngombe, Garden and Chipata.

The notion that perceived female ridership is higher in commercial and upper-scale neighborhood can be supported by the Zambia Labor Force

Occupation	Total		
	Both Sexes	Male	Female
	Number	Percent	Percent
Total	**3,164,748**	**60.5**	**39.5**
Managers	193,010	56.7	43.3
Professionals	258,542	55.9	44.1
Technician and Associated professionals	157,005	60.1	39.9
Clerical support workers	50,887	57.9	42.1
Service and sales workers	942,434	42.5	57.5
Skilled agriculture and forestry workers	461,392	63.2	36.8
Craft and related trade workers	332,357	85.3	14.7
Plant and machine operators and assemblers	177,785	95.8	4.2

Figure 6-7: Male-Female workforce by employment category, Zambia LFS 2021

Survey[8] that shows most females in the workforce work in the service and sales sector, followed by management and professional services.

It is worth noting that this phenomena is not a general trend. There are other twonships with significant female to male boardings ratio which have different characterstics to the ones mentioned, such as: Bauleni and Jack which are considered "informal" settlements with most of residents working in the informal economy[9].

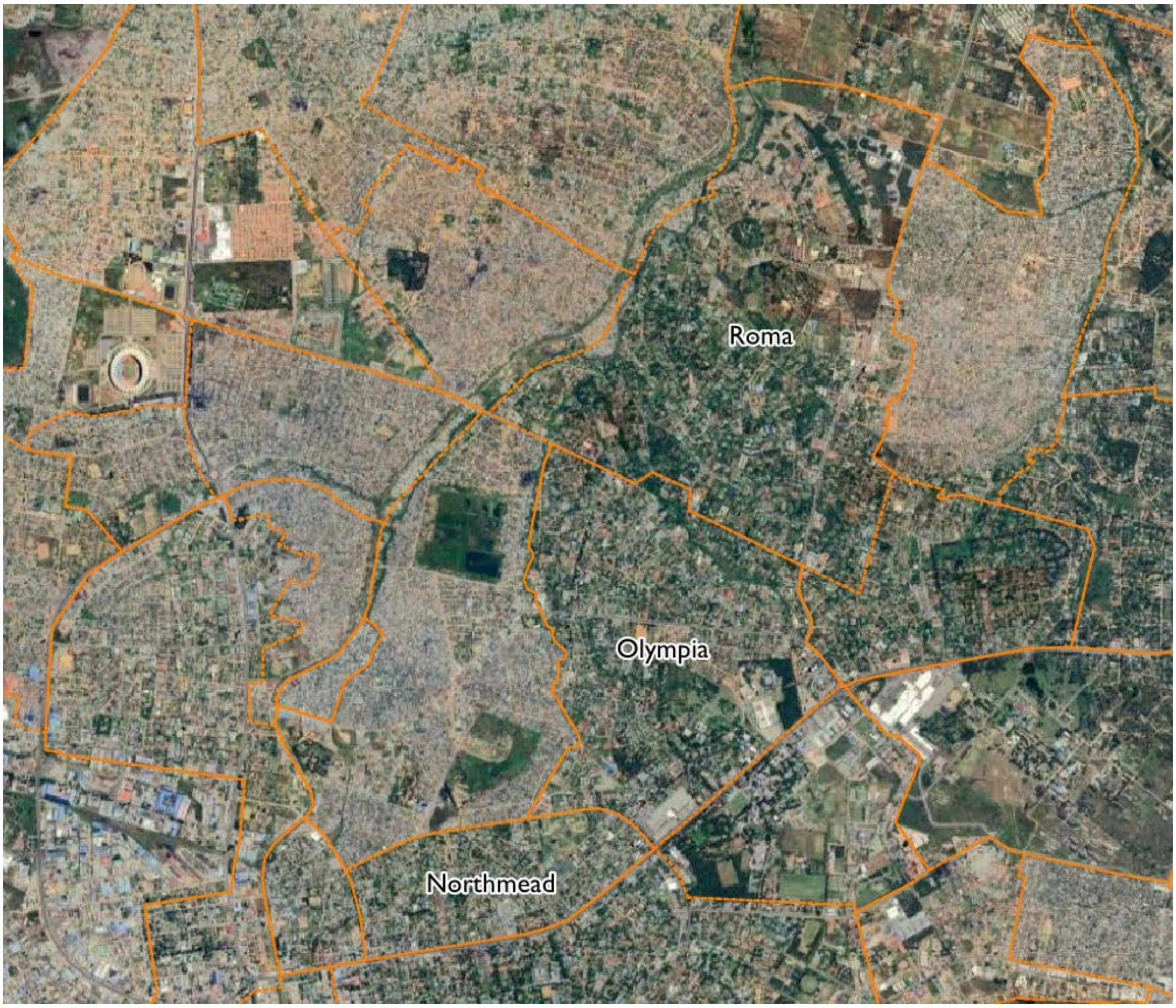


Figure 6-9: Roma-Olympia-Northmead townships

Data collected from onboard surveys is observational, meaning the focus is on the "effect" and there is the need to look at the "cause". In the case of demand data, this means that the measured female-male demand ratios do not accurately reflect females' latent demand. Women's accessibility to PT -or lack of- must severely affect measured demand data.

[8] https://www.zamstats.gov.zm/wp-content/uploads/2023/05/2021-Labour-Force-Survey-NHPP.pdf

[9] https://www.frontiersin.org/articles/10.3389/frsc.2023.922419/full

One example of male dominated boardings is Kanyana township, the most populus township in Lusaka. Kanyama is characterized by low access to utilities, high population density, and vulnerability to flooding given it topographically falls in Lusaka's lowlands[10]. These conditions therefore must disable women's access to (a) spending on transit (b) walking to and from transport services due to poor NMT infrastructure and the occasional floodings, and (c) workforce and education.

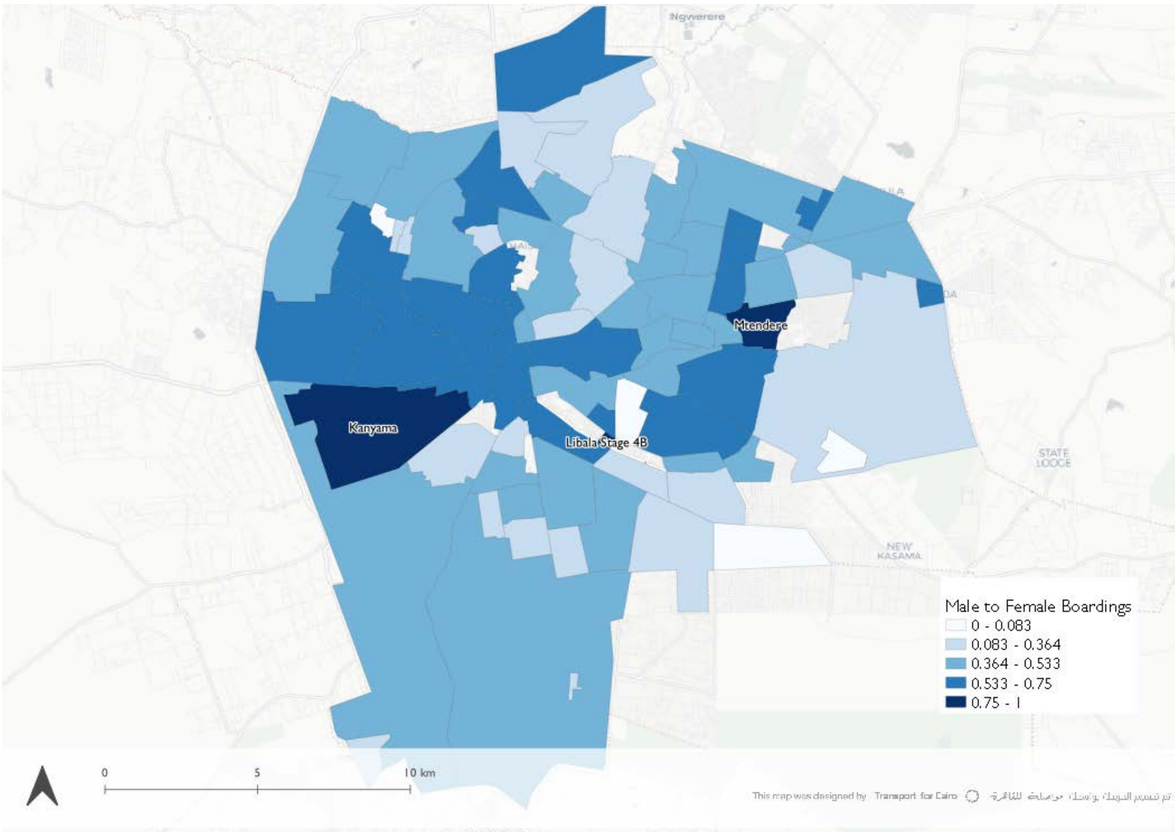


Figure 6-10: Male to Female ratio of boardings from Onboard survey data

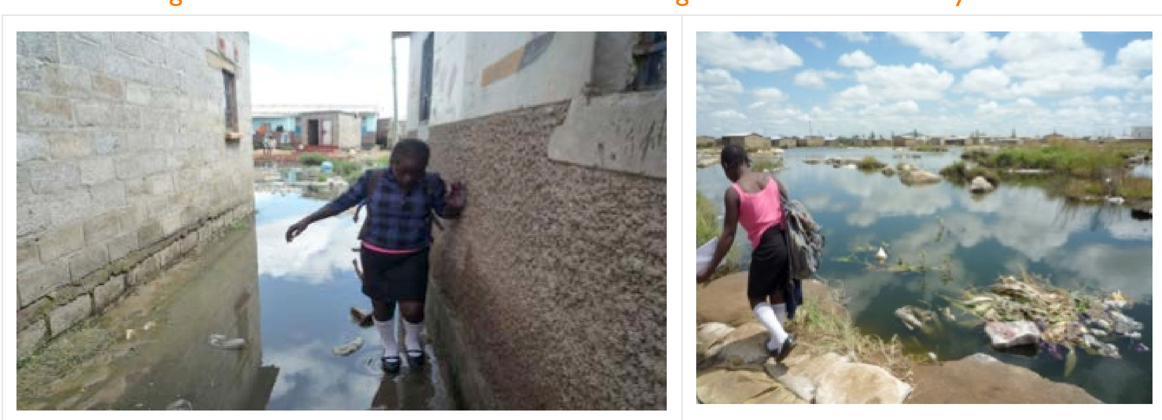


Figure 6-11: A schoolgirl from Kanyama's daily trip to school, "Me and my world" DevelopmentEducation.ie Blog

[10] https://saipar.org/wp-content/uploads/2021/11/WaterAid-Final-Paper-2.pdf

7.1.2 Hourly Passenger Activity

This section explores spatiotemporal patterns from the passenger activity captured in onboard surveys. Figure 6-12 visualizes the spatial distribution of boarding and alighting activity over 3-hour intervals from 08:00 to 20:00. During the data collection, no onboard surveys were started later than 18:00.

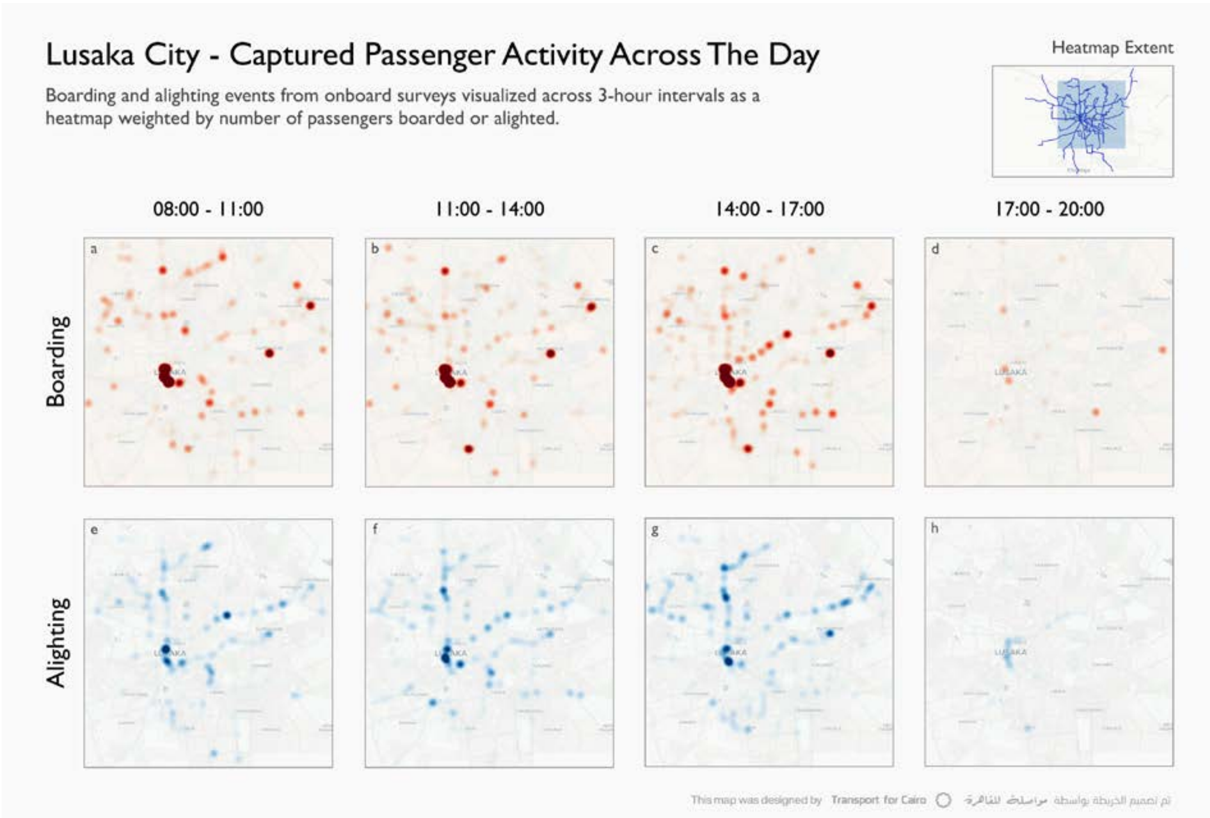


Figure 6-12: Passenger activity heatmaps across the day

Key observations from temporal disaggregation of passenger activity are as follows:

- **Extremely busy city center:** Figure 6-12 reiterates the highlight observation from the data; the activity in the city centre terminals is disproportionately higher than other locations. The star-shaped topology of the road and transit network, as explained later in section 7.2, results in passengers going from any part of the city to another having to make a transfer at one of the terminals in the city centre.
- **Afternoon boarding activity on East Road:** Sub-figure (c) in Figure 6-12 shows a significant cluster of hotspots northeastern of the centre, the largest of which is at the University of Zambia. A similar hotspot at the university also shows in the morning interval alighting activity in sub-figure (e). This point along East Road exhibits the second highest passenger activity in the city centre after the Central Business District (CBD).

7.2 Vehicles & Passenger Flows

Spatial aggregation of onboard survey data can produce several network-level datasets.

Firstly, commercial speeds can be estimated from GPS traces. Figure 6-13 visualizes the estimated PT commercial speeds from raw data in the morning peak period. Average speed on most roads is between 20 and 30 km/hr. Another city previously mapped by TfC, Alexandria, Egypt, had average commercial speeds falling mostly between 10 and 30 km/hr[11]. However, Alexandria has far more traffic congestion.

The outer edges of Lusaka -where trips are starting or ending- have the lowest commercial speed profiles, this is to be expected given drivers are not loading passengers from a designated terminal as is the case with downtown, but rather continuously picking up passengers along the way or pausing to wait for potential passengers to pass by.

It is therefore a priority for decision makers to examine these segments and deduce whether the low-speed profile is stemming from overall traffic congestion -less likely in the outskirts of rural Lusaka- or if the loading and offloading mechanism of minibuses on those segments can be improved to be more efficient for the road traffic flow and for the passengers themselves.

The allocation of designated terminals at destinations outside of downtown is a priority. The demand data along with the commercial speed segments data answers the question of "where" it would be be best to place said terminals. It is necessary in some cases to have an adequate set of interventions to compliment the terminals allocation such as the improvement of NMT infrastructure conditions surrounding the area and/or the concession of last-mile feeders between terminals and the nearby towns and compounds.

[11] Digital Transport for Africa: Mapping Alexandria, https://transportforcairo.com/wp-content/uploads/2023/09/WRI-TfC-DT4A_Alex_FinalReport_V2-1.pdf

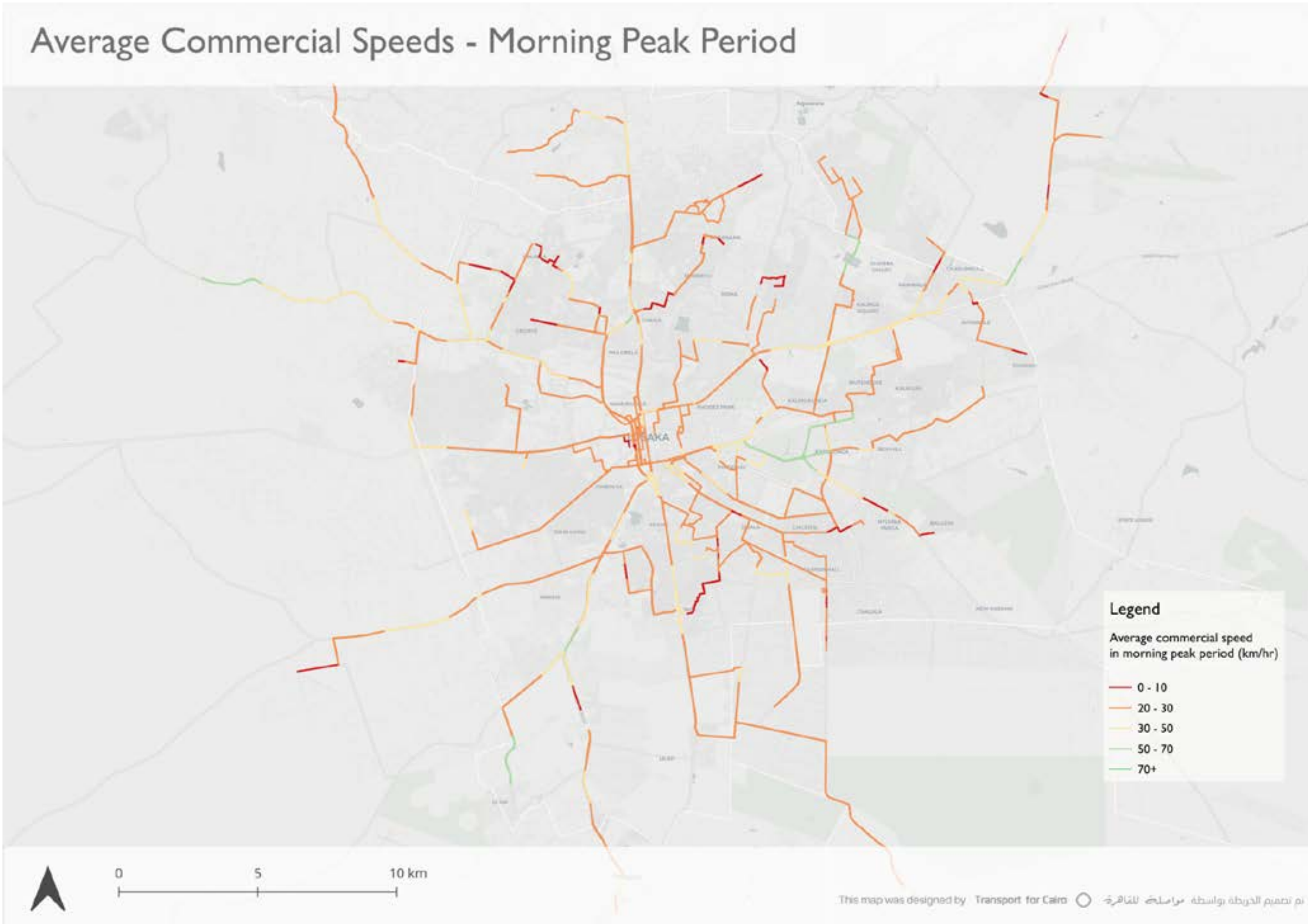


Figure 6-13: Average PT commercial speeds - Morning peak period

Passenger flow per network link is also estimated from onboard survey data. Figure 6-14 visualizes that for just the morning peak period. This estimation pipeline combines onboard survey data and frequency survey data. Vehicle occupancy is calculated from onboard survey data, then it is multiplied by a factor based on the estimated headway of the corresponding trip to reach the total passenger flow estimate for a given time period.

The star-shaped topology of the road network in Lusaka City can be clearly observed, with a huge emphasis on town as the obvious central hub. The Northern part of the network is observed to have three significant arterials namely: Great East, Great North and Lumamba roads, However the south-eastern section shows better horizontal coverage.

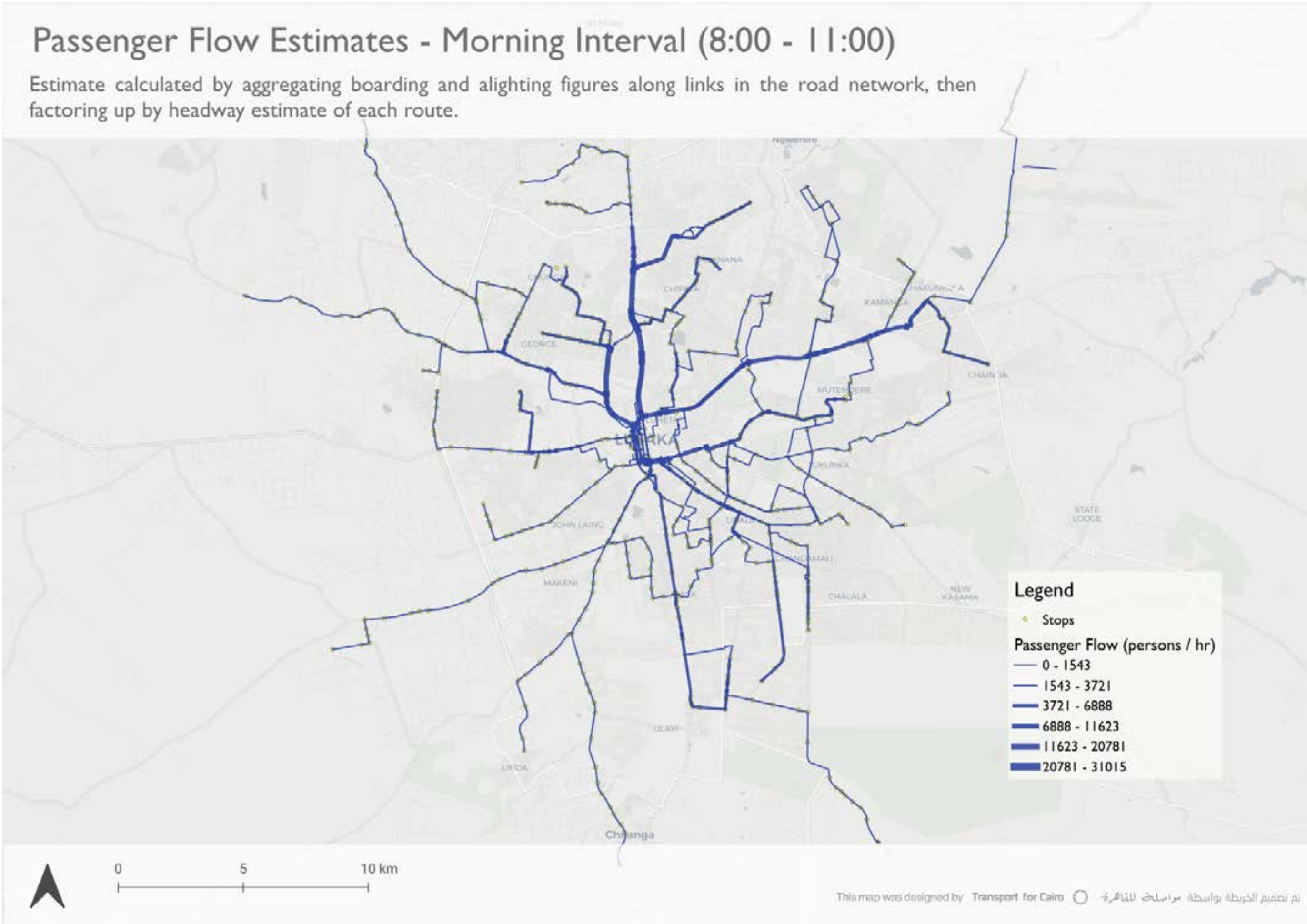


Figure 6-14: Passenger flow estimates - Morning peak period

7.3 Network Efficiency

Lusaka's radial network is highly inefficient. Measuring cumulative opportunity index[12] for population within a 60-minute interval shows average access to **5%** of the city's population. This means that if you're a citizen of Lusaka using public transport and walking for a total trip duration of 60 minutes, depending on where you're starting your trip, you are most likely not able to reach more than **5%** of the city's total population.

GTFS and road network data are used to create isochrones for 60-minute trips, and an H3 hexagon grid, resolution eight, is used to provide trips start points from each hexagon's centre. This uniform grid allows to aggregate both the population living within and the percentage of population accessible per hexagon. The following formula explains the average accessible population calculation:

[12] El-Geneidy, A., and David Levinson. 2021. "Making Accessibility Work in Practice." Transport Reviews. https://doi.org/10.1080/01441647.2021.1975954.

$$(ap_i * p_i)/\sum p$$

$\boldsymbol{ap_i} = \textit{Percentage of population accessible from origin hexagon } i$

$\boldsymbol{p_j} \quad = \textit{Population living within hexagon } i$

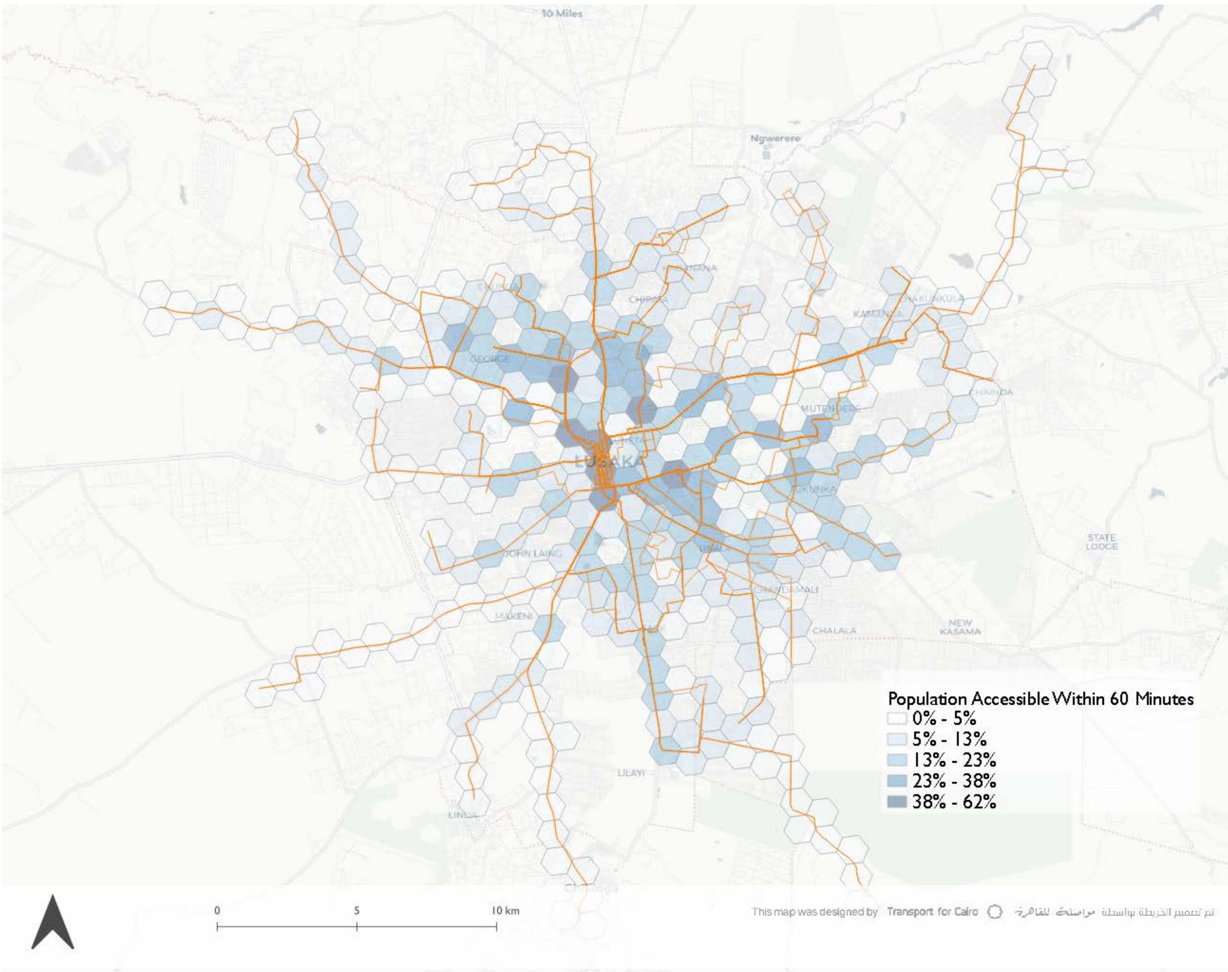


Figure 6-15: Accessible Population within 60 minutes using Public Transport and Walking

To put the "reachable population" metric into the wider context; The European commission publication "How many people can you reach by public transport, bicycle, or on foot in European Cities?"[13], albeit using a slightly different methodology, shows the city with lowest average access to population using public transport, cycling, and walking is Athina with around 32% of population accessible within a 45-minute interval. This is still much higher than Lusaka's 5% in a 60-minute interval.

[13] https://ec.europa.eu/regional_policy/sources/work/012020_low_carbon_urban.pdf

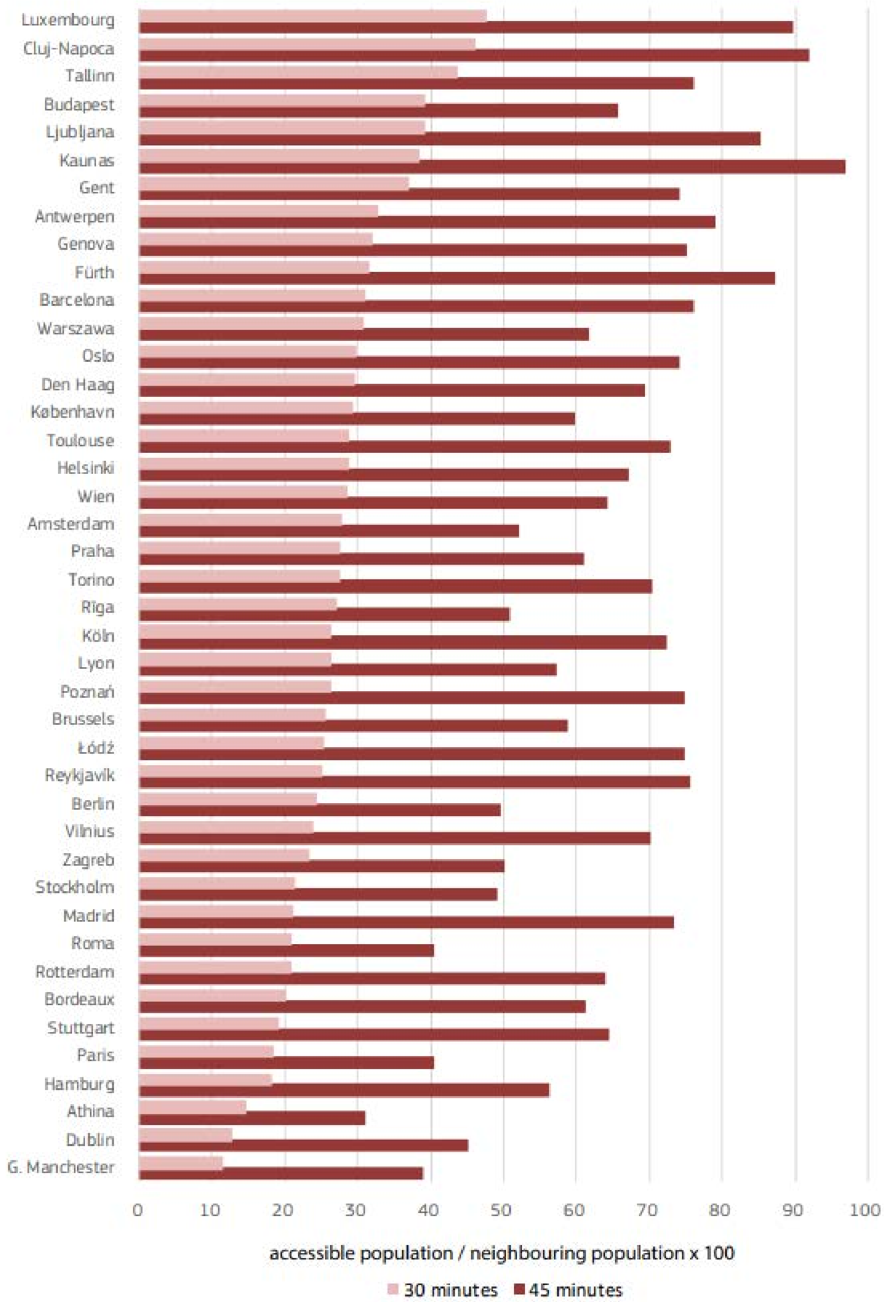
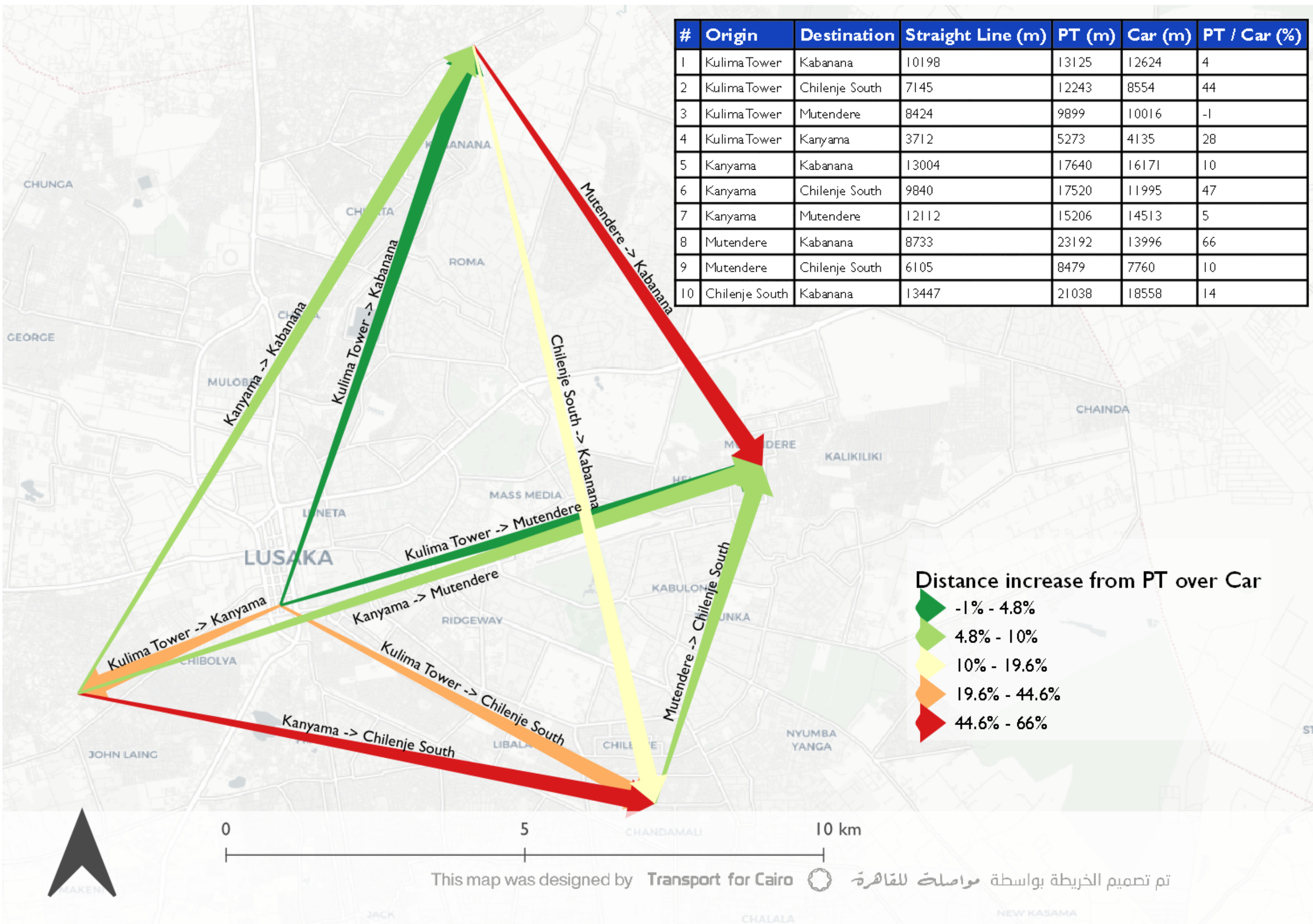


Figure 6-16: Public transport performance within 30 and 45 minutes, source: European Commission

Access to population is not the only metric of efficiency for a PT network, as the city's distribution of residential zoning plays a role as well as the focus of PT services which may be more efficient in providing accessibility for other purposes such as employment opportunities.

Travel distance is compared for itineraries between a set of origins and destinations using (a) Public transit + walking and (b) private car. This comparison is made to discern how efficient the PT route design is compared to the door-to-door service of a private car.

The matrix was constructed between points on the outskirts of Lusaka, with relatively high population density, and Kulima Tower in downtown. Given the network's radial structure, and the problem of exchanging routes only at city centre, the inefficiency of PT compared to private car is exacerbated between OD pairs on the outskirts. Prime examples are "Mutendere → Kbanana" and "Kanyama → Chilenje South" where PT travel distance is 65% and 47% increased from private car respectively.



#	Origin	Destination	Straight Line (m)	PT (m)	Car (m)	PT / Car (%)
1	Kulima Tower	Kabanana	10198	13125	12624	4
2	Kulima Tower	Chilenje South	7145	12243	8554	44
3	Kulima Tower	Mutendere	8424	9899	10016	-1
4	Kulima Tower	Kanyama	3712	5273	4135	28
5	Kanyama	Kabanana	13004	17640	16171	10
6	Kanyama	Chilenje South	9840	17520	11995	47
7	Kanyama	Mutendere	12112	15206	14513	5
8	Mutendere	Kabanana	8733	23192	13996	66
9	Mutendere	Chilenje South	6105	8479	7760	10
10	Chilenje South	Kabanana	13447	21038	18558	14

Figure 6-17: PT vs Private Car travel

Ideally this comparison would be measured in travel time, however the lack of traffic congestion data gives unfair advantage to the private car mode estimations over the PT travel time estimations from the GTFS, which incorporated actual commercial speeds from onboard surveys.

The geographic distribution of origins and destination pairs highlights the centrality problem of the PT network and the lack of connections between points on the outside of downtown. For example, there is only 5% distance increase between "Kanyama → Mutendere" because it's a **straight** itinerary between east and west, passing through downtown, which would make the geographic itinerary of the PT routes and car similar. However, when trying to go from **north to west** (Mutendere → Kabanana) or **east to south** (Kanyama → Chilenje South) the gap in distance between PT and car widens. That is because the road network allowed the car to go directly whereas PT forces the passenger to go up towards downtown to exchange routes before continuing to destination.

This type of analysis, validated with a comprehensive passenger OD survey, should be able to direct the decision makers to the concession of **direct routes** between **prioritised** OD pairs.

7.4 PT Fleet Characteristics

RTSA provided a detailed dataset of all public service vehicles (PSV) registered to operate in Lusaka City, with the following fields:

- Model year
- Brand
- License start date
- License end date
- Fuel type
- Seating Capacity
- Type of license (e.g. Local routes, Intercity routes)

The dataset included 6191 vehicles in total. Figure 6-18 shows that, according to the dataset, each type of vehicle is on licensed to serve one category of routes. On the other hand, the mapping exercise shows that minibuses operate on peri-urban routes and Rosas on local routes. Figure 6-19 visualizes the distribution of model year in the dataset. 80% of the registered PSVs are from 2004 or older.

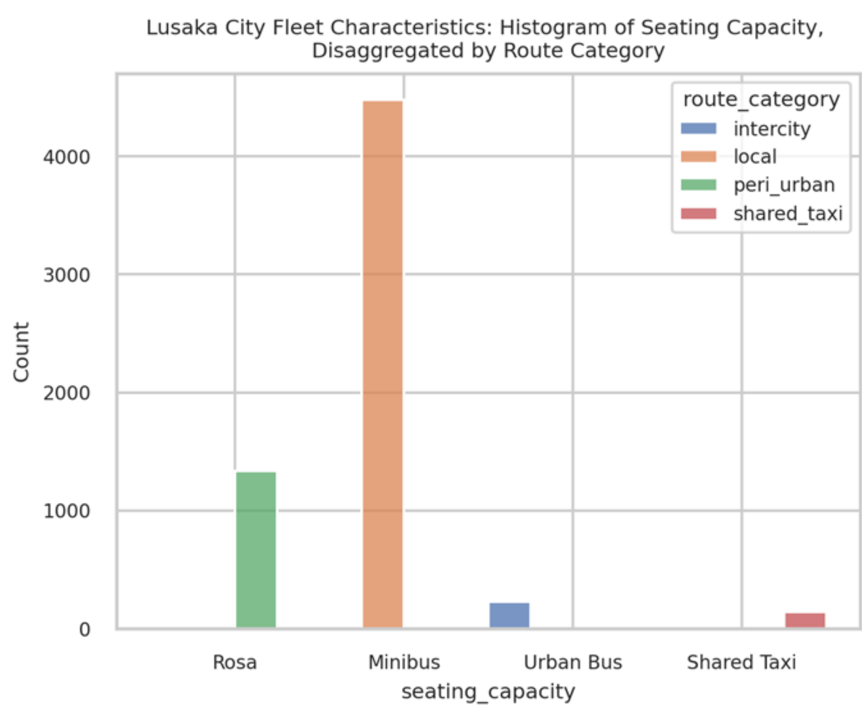


Figure 6-18 Histogram of seating capacity, disaggregated by route category

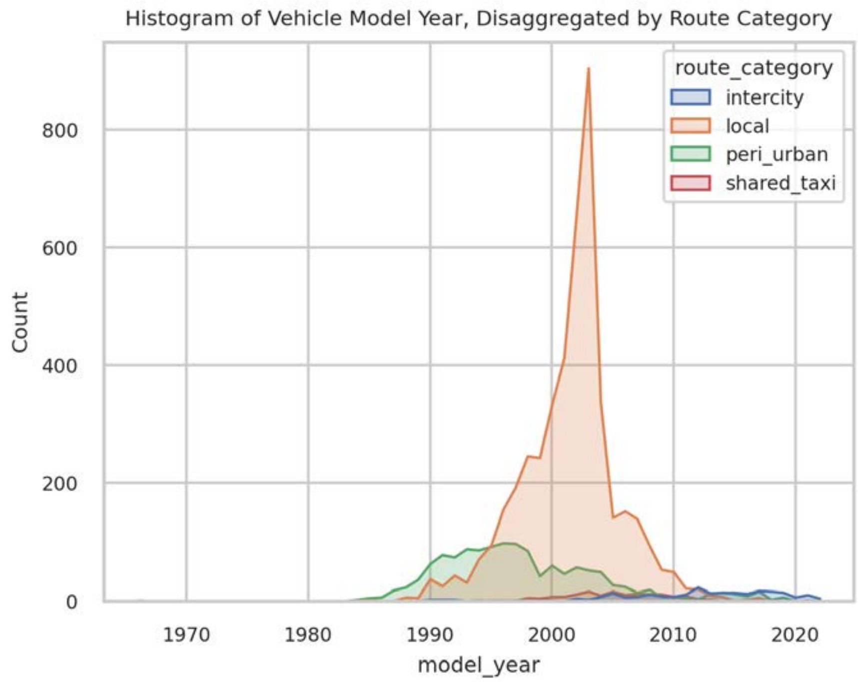


Figure 6-19 Histogram of vehicle model year, disaggregated by route category

The fleet data available can be cross compared with license plate identification mechanisms from existing installed traffic systems[14] to monitor which vehicles traverse which corridors and whether those instances match their pre-designated route category. Also, closer consultation with station managers is needed to (a) get data on actual departures per route and (b) understand the needs of drivers operating on a different route category, or vehicles that are unlicensed to dig behind the reasons of the violations observed during the field research.

7.5 GHG Emissions Model from PT

7.5.1 Methodology

The gtfs2emis[15] bottom-up approach is used. Its inputs are:

1. GTFS feed
2. PT fleet characteristics dataset, which includes vehicle profiles (model year, euro stage, fuel type) and their share in the total fleet.

Table 6-2 shows a few rows from the PT fleet characteristics dataset used in the model. The "size" column is the size of the group of vehicles with a certain profile. The 6191 vehicles in the original fleet dataset, analysed in 7.4, were filtered down to **5064 vehicles** whose operating end date is later than June 2023 and are licensed for run local routes, peri-urban routes, or shared taxi routes.

[14] https://www.znbc.co.zm/news/rtsa-installs-speed-camera-on-seven-lusaka-roads/

[15] Bazzo Vieira, João P., Rafael H. M. Pereira, and Pedro R. Andrade. 2022. "Estimating Public Transport Emissions from General Transit Feed Specification Data." OSF Preprints. November 2. doi:10.31219/osf.io/8m2cy.

Table 6-2: Extract from the PT fleet characteristics dataset

	model_year	seating_capacity	fuel_type	size
0	1984	18_to_30	Diesel	2
1	1985	18_to_30	Diesel	3
2	1985	7_to_18	Diesel	1
3	1986	18_to_30	Diesel	6

The method comprises the following steps:

1. The GTFS to convert to a "**transport model**" i.e., synthetic GPS traces. The transport model includes every segment traversed by any trip throughout the day, with the distance and speed calculated from the GTFS.
2. Estimate emissions per segment by multiplying its length by the corresponding **emission factor,** which is the emitted mass of a pollutant per kilometre travelled at a specific speed, vehicle weight and fuel type.

The gtfs2emis package includes emission factors[16] from the CETESB (The Environmental Company of Sao Paulo) model and the EMEP model by the European Environmental Agency. The former has factors for minibus taxis, but factors are not speed-dependent, while the latter has speed-dependent factors. The package offers a hybrid model that first applies emission factors from CETESB, then scales them by factors from EMEP.

The current implementation of gtfs2emis calculates the emissions factor per segment as the weighted sum of the emission factors from the whole fleet. Effectively, this approach samples a vehicle profile per segment. However, our approach changed that to sampling a vehicle profile *per trip*. 7.5.2 explains implementation details. The vehicle profile, and consequently the emission factor, assigned to every synthetic trip is selected by weighted sampling from the fleet dataset.

7.5.2 Implementation

The implementation utilizes the R package gtfs2emis[17]. The package documentation includes illustrative examples.

The pipeline steps can be summarized as follows:

1. Run gtfs2emis with GTFS and fleet characteristics data, to get the emission factor per trip segment per vehicle profile.
2. For each trip in the output of step 1, randomly sample a vehicle profile and assign it to all the segments of the trip.

[16] https://ipeagit.github.io/gtfs2emis/#emission-factor-models-and-pollutants-available

[17] Vieira, J. P. B., Pereira, R. H. M., & Andrade, P. R. (2022). Estimating public transport emissions from GTFS data with gtfs2emis

3. Multiply segment's length by its sampled emission factor to get GHG emissions estimate.
4. Repeat steps 2 and 3 100 times with different random seed values-- a Monte Carlo simulation[18], and take the average for every trip segment.

The pipeline above is executed for three types of pollutants, namely **CO2**, **NOx** and **PM10**.

7.5.3 Findings

Figure 6-20 shows the total estimated CO2 for the 100 runs, with an average value of 225.17 tons.

The transport model had a total of 29,970 trips from 08:00am to 07:00pm. Given there are 5,064 officially registered PSVs, this means 5.6 trips per vehicle per day.

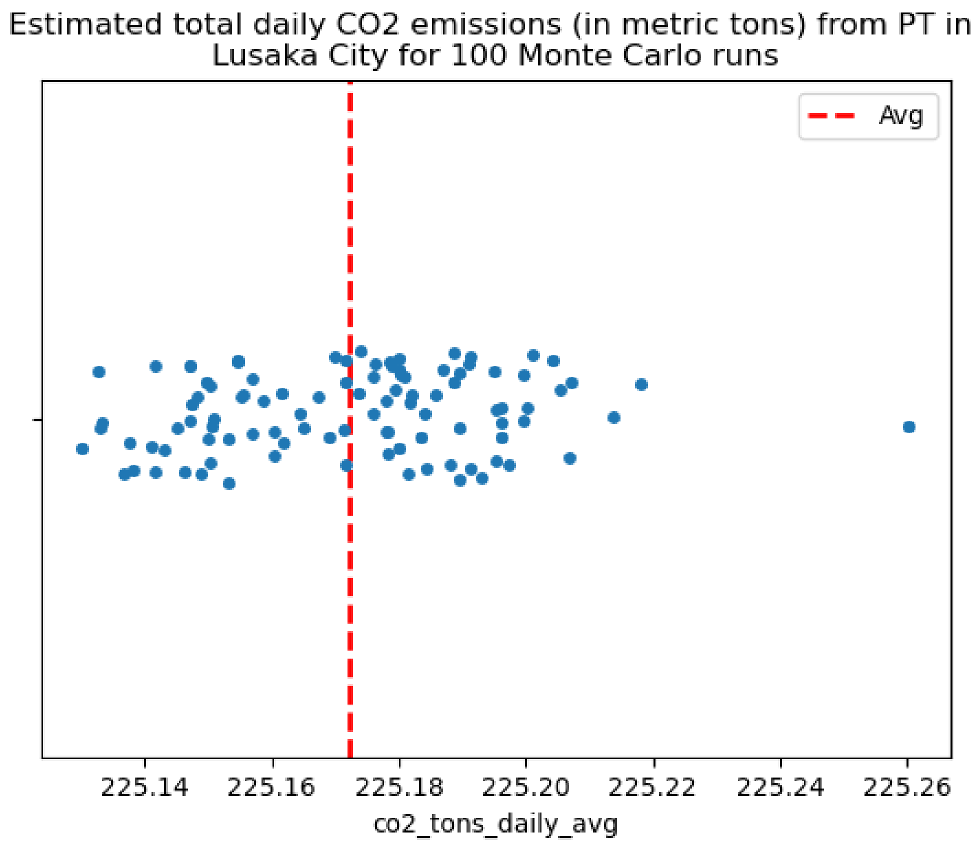


Figure 6-20 Estimated total daily CO2 emissions (metric tons) from PT in Lusaka City for 100 Monte Carlo Experiments

The methodology explained in 7.5.1 produces a spatial and temporal emissions model for each of the calculated pollutants; CO2, NOx and PM10. This section provides spatial and temporal analysis of the emissions model, integrating population data, to highlight high-impact locations for intervention design.

[18] https://en.wikipedia.org/wiki/Monte_Carlo_method

Table 6-3: Transport Model Statistics

Variable	Value	Units
25th percentile of speed	16.6	km/h
Mean of speed	22.1	km/h
75th percentile of speed	28.1	km/h
Total daily trips	29,970	Trips
Total Vehicle Kilometres Travelled (VKT)	0.35 million	km
Total travel time	16,641	hours
Average bus stops per trip	23.6	stops
Number of routes	68	routes

7.5.3.1 CO2 Emissions

Spatial Analysis

Figure 6-21 shows the spatial distribution of estimated daily CO_2 emissions from PT in Lusaka City. They are predictably highest and most concentrated in downtown, since 90% of routes are originating from downtown terminals, and the vast majority of transfers happening there.

Otherwise, the remaining significant portions of the total emissions are distributed along a few main corridors, marked with arrow in Figure 6-21:

a. Lumumba Road
b. Great North Road
c. Great East Road
d. Chilimbulu Road

Intervention design for CO_2 reduction should target routes that run on those four corridors for the largest impact on the CO_2 footprint of PT in Lusaka City.

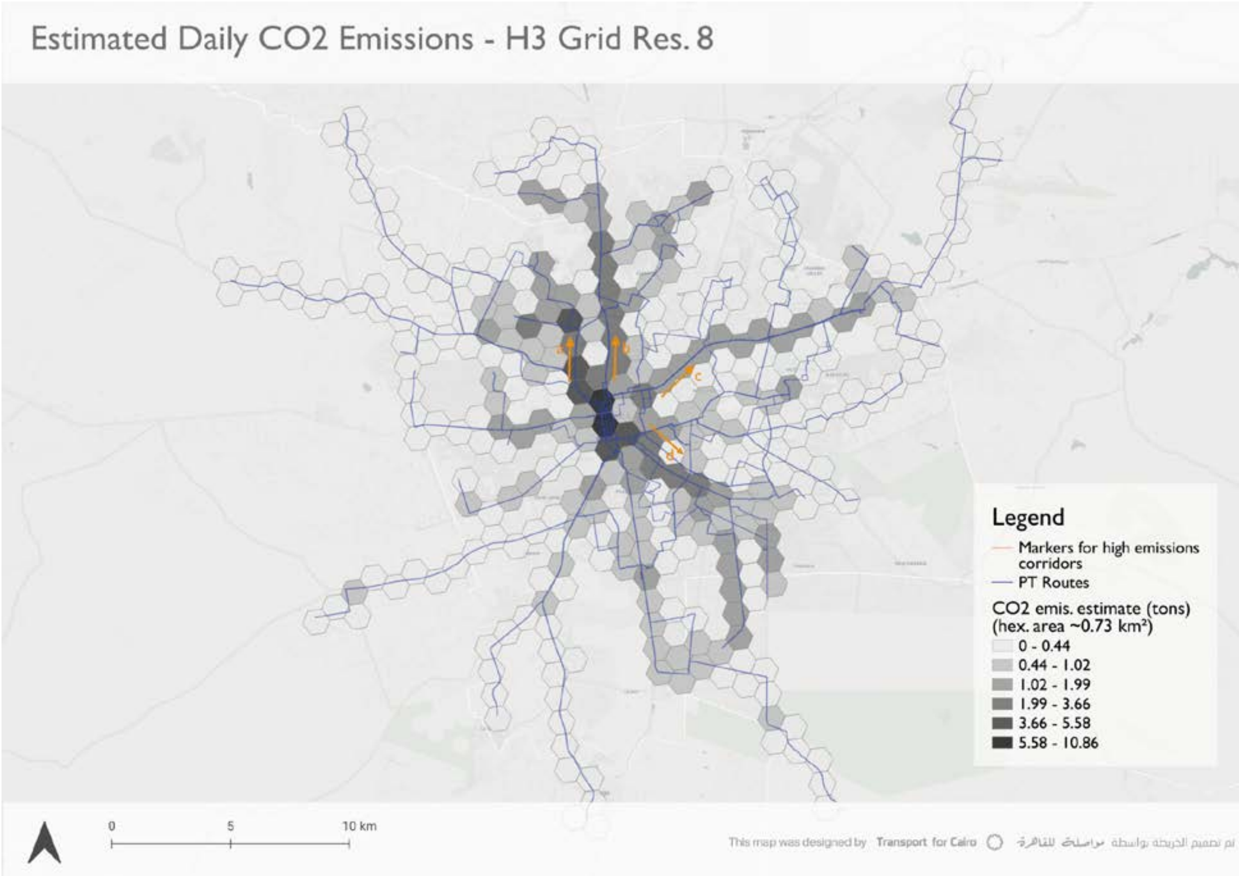


Figure 6-21: Estimated Daily CO2 Emissions - H3 Grid Resolution 8

Temporal Analysis

Figure 6-22 plots emission levels across the day for CO2, NOx and PM10. Two peaks corresponding to morning peak and afternoon peak hours can be observed. However, the variance in emission levels overall throughout the day is small. Figure 6-12 shows the corresponding passenger activity levels throughout the day. Passenger Activity, and consequently, PT emissions show no significant difference between peak and morning off-peak hours in Lusaka City.

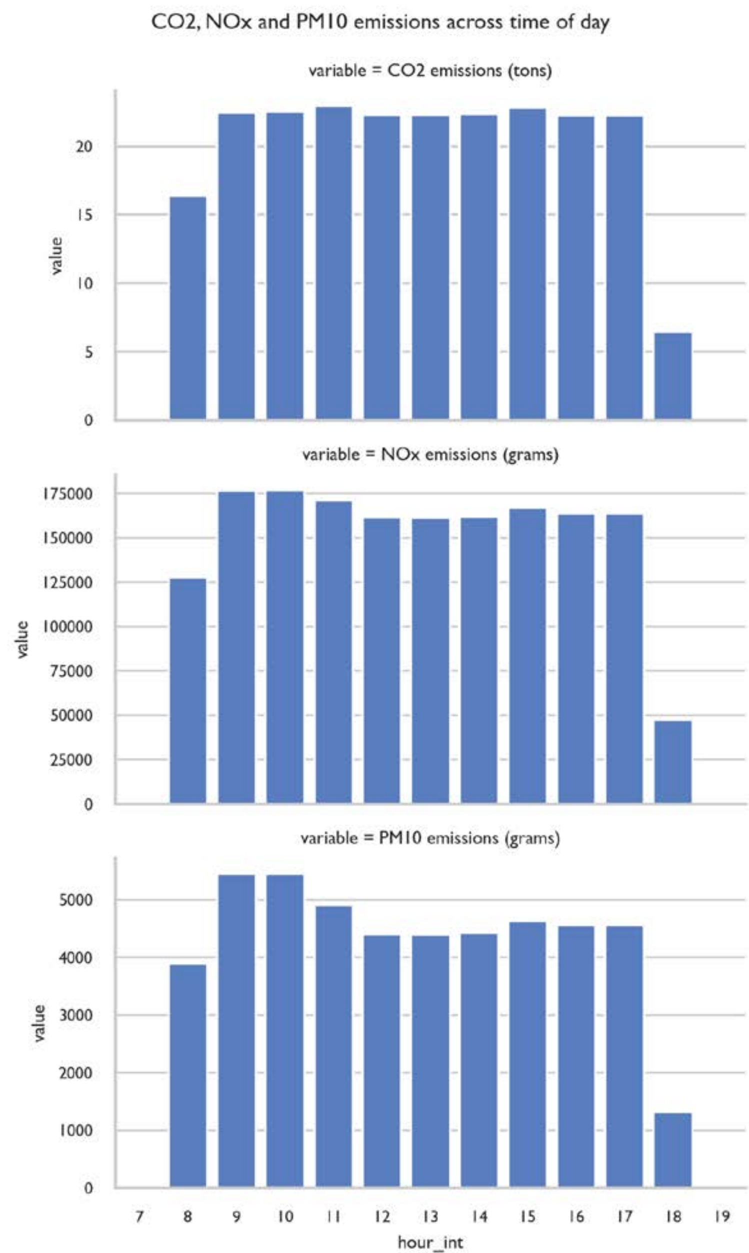


Figure 6-22: Total pollutant levels by time of day

7.5.3.2 Spatial Analysis for PM10 emissions

In this section, we investigate the spatial distribution of PM10, and use other datasets to understand its impact on the people.

Starting with Figure 6-23, it can be described at a high level as a comparison between locations of high PM10-induced impact on (1, left) resident population and (2, right) pedestrians. For the former, the grid tile's color is proportionate to both PM10 emissions and the total population within the tile. For the latter, instead of total population, boarding activity captured in onboard surveys within the tile is used.

It's noteworthy that the boarding activity to represent pedestrians, rather than boarding and alighting activity combined, was chosen. Boarding passengers wait for their vehicle to arrive and then to board, so they are more likely to be impacted by air quality. On the other hand, alighting passengers usually continue directly to their destination.

Key insights from the comparison in Figure 6-23 are:

- High PM10 emissions and high population neighborhoods are concentrated in the northern quarter of the city.
- On top of CBD terminals, Chelstone, Zanimuone and UTH Hospital terminals exhibit both the highest demand and PM10 emissions.

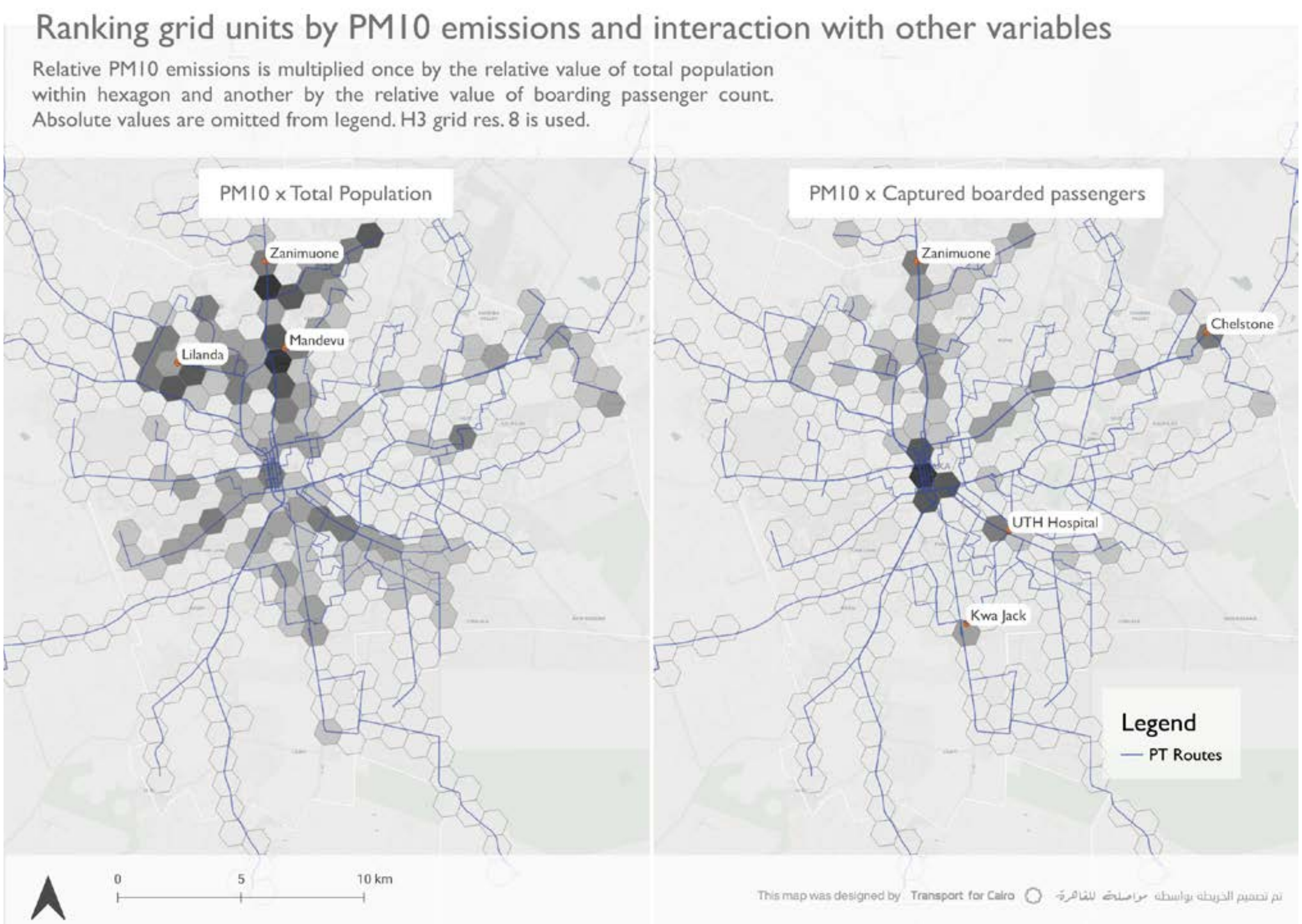


Figure 6-23: Interaction of PM10 levels with population and passenger activity

"Chazanga" (i.e., Zanimuone) and "Kabanana" are two neighboring townships with the highest ratio of pollutants to population. Both townships are surrounded by two corridors with high flow of route services, "Great North" and "Kabanana Road" have 9 routes operating on them both, with median headway of almost 3 minutes for the routes combined.

The frequency of existing services and the number of people affected by the resulting PM10 and other pollutants, both point towards the need to upgrade the capacity of the existing PT services on the two corridors from which pollutants are emitted. 4 out of the 9 routes operating are already higher capacity

Rosa buses while the remaining are 14-seater minibus taxis. Each route should be assessed individually for the possibility of assigning Rosas instead of minibuses, or the prioritization of these areas for assignment a proper high-capacity passenger bus when the city is able to procure them.

7.6 Training Session #2: Data Analysis & Processing

A hybrid capacity building session was conducted on the 21st of February 2024 titled "Analyzing Paratransit". The session took ninety minutes and consisted of forty-five minutes of presentation and the remaining time as open discussion. The session was attended by forty-three people -excluding TfC members- from Zambian government, private sector and civil society.

The presentation focused mainly on a simplified explanation for the mapping process from the starting point of data collection to processing, to analyzing the data and the insights generated. First, an overview of the "data lifecycle" is presented to explain where each piece fits in the puzzle, that is the digital database of the PT network.

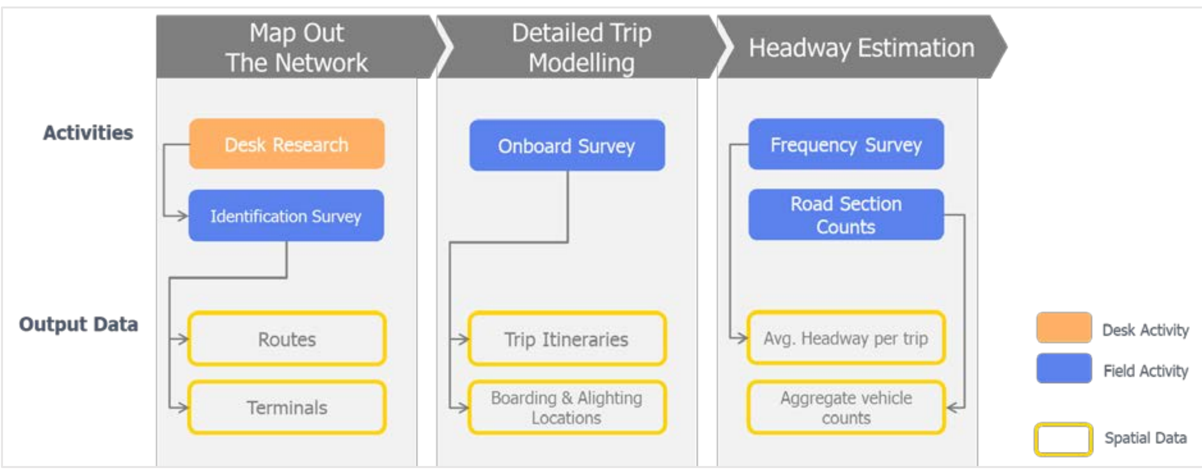


Figure 6-24 Surveys Overview diagram - excerpt from "Analyzing Paratransit" slides

This is followed by a recap of each survey type performed to reiterate the methodology and data outputs of each. Then, data processing steps are explained with an emphasis on the rationalization of the paratransit reality to the digital database. Lastly, every data analysis activity done during the research is explained in terms of (a) steps, (b) data inputs, and (c) software tools used. The GHG model is highlighted in a separate dedicated section in the presentation.

Follow-up discussions were initiated by questions from the attendees. A valid concern was raised on the need to act on this study -and previous research- rather than stopping at the research stage. This point highlighted the importance of conducting **stakeholder consultations** to understand their actual needs from the research; as well as the use of open-source **data** and **software** to ensure reproducibility of the research and local stakeholders ownership.

8 The Lusaka Transit Map

The Lusaka transit map is designed to represent transit data in the utmost user-oriented interface. This map focuses on presenting the prevailing public transportation (PT) modes & their interchange options within and beyond the city bounds. The scale & definition of PT network in Lusaka shaping the design of the map are entailed through these guiding design elements bellow:

1. Basemap
2. Route Shapes, Stops & Stations
3. Iconology and POI
4. Legend

8.1 Basemap

The Lusaka Transit Map followed a **hybrid approach** between a geographic and a schematic one, having more aspects of a geographic map. The base map was designed to follow the geographic arrangement of the city, while abstracting and simplifying it. This design choice was made based on three aspects:

1. *This is a bus map; thus, a geographic approach is more valuable than a schematic one.*
   A geographic map does not distort distances, whereas schematic maps are usually for readers mainly interested in connectivity and not geography, making it more suitable for rail-based transport such as the subway or Monorail.
2. *The nature and dynamics of the streets and accordingly the trips.*
   This is where the « abstraction » element in schematic map design comes in handy and helps relieve the map from too much complexity arising from Lusaka's dense network.
3. Geographic Transit Maps are more easily readable and relatable, especially for users who are not used to transit maps.

Further geographic elements are abstracted to manifest the basemap, including 'Wards' & the 'Street Network'.

8.1.1 Wards

The administrative boundaries of the wards (neighborhoods) are used as a base for the map. These wards are geographically abstracted & mapped where each polygon represents a distinct neighborhood in Lusaka. This further guides the overlaying of street network as well as bus route network on the map.

8.1.2 Street Network

The street network hierarchy is generally identified by OSM into 4 main categories: Primary, secondary, tertiary & residential. The street networks shown on the map only portrait 2 categories, the primary and secondary streets. Each category is identified by different opacity levels & thicknesses, based on the street's importance. Primary roads have darker opacities & are thicker than secondary roads for example. Only the most important streets (according to the scale of the map), as well as the streets on which the trips are located, are shown on the map.

Figure 6-25 Geographic map abstracted to wards & overlayed with street network

8.2 Route Shapes, Stops & Stations

To be able to design a comprehensive and readable map, routes need to be aggregated to be readable on the map. This is achieved through trip filtration & grouping.

All routes on the map went through a 3-step filtration process, enabling us to arrive from approx. 136 unique trips to approx. 54 routes visualized on the map.

Table 6-4: Filtration steps

Filtration Process	Description	Numbers of Routes
Without Filtration		136 unique trips
Parent vs Child	Routes (children) that lie within a longer route (parent) having a 70% identical path and operate on the same direction were coupled with longer routes in the same route.	28 trips
Categories' filtration	All duplicate routes (having the same OD or within 500m buffer) that pass by the same stages or within a 500m buffer from the same stages are removed	8 trips (originating from Kamwala)
Route categorization of trips with same OD	All trips having the same Origin-Destination (OD) are grouped together. Each group is seen as one route.	108 trips grouped to **54 routes**

8.2.1 Stations & Stops

The stations shown on the map are either origins or destinations of all the routes. Stations located in the CBD area are close to one another & where almost most of the routes originate from. To avoid cluttering in the map, 'Kamwala' station was only removed, considering routes are repeated originating from 'Kulima Towers' in close proximity. Stations in the CBD are visualized differently than destination stations around the city, whereas stops are further filtered to identify the most significant locations in the city & visualized on the map.

8.2.2 Style and Colours

To differentiate the routes, two techniques are used, line style and line color. The different line styles represent the two different route agencies (shared taxi and bus). Routes ideally represent both directions, however if one direction diverts from the other, a dashed line is commonly used to show the trip in the opposite direction. As for the colors, each different OD category is being represented with a different color.

8.3 Iconography & POI's

The selection and prioritization of Points of Interest (POIs) and icons for a map involved a combination of factors. User preferences (e.g. high-user ratings) from as well as geographic importance (eg. major landmarks, attractions & important infrastructures) guided this selection.

POI's were further categorized to special & generic iconographies. Special iconographies were developed to showcase the façades of major buildings in Lusaka. Local knowledge and brief analysis to city skyline illustration designs, identified the most prominent buildings. Only several public buildings were further selected & designed for the map. Generic icons were chosen for the rest of the destinations that presented geographic importance to the city.

Figure 6-27 Skylines from various artists identified most unique buildings in the city

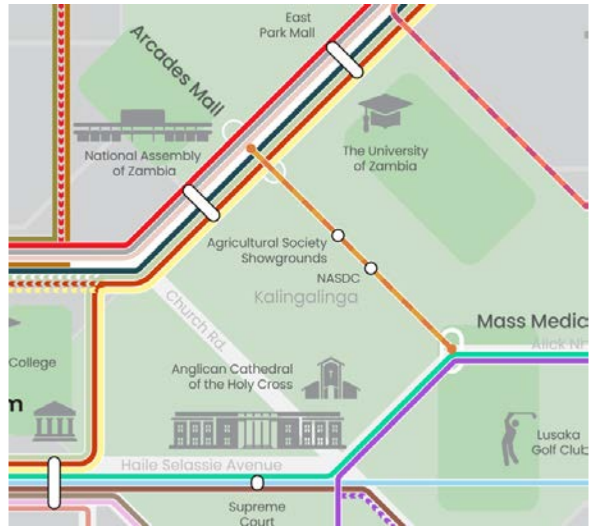


Figure 6-26 Lusaka transit map displaying both special & generic icons

8.4 Legend

The legend provides essential information about symbols, colors, and geographical elements in the map. Consequently, it is also used to showcase a summary of route-coding system created whilst guide users to easily interpret the different routes & the map as a whole.

8.5 Transit Map Final Design

The following map is the final draft for the Lusaka City transit services, that is to be delivered to the project's steering committee.

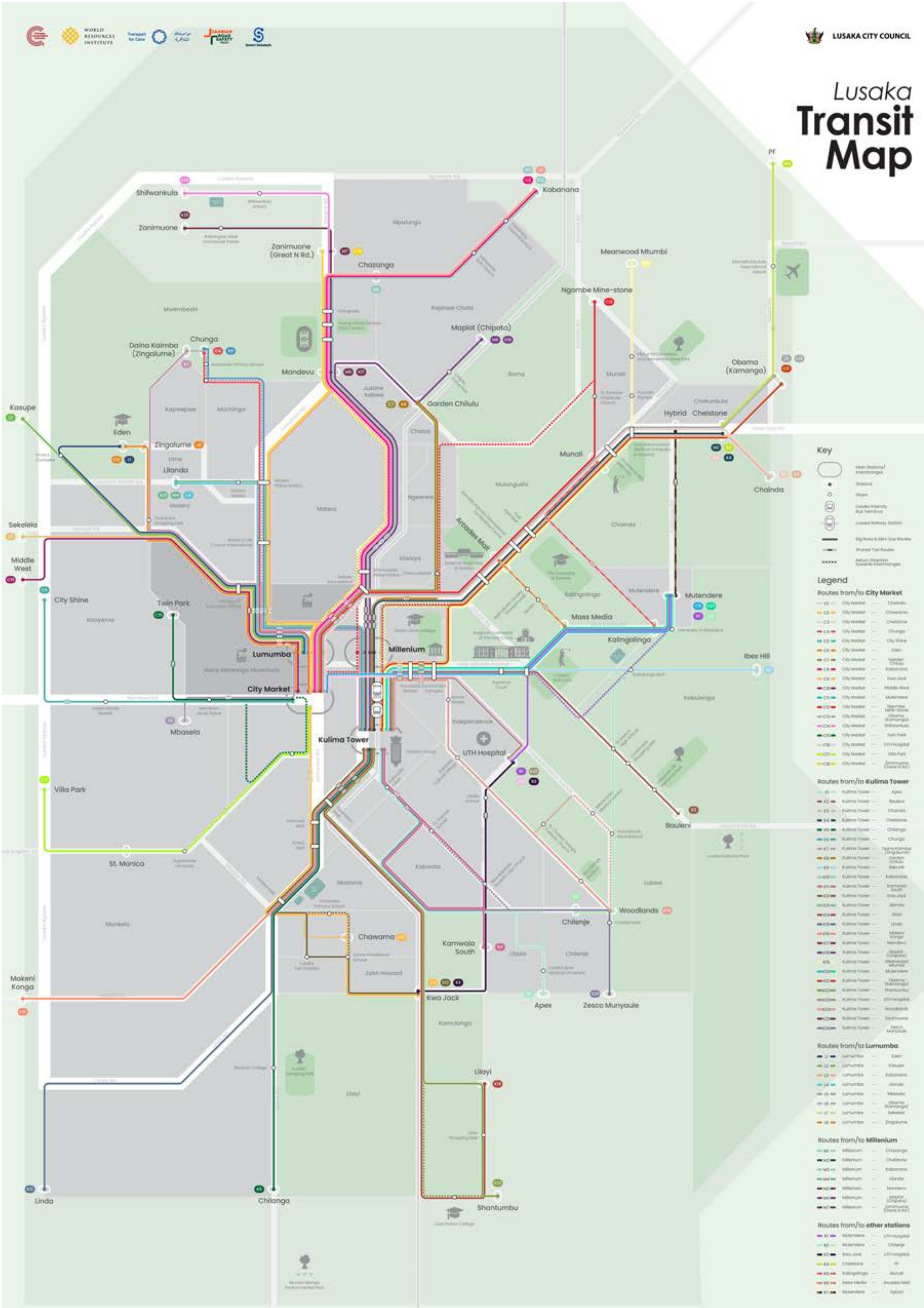


Figure 6-28 Lusaka Transit Map

9 Conclusions & Recommendations

Conclusions:

1. Passengers are more incentivized to pursue a private car or a motorcycle than to use PT or active travel. This lack of incentive comes from the fact that private travel trumps PT and active travel in several parameters including travel time, distance, and the overall user experience.
2. There are gaps between government organizations drafting national policies and the organizations implementing them. Those gaps are exemplified in Lusaka where MoTL issues the National Transport Policy and LCC requiring additional capacity and the formation of a PTA to properly implement said policies adequately.
3. The traffic congestion and pollution burdens of Lusaka's CBD is not caused by demand alone, but inefficiency of the network design is a main contributor to the problem. Passengers going between virtually any two points in Lusaka will mostly have to either go from or pass through the CBD to reach their destination.

Recommendations:

1. LCC should assign resources to work with an institute with technical capacity such as ZIPAR to maintain a digital database on PT services in the city, using the same or similar methodology as the one followed by this research. Transport planning within LCC should integrate digital data in the planning and decision-making process, while public relations can focus on passenger information systems. PTA formation with LCC is therefore a priority to "host" this database and enact regulations and PT network reforms accordingly.
2. Three corridors can host a potential public transport intervention (PPTI), those are Lumumba, Great North, and Great East corridors. Data shows a high rate of passenger flows as well as high levels of GHG emissions at the three corridors; Geographic granularity of the data means PPTI segments can be further studied to design routes and cross-connections between them.
3. More short-term, quick wins can be achieved by assigning larger capacity vehicles to minibus routes with rapid frequencies and high demand. Existing Rosa fleets can be assigned those routes. During peak hours, some minibus routes are observed to have headways of one minute or less, those include:

    - Kulima Tower → Lilanda: 29 seconds headway at peak
    - Kulima Tower → Apex: 31 seconds
    - Kulima Tower → Zanimuone: 38 seconds
    - Kulima Tower → Chunga: 72 seconds

4. PT services ought to provide direct services between townships in a network that is less centralized and less dependent on CBD interchange. Planning of new, direct routes for those services should be prioritized based on (a) Passengers travel patterns (requires household or trip diary surveys) (b) Origin-destination metrics with the lowest inefficiency (in terms of distance, time, or both) (c) Existing road infrastructure.
5. Passengers last-mile challenges must be assessed and NMT conditions improved for paths within residential compounds. Passengers' participation in using PT could be hindered by the large

walking distance between their households and the nearest PT service. Investing in NMT infrastructure within compounds will allow for (a) centralized terminals at Lusaka's edges, and (b) more active travel and PT modal share.

Lessons learned:

1. This study focused on the quantification of PT in terms of supply, demand, geography, and emissions. While the results present granular, geographic areas to target on a micro-scale, one shouldn't draw conclusions on passenger perceptions or challenges from studying PT services alone. Passenger surveys and participation in a sample-based approach is key to understanding and addressing mobility challenges in the city.
2. Further to the previous point, studying gender-disaggregated boarding and alighting data allowed for key geographic insights on disparity in male/female participation in PT in certain areas throughout the day. Further gender-focused surveys with passengers are therefore needed to arrive at conclusive insights.
3. Section counts and frequency surveys are both complementary to one another in understanding the actual volume of PT supply in a paratransit context such as Lusaka. The so-called "Pirate" services operating from outside terminals and picking up passengers along the way are seldom quantified and their exact percentage of ridership share is unknown. However, route-based frequency estimates can be calibrated by route-agnostic section counts at select corridors.

10 Appendix

10.1 Consultations Documentation

10.1.1 National Level Governance – Agencies

- *RTSA*

Name of Consultation	Road Transport & Safety Agency (RTSA)
Key Stakeholder	CHNUNKY KANCHELE (Head Planning, Research and Development),
Attendees	Ghada (TfC), Natasha Christine
Location, Date	RTSA Offices, 8th August
Information disclosed points of discussion	- **Licensing process:** include RSL for drivers of PSVs and the category of vehicle's registered as PSVS include: o Big buses for intercity trips (capacity: 56 and above) o Rosa buses (medium buses – between districts) o Small buses (16 – 18 – 22 seaters) intracity trips but sometimes they travel longer distances, which is against their registration papers.

	- **Route planning:** is within the mandate of the LCC but during vehicle registration (PSVs) in RTSA the operator defines any district to operate in based on the operator's assessment which area is more profitable, and seemingly route design and planning is controlled by the operators themselves. o Local authorities are therefore not up to date on the changes in routes. o RTSA has a very limited role in the routing system, and therefore it is not included in the reporting cycle between operators, associations and LAs. - **RTSA's** Examination includes ensuring that the buses are in good condition (Road Act #8 of 2022) through examinations unit which focuses on assessing the external condition of the bus and its fitness level. There is also a mechanized testing unit (MIMOSA) of the carbon emissions of the vehicle (only one station unit is available in Zambia). o The fitness level of PSVs is valid for one year. - **RTSA's organizational structure** includes the o Road Safety Department, which has three units: Engineering, Education and Enforcement units. o Planning and Research and Planning Department o The Road Transport Department has three units: Registration, Examination and Licensing units. - Previous Studies conducted in the Planning Department include a study on the congestion in bus stations and their carrying capacity, this is partially due to the regulations on PSVs to load and off-load pedestrians outside stations. - Recommendations for the improvement for PT provision o Satellite bus stations to offload congestion from the CBD. o Rerouting bus routes to connect satellites cities to each other and collecting data on the passenger trips to understand the number of interchanges being done in a spoke and hub network. - Local authorities include different councils according to the geographic jurisdictions.
Summary of activity – Outcomes of the consultation	- **Intracity buses** are licensed by the district (operation area ex: Lusaka - Chongwe) and not routes and therefore this doesn't create a demand driven route plan. - **Local Authorities (LA)** (affiliated to MLGRD) **mandate** includes geographic scale of buses**,** routing system and management of the bus stations. - **Operators** represent and organize themselves through associations that regulate themselves and agree on enforcement regarding the routes.

	- Motor Vehicle Certificates for PSVs don't contain details on exhaust treatments or parameters related to environmental aspects.
Links to more information	- The Road Traffic Act No 11 of 2022 (hardcopy) - 2021-Road-Transport-and-Safety-Status-Report.pdf - Registered associations have their own constitution to organize their members: The law Associations of Zambia Act - http://wikimapia.org/36923655/RTSA-Mimosa-Vehicle-Testing-Centre

Name of Consultation	Road Transport & Safety Agency (RTSA)
Key Stakeholder	Mr.Mioko (Head of Examination Unit in Transport Unit)
Attendees	Ghada
Location, Date	RTSA Offices, 8th August
Information disclosed points of discussion	- Privatization of the transport services meant the market depends largely on individuals importing panovans that are fitted with chairs inside Zambia and then licensed. The following are the highest imported types: o Small buses (14 -16 seats): FORD transit (flash buses), Toyota HIACE, Nissan Caravan, Toyota quantum (newer with in-build chairs), o Larger buses (30 buses): Rosa, Toyota coasters - **Policy related to vehicle import**: newer vehicles are considered a product that is higher value so its higher in taxation, and since upgrading the fleet is not incentivized, most owners tend to relicense older buses instead of getting new buses. (Which lies within the mandate of the Ministry of Finance) - RTSA has mechanized testing equipment with an in-build feature to test for emissions, but there is no national standard on emissions, which should be developed through Zambia Environmental Management Agency.
Findings related to the consultation	- Taxation on importing motor vehicles in Zambia includes Custom Duty, Excise Duty, Value Added Tax (VAT), Motor Vehicle Fee, Asycuda Processing Fee, and Motor Vehicle Surtax. There is an additional carbon emission surtax that depends on the engine capacity. - The taxation of used motor vehicles from two to five years is almost twice the taxation on motor vehicles that are aged more than five years.
Links to more information	- ZEMA's work with an African consultant to develop standards related to emissions. - SPECIFIC DUTY RATES ON USED MOTOR VEHICLES

Name of Consultation	Road Transport & Safety Agency (RTSA)
Key Stakeholder	JOSEPH MUMBA (Deputy Director - Transport)
Attendees	Ghada
Location, Date	RTSA Offices, 8th August
Information disclosed points of discussion	- If a company registers for an RSL and comprises of less than 75% Zambians, it should apply for an investment license. (Ministry of Commerce) - Passengers and goods have the same registration and licensing process. - RTSA only asks registers of passenger transport to define the 50km radius in which they will be confined to operate in, but they do not require a route-specification. It's the operator's decision to choose routes based on profitability. (RSL for a 50 km radium in district not a route) - RTSA believes that routes in the future should be assigned by RTSA, to follow up with enforcement and penalizing system. It will be restrictive and ease the monitoring.
Summary of activity – Outcomes of the consultation	- Registration of PSVs is district bound and not route bound, which makes enforcement role of RTSA harder on passenger vehicles.
Links to more information	- Section 100 in the Road Act focuses on the PSVs registration (for vehicles) and Road Service Licensing - RSL (for drivers)

Name of Consultation	Road Transport & Safety Agency (RTSA)
Key Stakeholder	ALINANI MSISYA (Deputy Director - Road Safety)
Attendees	Ghada (TfC), LINDA MUWOWO (Head of Education Unit)
Location, Date	RTSA offices, 8th August

<table>
<tr><td>Information disclosed points of discussion</td><td colspan="2">- Challenges facing the PT provision in Lusaka from the point of view of the safety department include the lack of scheduled services, no proper mass transit, no intramodality between different systems, lack of street lights and designated bus stops.
- The enforcement unit is planning to increase the number of PSVs with GPS tracking.
o The GPS tracking is not aimed at tracking the routes or understanding the efficiency of the network but to easily track the locations of accidents, or violations of the PSVs.
o Currently 1000 PSVs have installed the GPS tracking.
o The aim of the tracking is to regulate the PSVs that violate the road act. These violations include loading and offloading passengers outside their designated stations and to integrate the reported accidents with the location of vehicles.
- The unit plans on utilizing the hotspots where incidents are reported to advise on intervention to the RDA (which holds the implementation role regarding road construction and development.)
- The Safety Department is divided into three units:
o Education Unit (Outreach and awareness)
o Enforcement Unit (Develops enforcement systems for violations)
o Engineering Unit (Inspects and advises with RDA through road safety audits (RSAs) and inspections (RSIs)
- Zambia police department holds the main role in street interception of violating vehicles, along with RTSA's enforcement unit.</td></tr>
<tr><td>Summary of activity – Outcomes of the consultation</td><td colspan="2">- The safety department is investing into its enforcement mechanisms and automating the process of fining, blocking, and suspending vehicles.
- The Department was interested in mapping the transit system of Lusaka to integrate the PSVs operations with the enforcement unit efforts in increasing compliance.
- RTSA's role</td></tr>
<tr><td>Links to more information</td><td>RTSA's portal</td><td>- 2021-Road-Transport-and-Safety-Status-Report.pdf (hard copy)
- https://www.rtsa.org.zm/traffic-offences/</td></tr>
</table>

10.1.2 Ministries

- MLGRD

Name of Consultation	Ministry of Local Government
Key Stakeholder	RICHARD KANGWA (Principal Engineer), STEPHEN MALUBILA (Technical Advisor)
Attendees	Ghada
Location, Date	MLGRD Location

Information disclosed points of discussion	- **LCC (local authorities) mandate and challenges:** LCC oversees the actual transport within the locality. The routine system is within the mandate of the LCC and the challenges they face is related to their lack of ownership of what their position entails as Local authorities regarding route planning.
	- **Operator Scales**: Individual (owners of 2-3 buses), Companies (owners of large fleets) and Associations (representing drivers, owners).
	- Challenges in the transit include:
	  o Large number of parked buses in the off-peak in the CBD waiting to load passengers. *Could this be an indicator of oversubscribed routes?*
	  o Network inefficiencies (spoke and hub) between the satellite cities.
	  o Loading buses taking up road-space
	- All service provisions are guided (technically)and supported (financially) by the MLGRD.
	- RDA has the overall responsibility for the maintenance and construction of all roads -except township roads-
	  o Township roads are considered as municipal services which is within the mandate of the local authority, affiliated to MLGRD.
	- Organizational Structure:
	  o Ministry of Local Government and Rural Development consists of
	    ▪ *Department of Rural Development (Housing and Infrastructure Development dept. previously) – Engineering functions*
	      • *Roads Unit (Road's infrastructure)*
	      • *Markets and Bus Stations Unit (Bus stations infrastructure)*
	      • *Solid Waste Management Unit*
	      • *Rural Development Unit*
	    ▪ *Department of Physical Planning*
	  o Cross organizational communication:
	    ▪ There is no transportation department in LCC, management updates related to the buses are reported to the *Housing and Social Services Department* in the Local authorities. (Organisational gap) -

	o MLGRD *Roads Unit* works with the *Engineering department* in the LCC on road related maintenance and construction. o Transport department in the LCC would harmonize the role of managing the routes and the bus stations. o Enforcement: Traffic Police and RTSA o Jurisdiction of the land provision is LCC responsibility, and the ministry operates on a bottom-up demand approach:[1] LAs shares AWPs with MLGRD. o Lack of integration of transport modes (intermodality)
Summary of activity – Outcomes of the consultation	- Recommendations and Priority Areas: Better utilization of routes, infrastructural improvements in, areas with high boarding or alighting values. - NTP (National Transport Policy - MoTL) recommended that LAs should have fully fledged transport departments, but it hasn't been actualized into action. - LCC requires an investment in building the transport department with skills related to transport planning, transport economy, traffic engineering, o Routes need to be revised (whose responsibility, is it?) o Masterplan is created by LCC so incorporating transport into these plans is LCC's responsibility. o Skill set related to transport data analysis is not available in LCC.
Links to more information	- Bus Drivers Associations (operating and managing their services) - Local government Act - Planning Authority

10.1.3 Local Authorities

- LCC

Name of Consultation	Lusaka City Council
Key Stakeholder	FERGUSON SIMUSAMBA - Town Planner
Attendees	SABBSON PHIRI - Assistant Director of City Planning, EVANS KAMBOLE – Bus Terminals Manager, Ghada
Location, Date	Civic Centre, Independence Ave, Lusaka, Zambia
Information disclosed	- **Organizational Department of LCC**: o City Planning Department (actual planning)

points of discussion	▪ District Planning Unit ▪ Town Planning Unit o Department of Engineering (road construction and maintenance and bus stops construction) o Department of Housing and Social Services - **Route System**: There hasn't been any updates on the routes, Intracity routes are not planned, but people from new developments are creating new demand. But LCC's priority has been in providing new bus stops along certain routes. o Following up on route changes: Each route at a station has a chairman who reports to the station manager and then engages with the Stations manager in LCC. o LCC is attempting pilot routes for big buses. - **Roads are classified**: o Highways (connecting districts) are within the jurisdiction of the RDA (agency), o Township roads are handled by Local authorities, and some are handled by Ministry of Works and Supply. - **Licensing**: Existing PSV license shows the operational district that they are confined to operate in, but there is a proposal to indicate the route system on the licensing. o The routes are given to individual transporters but not an individual to operate on, so its not indicated in the license. o The PSV is a stamped sign on a drivers' existing driver license. o The red number plates indicates that the vehicle operates for business (RSL license for vehicle) - Transport Unit in LCC: NTP establishing PTA within city councils initially, followed by municipal councils and district councils. According to this consultation, this PTA will regulate, plan and monitor routes. (Formalizing the system) o Challenges related to the implementation of this unit: ▪ Replacing smaller buses (14-16 seaters) shift to bigger buses (30-seater buses) would require a reduction in the number of operating buses, which would create a lot of resistance. ▪ Agreement with operators regarding their choices of vehicles can be communicated through associations. o Formulated of GIS expert transport planners, representatives from RTSA, MoTL. To ensure that all criteria is met.

10.1.4 Civil Society Organisations and Co-operatives

- PPTDAZ

Name of Consultation	Public Passenger Transport Drivers Association of Zambia
Key Stakeholder	Mr. Sidney Mbewe (Association National Secretary)
Attendees	Ghada
Location, Date	7TH August 2023 (Cha Cha Cha Road) at PPTDAZ's Location
Information disclosed points of discussion	- **Cooperative aim** is to attempt gathering individual single operators into a one single management setup with a magnified voice that channels the needs and challenges through the cooperative to the government. - **Single Fleet Operation Approach (since 2018)** being advocated for by the cooperative is facing some skepticism from the operators because they need to understand how expenses will be managed (inc. vehicle servicing, driver salary, road tax, RSL license…). The concept note also advocates for o **Digital Payment System - DPS** ▪ Ridership Data to operators (to calculate their profit more efficiently) and regulators (to understand the demand). ▪ Incentives on using DPS – less fares if its in e-payment. o **Continuous Ring Road Routing System:** ▪ Direct connectivity between destinations (shorter travel time and less cost) o **Renewing Bus Model** ▪ Buses of certain old models should not have their license renewed, and there should be an investment in newer models of buses. ▪ During the seats fitting of imported panovans, no considerations are made regarding safety and comfort. ▪ Trying to invest in newer models of buses with better quality with the support of the government. o **Scheduling the PT** service: the current service imposes long waiting times for passengers, and low levels of comfort and safety. o **Leave no one behind Strategy**: The current transport services are also not inclusive for people with disabilities, and the elderly, and caregivers. The cooperative proposes deductions in the fare system

	for these different groups. Designing a system that encourages different groups to use. o **Cooperatives**: Bus owners can register their buses with cooperatives (such as flash) and these companies manage these buses including: (driver employment, servicing, insurance, RSLs..) and give the bus owners their income packages. ▪ It's the cooperative setup that is responsible and representative regarding labour, taxes, insurance.. o Lusaka is divided into five zones: each zone is a concession that is advertised for, and the winning companies or cooperatives will operate in these areas. In that concession you can't operate in a different routing concession. o Challenges resulting from the drastic increase in number of PSVs registered: High consumption of spares, continuous road maintenance, and the gas emissions of the bus fleet, (Zambia is committed by the Paris agreement to reduce carbon emissions by 25%) ▪ Congestion is making the travel time longer. o Motor vehicles are producing 23% of the GHG emissions with no active strategies from the government to how they will meet the agreement. o Infrastructure is an important factor in the migration to bigger buses, the road must have the capacity and the bus stops to run. o Encouraging operators to better choice buses, and a single management system. [51:23]
Summary of activity – Outcomes of the consultation	- The Public Transport Sector Management Setup diverges amongst stakeholders leading to the lack of advocacy for standardization, efficiency, fleet safety management. - Cooperatives are the key structure that helps governments administer its economic objectives with sectors such as transport which is a liberalizeD market and cooperatives ease the communication channel with the members. (Interaction between government and private sector) in regard to insurance, pension scheme, loans .. o It's easier for regulators to follow standards, administrative requirements related to taxes and insurance when dealing with companies or cooperatives. - Lack of data regarding ridership and the demand. o RTSA or any other entity has no data (or system) on the number of passengers using the transit system, and therefore the planning for a demand-driven system is challenging. o Operators are also unaware of the demand they are covering.

	- Current policies encourage over investment in low-capacity vehicles, and the reuse of older models of vehicles that can be running for almost 20 years. - The challenges facing the cooperative in adopting this concept is financing, especially the cost of the buses (600,000$/bus). GCF (Green Climate Funds to buy a smaller model of the buses as a pilot phase (30 seaters) and to create visibility for the operational scheme being developed by the co-op.	
Links to more information		• Concept Note by the Cooperative • NAPSA: pension plan • NIMA: health insurance • Vehicle population distribution of Zambia shows that most vehicles are registered in lusaka.

- PP&C

Name of Consultation	Passengers, Pedestrians and Cyclists NGO
Key Stakeholder	Foster Chileshe (CEO), Shupiwe Sakala (Board member)
Organizer	TfC (Transport for Cairo)
Attendees	Ghada
Location, Date	Holiday Inn, Thursday 10 August 2023
Information disclosed points of discussion	• The PP&CA started in 2013 due to an increase in the number of accidents and they have focused on advocacy action such as: sensitization programs with different stakeholders, advocacy for 30 km speeds in highly pedestrian streets, and advocacy for safer roads. • Human errors are the main reasons for crashes, and therefore PP&CA works on a shared responsibility and rights amongst all road users, including pedestrians. • Challenges facing pedestrians are: o Longer waiting hours specifically for longer distance commutes. o Inconvenience caused to passengers when drivers drop them off before their final drop-off stations to return and load passengers. o Longer walking distances to reach transit modes in outskirts. • Statutory Instrument (SI) Number 76 of 2022 is considered a positive step since it weighs the presence of pedestrians gives them agency. • LCC and MLGRD are the two entities involved with improvement of signage for pedestrians and street lights.

Links to more information		• Statutory Instrument (SI) Number 76 of 2022

10.1.5 Institutions

- ZIPAR

Name of Consultation	Zambia Institute of Policy Analysis and Research (ZIPAR)
Key Stakeholder	JOHN MUTUTWA - Research Fellow - Transport and Infrastructure Development
Attendees	Ghada (TfC), Agraw Ali (WRI)
Location, Date	Friday 11 August 2023 (ZIPAR offices)
Information disclosed points of discussion	- Challenges facing the governance of PT in Lusaka include the lack of institutional framework that holistically manages the transport services in Lusaka. - ZIPAR's recommendation to launch a **Public Transit Association** (PTA) as an independent body under the MoT that focuses on route planning, registration and fare and ticketing. - ZIPAR's **organizational structure** includes the Transport and Infrastructure unit (launched in 2014), Macroeconomics Unit, Trade & Investment Unit, Public Finance Unit, Emerging themes Unit, and Human Development Unit. - **Policy and Implementation in Transport** is divided between different stakeholders. o Policymaking: MoTL (ex: NMT strategy) o Implementation: MoIHUD, RDA (affiliated to MoTL), LCC (affiliated to MLGRD) - **Operational Overview:** o Most routes in the inner city are over-fed by buses. o There were previous plans to run bigger buses on inner city routes instead of smaller buses, but there was no implementation due to organizational and operational challenges. o Operators include three to five companies which own fleets of almost 250 buses, and individual owners who organize themselves through associations such as (BTOAZ). o Changes in fare are influenced by change in fuel prices, upon which the operators recommend the change in fare and RTSA approves this increase.
Summary of activity – Outcomes of the consultation	- The current structure of transport management in Lusaka is distributed across entities with different power weights. - The Spoke & Hub network of PT services hasn't changed in Lusaka partly because of the street condition of the road network between the destinations outside the city, and because this network serves the current fare system which brings more profit for the operators and less convenience for the passengers. - LCC should be a priority stakeholder to undergo capacity building programs and accommodate the increasing skill set required for managing transport.

Links to more information	Policy Paper	• Institutional preparedness for urban public transport reforms in Zambia. (Hard copy) • Amendment of the Road Traffic Act 2022 include the increase in the driving age, changes in the registration of PSVs, and Statuary Instrument on nighttime travelling.

10.1.6 Operator

- Flash Buses Operations

Name of Consultation	Flash Buses Company Operator
Key Stakeholder	ISMAIL KHANKARA - Owner of Flash Buses (founded in 1984)
Organizer	Mr. Joseph Mumba connected TfC to Mr.Khankara
Attendees	Ghada
Location, Date	Flash Buses Warehouses
Information disclosed points of discussion	- **Route Planning** o Operators have the freedom to choose the routes they want to operate on, and from their point of view, this increases competitiveness and improves level of service. o Other than companies, many individuals own and operate 2-3 PSV buses as a subsistence living. o The operators can change their routes based on a change in demand with no restrictions on route operations from the licensing authority. (RTSA) - **Fleet Characteristics** o Flash operators have a fleet of 278 buses, which is mostly 22- and 18-seater FORD buses. o The Company retrofits the buses in their warehouses with a continuous line of production of seating for the buses. o Upgrading their fleet with newer models of buses would be very costly due to the high interest rate on importing new buses (no policy initiated by the government to improve the quality of the operating buses. - Flash buses are the only company that owns and manages a bus station (Millennium Bus Station), other bus stations are owned and managed by LCC.

Summary of activity – Outcomes of the consultation	• Provision of public transport in Lusaka is developed from the owners' and companies' mindset to make profit from the industry, and any changes in the fleet or the route planning is influenced by a cost analysis of these changes.	
Links to more information	Information on bus fleet of Flash Buses	Buses List summary.xls

10.2 Transit Map Design Elements

The level of detail (LOD) in presenting public transportation network is crucial in choosing the adequate design elements. The scale & definition of PT network in Lusaka shaped decisions regarding maps LOD. The following table summarizes the main design elements & decisions defining the LOD through-out the design experience.

Map Elements	Definition
Basemap	Basemap defines the urban context and provides spatial reference for data overlayed. The map will follow a ***hybrid language*** between geographic and schematic basemap design. The base-map is geographically distorted in scale to accommodate the transit lines, and shaped by both ward & street structure shaping the city. The colour of the base-map further demonstrates urban, rural & industrial areas in the city.

Figure 10-1 Zoom-in on hybrid basemap defining Lusaka's context

Line Shapes, Stops/ Stations

Line shapes, colors, and thickness are elements that highlight and differentiate routes from one another. Lines patterned by arrows define the transit network towards only one direction, while the other one defines the route. Other line-shapes show other public transport options such as rail-network.

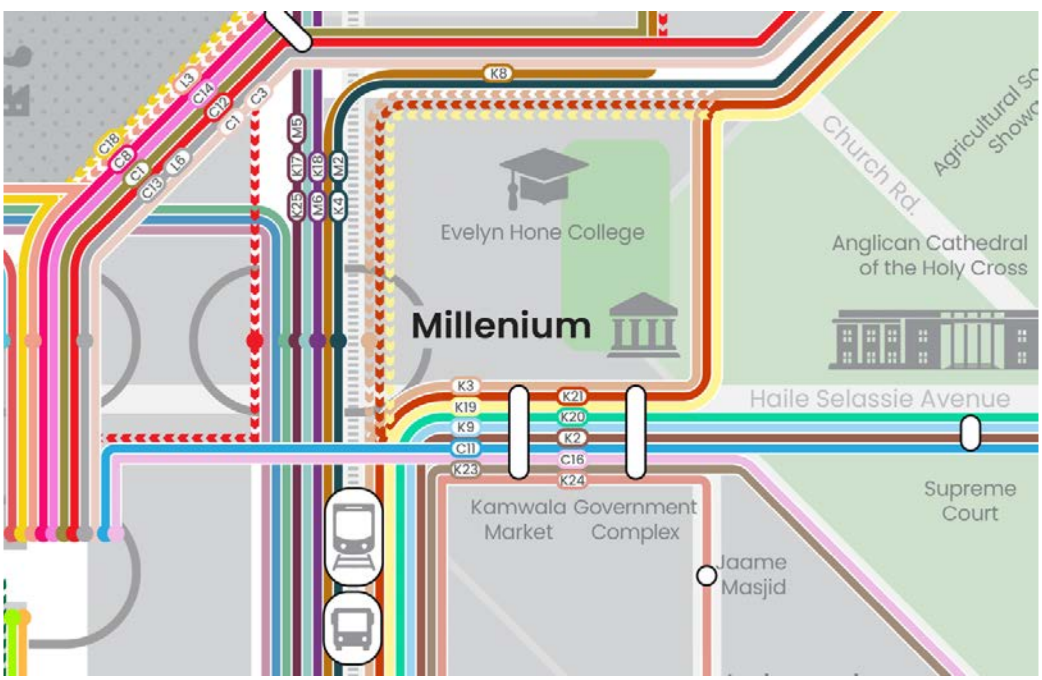
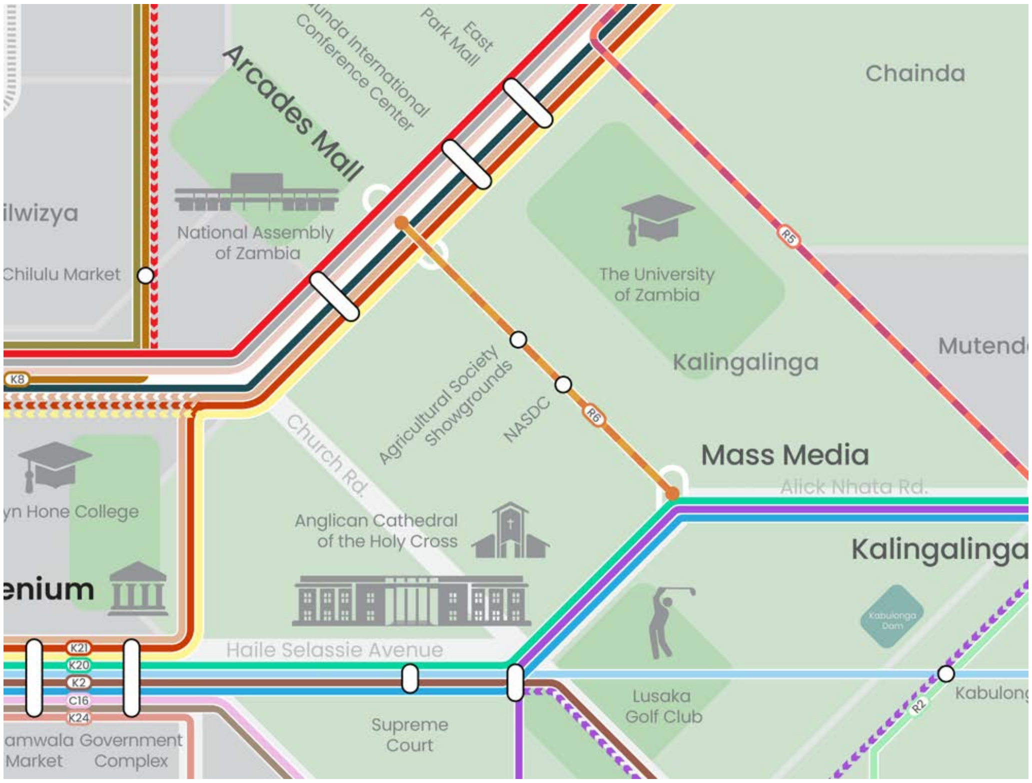


Figure 10-2 Zoom-in on Lusaka's map showing transit routes in different line types, colors & shapes

Iconology and POI	Landmarks and POI give the commuter more orientation and context for easier legibility and understanding of the map. Special icons are the ones tailored to show Lusaka's prominent landmarks eg. Findeco House or Supreme Court. While other generic ones illustrate public facilities or POI's in the city.  Figure 10-3 Zoom-ins on Icons & POI's
Legend	Legend presents detailed explanation for the symbols, lines & colors used. The routes are also codified in relation to the 4 main central interchanges in the city: City Market (C), Kulima Tower (K), Lumumba (L) & Millenium (M). These codes facilitate user experience when try to identify the different routes, origins and destinations efficiently on the map.

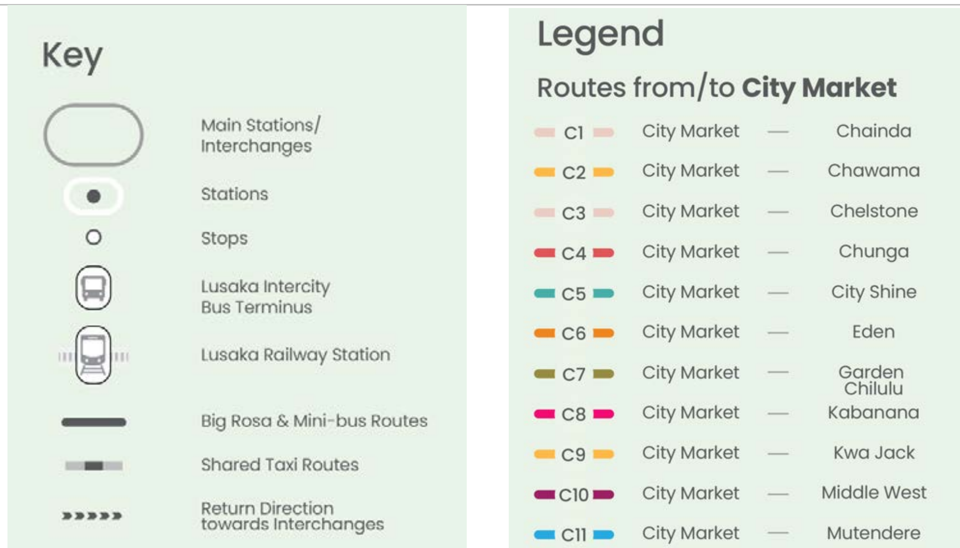


Figure 10-4 Key explaining different symbology & coding structure

10.3 Surveys Detail

To construct a comprehensive database for Lusaka's paratransit network, all routes have to be identified, have their level of service measured, and itineraries traced from the field. As with most cities with paratransit services, there is no real-time data capturing operational parameters. Therefore, the network needs to be surveyed in a manner that allows to have an accurate "snapshot" that can lead to accurate estimates.

Given the main goal is to have accurate GHG emissions estimates for said network, the surveys will be done redundantly over routes to ensure averages are accurate and outliers are visible and excluded. To maximize accuracy, the surveys will be focusing on the morning period, or half-day of a typical weekday of operations.

10.3.1 Identification

Purpose

For the mapping to be of significant added value to this project and the city of Lusaka, it has to be as comprehensive as possible. That is, to capture the majority of actual paratransit services operating in the city and subsequently be able to provide accurate estimates on the network or corridor levels alike.

For this to be achieved, there has to be field-based inspection of **what** services are there, **where** they start from and where do they go to. This is what the "Identification" survey deals with.

Method

Identification is usually the first survey done in the field. FRs will start by visiting well know bus terminals in the city. At each terminal the FR would geographically locate bus routes operating from that terminal and describe it's attributes as such:

- Route Origin (The terminal the FR is currently at)
- Route Destination (Based on the name called by the conductor/driver or if a sign is available)
- Vehicle type (to be selected from pre-identified list of vehicle types) This is important to assess passenger capacity later on
- Where the route is loading from (coordinates, whether it's an organized bus queue or a sporadic area of loading passengers)

The received surveys would help the team digitize bus terminals and create routes in the RL database for the routes to be surveyed later.

This process should be repeated for each terminal in the network in a snowball approach. Practically this is done by mapping one terminal, then taking a bus to one of the newly identified "destination" terminals, the destination terminal is then mapped, and a bus is taken to one of the unvisited destinations, and so on until each terminal **location** and **routes** are identified.

Figure 10-5 Example of identified routes operating between origin and destination terminals in Accra, by TfC (2021)

To ensure comprehensiveness, the team will be searching for **other instances** of busy routes within the same terminal and report them. That is done to later be able to devise ways to better estimate the "actual" level of service per route.

For example, a bus going between terminals "x" and "y" when measured for frequency from its queue would give an average headway of 15 minutes. But noting that on the other side of terminal "x" there are buses loading to "y" at the same time, that would mean the actual headway could be much less than

15. The aim of mapping all instances of routes is to be able to estimate "how much less" of a headway this service provides.

10.3.2 Onboard

Purpose

Onboard surveys will map routes, capture boarding and alighting patterns (disaggregated by gender), stop locations, speed profiles and characteristics that affect user experience such as fare.

Method

Field researchers (FRs) will ride bus services from the point of origin to destination, as passengers. They will use the mobile app "Route Observer", part of the "RouteLab" software suite. The software enables live tracking by the back-office team and survey validation is done concurrently, parallel to data collection.

The routes that need to be surveyed are matched to FRs through the Route Observer app based on how close a FR is to a route requiring survey, similar to "Uber" matching passengers to drivers. Upon choosing a route, the FR heads to the origin station and boards the designated trip, collecting the following datapoints:

- Number of boarding and alighting passengers at each stop, disaggregated by gender
- Stop location (GPS coordinates): Special attention will be given to capturing "transit terminal stops" where drivers are expected to dwell for a long time calling on passengers somewhere during the trip
- Travel time
- User experience (fare, AC, wheelchair accessibility, etc.)
- Trip itinerary
- Trip start and end times

Onboard surveys temporal sampling will focus only on morning periods (morning peak and off-peak) with 3 surveys done per route leg, given each route has two route legs, this is a total of **6 surveys per route**.

Figure 10-6 Example of an Onboard survey results with boarding and alighintg locations

10.3.3 Frequency

Purpose

Frequency surveys determine the average headway of minibus services. These surveys will be performed at the terminals.

Method

This survey will focus on the same list of routes covered in the onboard surveys. Given headway values may change according to demand and travel time, we will target 3 different time intervals during the morning period and get average headway for each.

A field researcher will visit a terminal and choose a location with clear view of a given route's queue or vehicle parking location. They will proceed to record the time at which every vehicle departs from the terminal. This is done for a pre-defined duration (e.g., 90 minutes). Data collection will be fully digital using TfC's "Observer" app. This data will later be used to estimate average headways per time interval across a typical weekday.

Routes will be observed from one side, that is, one terminal. Which side to be chosen to observe a route's frequency is to be determined based on which side is more organized, thus making the FR able to observe vehicles departing more accurately and comprehensively.

10.3.4 Section Counts

Purpose

Given the city's road network topology, most transit routes connect the city centre to the suburbs through a few main corridors. Section counts at those corridors are to be used for validating frequency surveys at the terminals.

Method

Based on the trip itineraries collected in onboard surveys, section counts are to be conducted on corridors with the most overlapping routes. Two field researchers will be deployed, one on each side of the road, counting PT vehicles passing within a defined duration.

10.4 Software Tools

In addition to using off-the-shelf software tools such as the GIS desktop software (QGIS) and MS Excel to manage and edit data, the team made use of custom-built tools to support the data collection and analysis.

10.4.1 RouteLab Suite

RouteLab is the software suite developed by TfC to facilitate paratransit data collection and field research project management. The suite is composed of a set of web-based tools to monitor, process and validate field survey data; and a mobile app for field researchers named "Observer".

The web-based dashboard is used by project managers, field research managers, and data processors to do the following:

1. Define sampling parameters: **When** do we want to capture surveys? **Where** do we capture surveys?

2. **Build** an index of the **PT network**: to be surveyed: Create and manage terminals, routes, agencies, etc.
3. **Monitor** field research **progress**: in real-time, how many surveys are submitted? How many field researchers are doing surveys and how many surveys per FR? How many surveys are collected, compared to how many were deemed "valid" by data processors?
4. **Validate** and **Process** incoming survey data: Use "Snapper" web-based tool that is embedded in the RL Dashboard to align raw GPS traces to the road network; **Mark surveys** as valid or invalid, if invalid the survey is reassigned to FRs to do again.
5. **Export** raw and processed survey data into different formats.
6. **Transform** processed survey data into **GTFS** format.

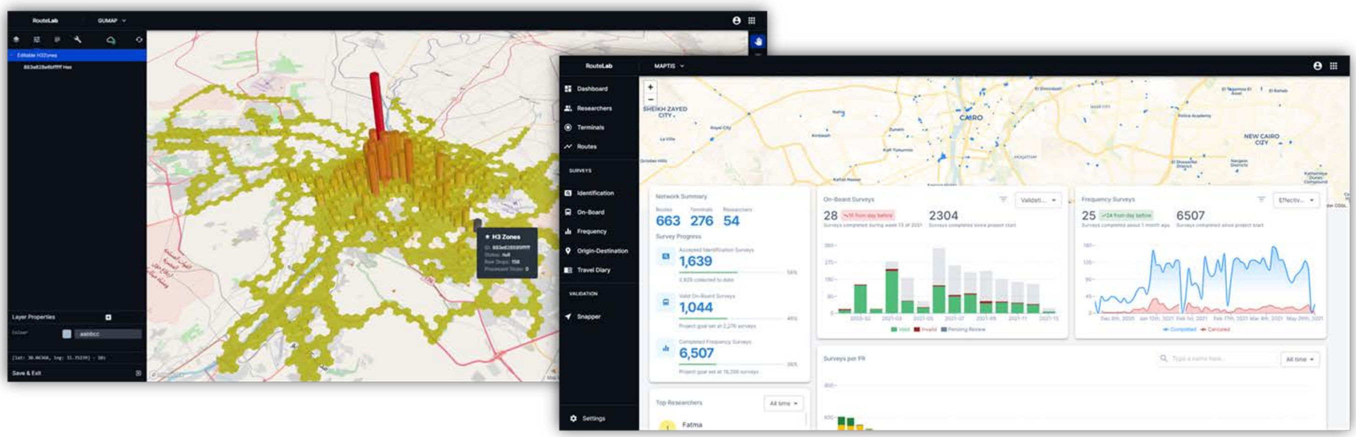


Figure 10-7 RL Dashboard

FRs use the "Observer" mobile app, which is connected to the project set up on the RL dashboard. Thus, the app shows the surveys assigned for FRs at their given location and at the designated time. FRs can see on a map which terminal they should head to in order to start boarding a given route, and how many times they should repeat each survey within a given time interval.

This system allows for a dynamic, semi-automated assigning system for FRs in the field by showing FRs the closest assignments to them they can start at any given time/location. In the back-office, the FR manager or data processor can see where the FRs are at any given moment while performing surveys and their individual survey progress and intervene or give direction if need be.

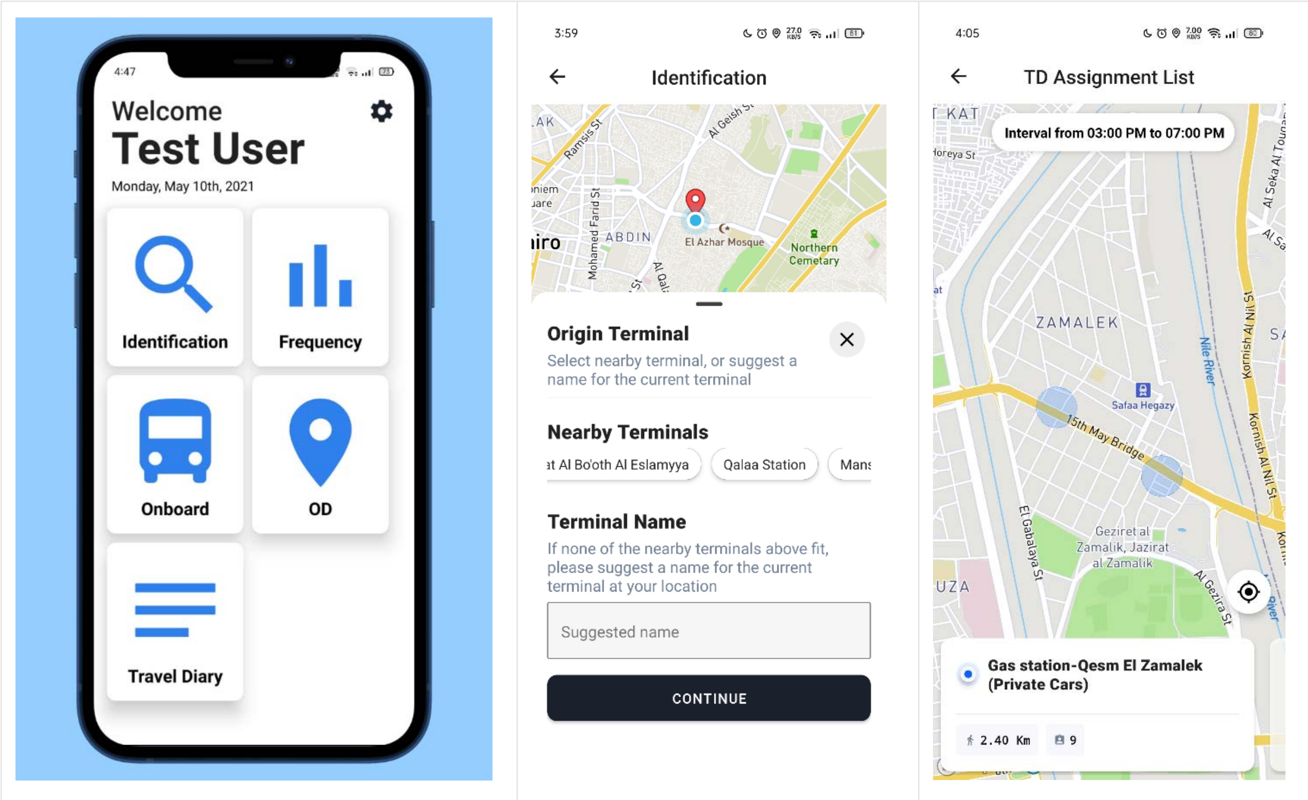


Figure 10-8: Observer Mobile App

10.4.2 gtfs2emis

As its name indicates, gtfs2emis is an R software package dedicated to modelling GHG emissions from public transport routes using GTFS feed as its main input. In addition to GTFS, the package takes as input basic fleet characteristics, including vehicle age, technology, fuel, and Euro stage (Based on European emission standards)[19]. The package implements multiple published emissions models, each requiring its own set of fleet description variables.

The package was released in 2022, introducing a novel method for estimating GHG emissions. Previous methods in the literature require more data such as live GPS traces. The application of gtfs2emis for Lusaka's PT network is considered to be a somewhat novel exercise where the standard GTFS data collection and analysis workflow the team has built over the years is supplemented by GHG modelling exercise.

[19] Vieira, J. P. B., Pereira, R. H. M., & Andrade, P. R. (2022). Estimating public transport emissions from GTFS data with gtfs2emis