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solutions plus

Final Report

Feasibility assessment to electrify feeder three-wheeled vehicles in Dar es Salaam

Imprint

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Contributing partners
Several SOLUTIONSPlus partners participated to the report drafting, related data collection activities and workshops: Urban Electric Mobility Initiative (UEMI), Dar Rapid Transit Agency (DART), the Institute for Transportation and Development Policy (ITDP) and Deutsches Zentrum für Luft- und Raumfahrt - German Aerospace Center (DLR).

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UITP ADVANCING PUBLIC TRANSPORT

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UN environment United Nations Environment Programme

UN HABITAT FOR A BETTER URBAN FUTURE

PLUSERVICE.NET Integrated Information System for Mobility

T-Systems

Partnership on Sustainable Low Carbon Transport

ZLC TALENT HUB FOR SUPPLY CHAIN Zaragoza Logistics Center

Table of contents

List of abbreviations

BRT	Bus Rapid Transit
CC	Cubic Centimetres
CKD	Complete Knocked Down
CPF	Custom Processing Fee
DART	Dar Rapid Transit Agency
DIT	Dar Institute of Technology
DLR	Deutsche Zentrum für Luft- und Raumfahrt
E2Ws	Electric two-wheeled vehicles
E3Ws	Electric three-wheeled vehicles
EAC	East African Community
EUR	Euro
FAME	Faster Adoption and Manufacturing of Electric Vehicles
FO	Frequency occupancy
GPS	Global Positioning System
ICE	Internal combustion engine
IEC	International Electrotechnical Commission
IQR	Interquartile range
ISO	International Organization for Standardization
ITDP	Institute for Transportation and Development Policy
km	kilometer
LATRA	Land Transport Regulatory Authority
li-ion	Lithium-ion
LFP	Lithium iron phosphate battery
OEM	Original Equipment Manufacturer
pphpd	Passengers per hour per direction
RDL	Railways Development Levy
SKD	Semi Knock Down
TCO	Total cost of ownership
TBS	Tanzania Bureau of Standards
TRA	Tanzania Revenue Authority
TZS	Tanzanian Shillings
UEMI	Urban Electric Mobility Initiative
USD	US dollar
VAT	Value Added Tax

List of figures

List of tables

Executive summary

The SOLUTIONSplus project aims to accelerate change towards sustainable urban mobility through innovative and integrated electric mobility solutions. In Dar es Salaam, the project promotes the electrification of three-wheelers providing feeder services to the bus rapid transit system (BRT), tests innovative modes such as pedal-assist electric bicycles for urban deliveries and identifies policies to remove barriers to sustainable and electric urban mobility. The partners forming the SOLUTIONSplus Living Lab in Dar es Salaam are the Rapid Transit Agency (DART), UN-Habitat, UN Environment, the Institute for Transportation and Development (ITDP Africa), the Urban Electric Mobility Initiative (UEMI), the Wuppertal Institute (WI) the Deutsches Zentrum für Luft- und Raumfahrt - German Aerospace Center (DLR), FIER Automotive, and PluService.

To prepare for the electrification of three-wheeled vehicles ("bajajs") currently providing BRT feeder services, partners conducted a feasibility assessment in two successive steps.
First, data was collected on six corridors with existing bajaj supply and connectivity with the BRT system. The purpose was to assess technical, financial, and organisational characteristics as well as trip patterns of existing fossil-fuelled bajajs and drivers, to engage with these drivers to identify their needs and requests for the transition to electric mobility, and to determine potential routes where electric three-wheeled vehicles could be introduced. In a subsequent step, the regulatory, fiscal and market environment was analysed to identify the conditions for deploying electric three-wheeled vehicles as well as the adequate technology and charging strategy.

Recommendations

Transparency of data

- This report shall be made publicly available to transparently provide information to innovators interested in providing electric three-wheeled vehicles and related equipment. Making it available to a wide range of stakeholders, including decision-makers, government authorities, research institutions, and international organisations interested in scaling-up the pilot will allow opening the discussion on enabling conditions for the e-mobility transition.

General requirements for the pilot

- Integrating the views and preferences of bajaj drivers and their associations is essential to ensure a just and efficient transition. In particular, the pilot needs to consider three key needs identified by the drivers: sufficient range, vehicle robustness, and availability of spare parts.
- Disruptions should be avoided as much as possible, for instance, by limiting immobilisation to recharge during the day or avoiding designs varying too significantly from current models.
- Opportunities should be reaped as much as possible, for instance, by reducing operational costs for drivers and increasing net revenues.

Daily mileage in the pilot

- Surveyed drivers want electric bajajs to allow them to operate with a similar mileage compared to internal combustion engine (ICE) vehicles. The average daily mileage with ICE bajajs in the areas studied is found to be 120 km going up to 136 km (upper value of the interquartile range).
- The e-bajaj specifications and the charging strategy should be designed to allow a similar daily mileage while disrupting as little as possible current operational patterns of drivers and limiting the extent of costs.

Key characteristics for e-bajaj and charging in the pilot

- The international and local market analysis of electric three-wheeled vehicles shows that nearly all models enable *less* than 120-136 km on a single full charge. Only a few models come close to this range, such as the Mahindra Treo, with an indicated typical 130km on a single charge. Even in that case, the stated range should be taken with caution as it may decrease in case of high loads, slopes or poor road conditions. Allowing for additional charging during the day would provide more flexibility and reduce range anxiety.

- Based on the market analysis, two alternative options can be considered. It will be up to the innovators answering the upcoming call for funding to show how their proposed combination of vehicle parameters, charging frequency and strategy enables achieving the objectives stated above in “General requirements for the pilot” and “Daily mileage”. SOLUTIONSplus industry partners will evaluate how the proposals can match these requirements.

  A. **Overnight charging combined with limited top-up during the day**.
  To avoid immobilisation as much as possible during the day, most of the charging should take place overnight. Charging during the day should serve as a limited top-up, not necessarily requiring a full charge.

     Main charging: overnight. For this system to work, the battery should be sufficiently big to cover most of the needs on a single overnight charge. When looking at available products internationally and locally (variation of 12-17 km enabled by 1 kWh depending on the vehicle parameters and OEM estimations), this would be best achieved with a battery of circa 7 to 8 kWh. Smaller batteries would involve more frequent or longer recharge phases and vehicle immobilisation during the day. Larger batteries would unnecessarily increase vehicle costs, which are already high, especially considering the 46.7% of taxes adding to the equipment cost. An additional option of increasing the range by adding solar panels on the vehicle roof may be considered, yet with specific care as panels will increase the weight.

     Complementary day charging. Day top-up charging could be done either at a slow or fast rate. This choice will depend on the frequency and duration of power cuts: these have been reported as happening more frequently in the last trimester of 2022, which may not enable sufficient uninterrupted phases of access to electricity to allow for slow charging. On the other end, slow charging could be less costly in terms of equipment and have lower impact on the battery.
     Off-peak periods when drivers have fewer clients or during lunch breaks should be used to recharge the vehicle during the day. The focus group with drivers at two waiting points identified such phases of low demand, which should be refined with the drivers and their associations at the waiting points selected by the SOLUTIONSplus team for the pilot.

  B. **Battery swapping**. Exchanging depleted batteries at swap stations could be an alternative option to limit the immobilisation of e-bajajs during the day. However, this option could be disadvantaged by a couple of inherent challenges. First, ensuring that batteries are available at a swap station requires a larger pool of batteries, which incur additional investment costs potentially disproportionate for a small pilot. Secondly, swapping large batteries would require dedicated staff at the swap station as they are heavy, as seen via various electric moto-taxis companies in the East African region. Lastly, there is less feedback on such schemes, although it is gaining traction in India. If selecting this option, the innovators should justify the choice and indicate how these challenges will be mitigated.

- Prices of circa 3,500 to 3,800 USD for imported plug-in vehicles can be expected, increasing to 4,100 USD for swapping vehicles, before importation. Import taxes and other taxes amounting to a total of 46.7%, plus different additional charges (shipping charges, port charges, freight agent's commission) will add to these costs. When adding taxes, total vehicle costs of 5,130 to 5,574 USD (plug-in) and 6,000 USD (swapping) are found. Locally products seem available for approximatively 5,000 USD, including taxes.
  To increase the number of vehicles to be deployed, it is recommended to consider the entire business model, integrating the leasing fees paid by drivers. Instead of financially supporting the full purchase of vehicles, the SOLUTIONSplus pilot should provide complementary funding to innovators planning to enter or already active in the market ("gap funding"). For instance, the funding can cover part or totality of the costs of deposits requested from drivers, or the cost of additional batteries required in the case of a swapping scheme.

Additional characteristics for e-bajaj and charging in the pilot

- **Seating capacity**: the regulatory environment set by the transport regulatory authority LATRA and the standardisation authority TBS needs to be respected, such as the limitation to three seating passengers verbally requested by LATRA in February 2022, except if a local innovator can prove that a vehicle with a higher seating capacity has obtained a legal authorisation to operate from a Tanzanian public authority.
- **Overnight charging**: selecting an overnight charging modality (plug-in, detachable battery, portable charger) should be done carefully to ensure its feasibility and acceptability with regard to current night parking patterns. Depending on the waiting point, half or more drivers do not park at night at home but at a guarded parking space, for instance, at the political party's office or a supermarket. For these cases, and if a third party is currently involved in providing guarded space, it is desirable to involve this entity in the pilot. In both instances of charging at night at home or a protected parking space, further discussions are needed with the drivers and the association to refine the identification of night parking patterns. In addition, further discussions are required with the association and chairmen to refine the understanding of the frequency and duration of night power cuts.
- **Availability and affordability of spare parts**: this is a key request from drivers, which needs to be documented by innovators.
- **Maintenance and repairs**: this is a key aspect to ensure the pilot's sustainability and must be documented by innovators.
- **Local assembly**: this is a strong bonus for the selection of innovators.

Operational modalities

- Drivers and their waiting point associations should be tightly involved in the transition, as done throughout the surveys and focus groups.
- Using a ride-hail app seems less of a facilitating lever in the surveyed locations. If considering the introduction of an app, the reasons drivers currently do not use privately provided apps in these locations should be better understood (potential factors: low level of digital apps in general, sufficient trip demand without the need for apps, financial impact, trust, etc.).

Financial modalities

- Shifting to e-bajajs may reduce the drivers' operational costs by removing particularly high fuel costs, which currently represent nearly half of their daily costs. The extent of benefits will depend on the level of electricity fees and require an analysis of the total cost of ownership (TCO). This should be further assessed and communicated to drivers and associations.
- Setting a reasonable level of leasing fees for the e-bajajs may give the opportunity to ensure a just transition. In addition, the pilot must integrate the preference of bajaj drivers for a lease-to-own scheme to access the e-bajajs.

Selection of areas to deploy

- Eight criteria were examined for each corridor and waiting point located near a BRT station: existing demand for ICE bajaj services, BRT connectivity, organised area for bajaj services at the waiting point, road condition at the waiting point, available space for parking and charging at the waiting point, the interest of drivers in an e-mobility pilot, the topography of the corridor, and road condition of the corridor.
- This analysis shows that each waiting point and corridor has different advantages and flaws. Some locations present more challenges, such as poor road conditions of the route and/or the waiting point or lack of space for charging purposes at the waiting point.
- The two locations scoring higher on most criteria, and selected by the SOLUTIONSplus team for the pilot, are Kimara Korogwe-Maji Chumvi and Njia Panda ya Chuo-Changanyikeni.

Interest of the drivers

- The general interest of the drivers in an e-bajaj pilot (82% of them) is a positive factor for the project. Selecting waiting points where drivers showed clear interest in the pilot is important for local ownership of the project and continuous dialogue.

Policy environment

- Some elements of the regulatory environment are not fully clear, such as the maximum passenger seating capacity or the tax conditions. There is a need to clarify these with government authorities further.
- In particular, e-mobility start-ups face a challenge in receiving the incentive granted to semi-assembled vehicles in the East African Community, which should reduce the overall taxation level from 46.7% to 31.7%. Discussions to clarify this aspect will be necessary. Going forward, a debate on the level of taxes will be essential to identify pathways to facilitate the e-mobility transition and provide incentives compared to ICE vehicles.

SolutionsPlus

Feasibility assessment to electrify bajajs in Dar es Salaam

Introduction

Background

The SOLUTIONSplus project aims to accelerate change towards sustainable urban mobility through innovative and integrated electric mobility solutions. To deliver this objective, the project brings together highly committed cities, industry, research, implementing organisations and finance partners. It supports the integration of different types of electric mobility in large urban areas, addressing user needs and local conditions in Europe, Asia, Africa and Latin America.

In Dar es Salaam (Tanzania), the project aims to integrate electric three-wheelers as feeder services to the bus rapid transit (BRT) system, test innovative modes such as pedal-assist electric bicycles for urban deliveries, as well as identify policies to remove barriers to sustainable and electric urban mobility.

The partners forming the SOLUTIONSplus Living Lab in Dar es Salaam are the Rapid Transit Agency (DART), UN-Habitat, UN Environment, the Institute for Transportation and Development (ITDP), the Urban Electric Mobility Initiative (UEMI), the Deutsches Zentrum für Luft- und Raumfahrt - German Aerospace Center (DLR), and PluService.

Objective of the study

To prepare for the electrification of three-wheeled vehicles (commonly named “bajajs” in Dar es Salaam), already providing feeder services to the BRT, the partners conducted a feasibility assessment including two successive steps: data collection of ICE vehicles on selected corridors, followed by an analysis of the regulatory and market environment.

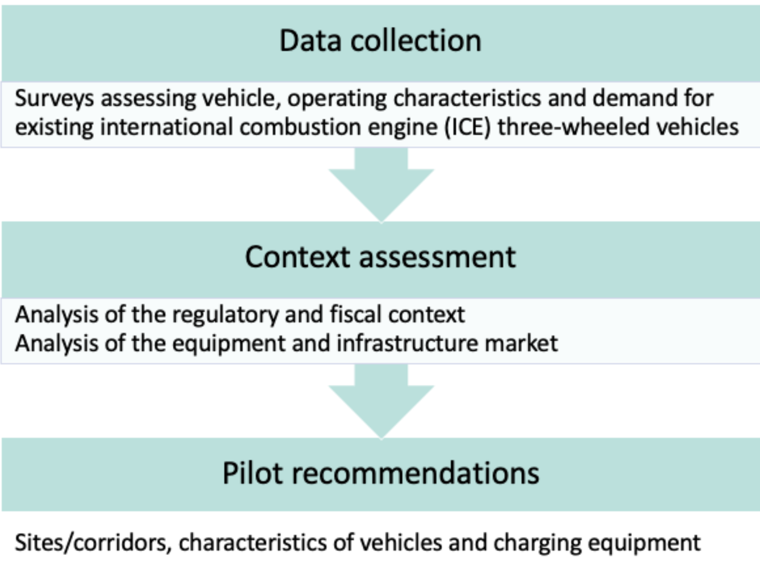


Figure 1: Feasibility assessment process.

This report compiles results from these two steps, concluding with recommendations to pilot the electrification of three-wheelers providing BRT feeder services.

Part 1: Data collection of existing conventional bajajs

1. Process

As the first part of the feasibility assessment, a multi-method data collection was conducted to assess characteristics of current ICE bajajs, determine potential routes where electric three-wheeled vehicles could operate and identify waiting points where they could start and end their trips.

The data collection process included five methods providing complementary information, depicted in Figure 2.

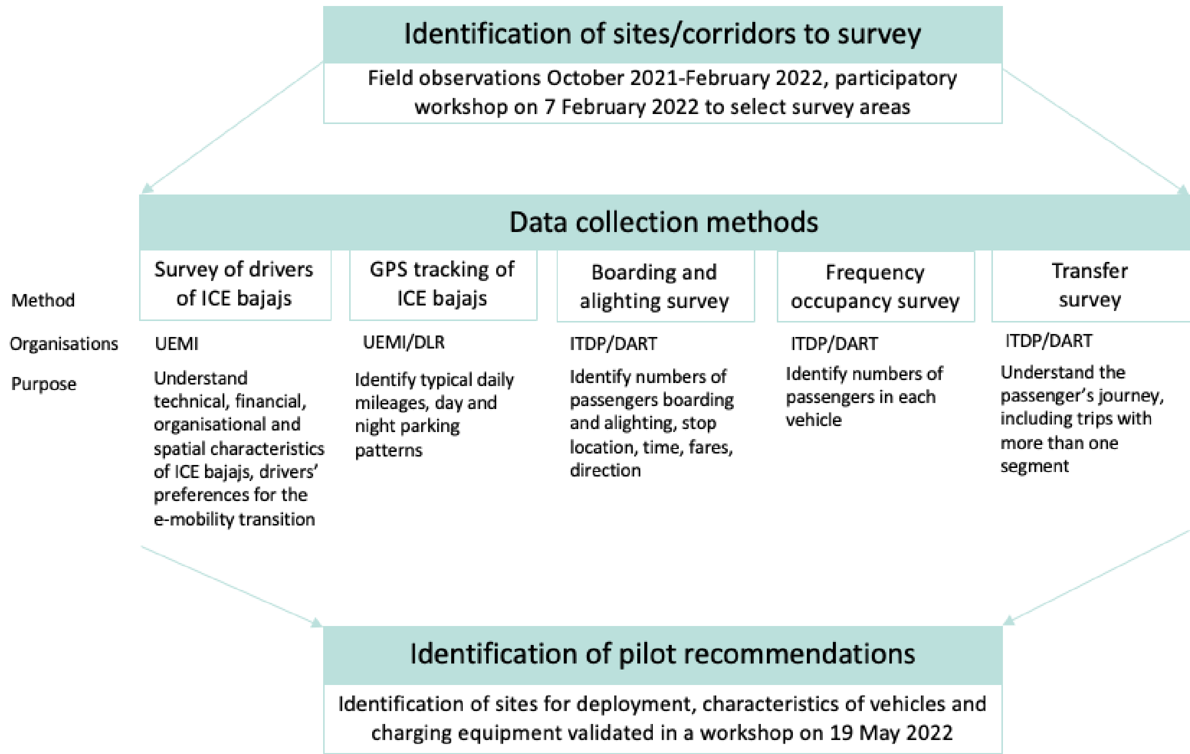


Figure 2: Data collection process.

2. Selection of waiting points and corridors to survey

The SOLUTIONSplus team made observations to identify existing waiting points and corridors of three-wheeled vehicles already feeder services to the BRT Phase 1 corridor along Morogoro Road from Kimara to Korogwe.

The team used multi-criteria analysis to select six high-priority corridors on which surveys would be conducted. The analysis considered the following initial criteria: existing bajaj demand, connectivity to BRT, road condition and terrain.

To avoid modal competition and legal uncertainty, corridors located on the route of future BRT lanes were excluded, as well as routes where bus services (dala-dala) currently provide BRT feeder services. Locations in the city centre were excluded, either competing with future BRT deployment or in the context of uncertainty regarding the future legal framework for these areas, as indicated by the Land Transport Regulatory Authority (LATRA) in a meeting in February 2022.

Field observations in October 2021 and February 2022 allowed screening of potential waiting points and corridors regarding the criteria mentioned above: existing bajaj demand, connectivity to BRT, road conditions, and terrain.

The six corridors selected to conduct the surveys, as shown in Figure 3, included:

- Njia panda ya Chuo-Changanyikeni;
- Kimara Korogwe-Maji Chumvi;
- Kimara Mwisho-Kwa Komba;
- Kimara Mwisho -Bonyokwa;
- Mbezi Mwisho-Goba; and
- Mbezi Mwisho-Kifuru.

Figure 3: Phase 1 BRT corridor and six current corridors with conventional three-wheeled vehicles

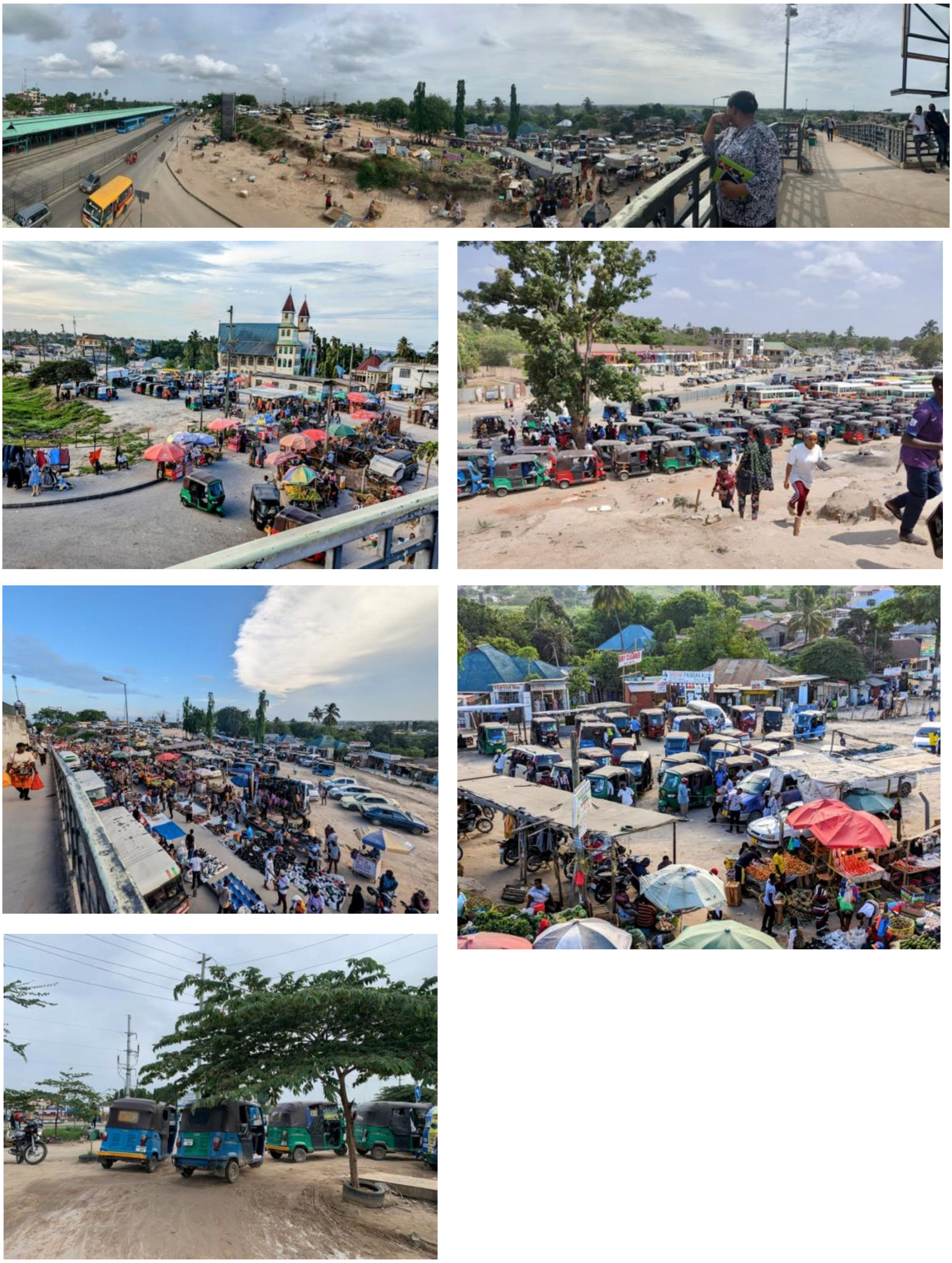


Figure 4: Waiting points.
From top-left to bottom-right, Kimara waiting point at BRT station leading to Bonyokwa, Kimara waiting point at BRT station leading to Kwa Komba, Mbezi Mwisho BRT terminus leading to Goba, Mbezi Mwisho BRT terminus leading to Kifuru (two pictures), waiting point at Njia panda ya Chuo leading to Changanyikeni.

3. Methodology

For the six corridors, the SOLUTIONSplus team identified waiting points located near BRT stations, where bajaj drivers wait for passengers during the day: Kimara Korogwe, Kimara Mwisho (northern side of the terminal towards Kwa Komba, and southern side towards Bonyokwa), Kimara Mwisho (northern side towards Goba, and southern side towards Kifuru), and Njia panda ya Chuo (Njia panda ya Chuo at the intersection of Sam Nujoma and University Road, going towards Changanyikeni).

While identifying these waiting points, the SOLUTIONSplus team engaged with drivers to determine the existence of a waiting point association and its chairman (Figure 5). The SOLUTIONSplus project was presented to drivers. If unavailable at the site, subsequent contacts were made to request the chairman's authorisation to conduct surveys with the drivers and deploy GPS trackers.

Figure 5: Engaging with the waiting point association at Njia panda ya Chuo to Changanyikeni

On 28 February 2022, the SOLUTIONSplus team trained the surveyors at the DART offices on the methodology for boarding and alighting, frequency-occupancy, and transfer surveys.

Figure 6: Survey training.

3.1. Survey of drivers of ICE bajajs

The survey of drivers had a dual purpose:

- Identify technical, financial, organisational, and spatial characteristics of ICE three-wheelers, refining or confirming data previously collected by DLR (Goletz et al., 2021). This step supports the identification of the technical specifications of electric vehicles and charging strategy, for instance, overnight or during the day.
- Assess the interest and preferences of current bajaj drivers for electric bajajs. Integrating their preference when identifying future business models is key.

Following the identification of waiting point associations, contact with the chairman and authorisation granted, a questionnaire was collaboratively drafted and translated into Kiswahili. Surveyors were trained to use the app "Magic Device" and tested the questionnaire before conducting the survey at the pre-identified waiting points in February 2022.

The questionnaire included closed questions, except for questions asking about numbers (for instance, the amount spent on fuel) or with a too high number of possible answers, such as the place of residence. Drivers were asked about values in Tanzanian shilling (TSh). Results are presented in this report in Tanzanian shilling and approximative value in US dollars (USD), as per the conversion rate of the 6th of May 2022.

To refine the findings, small focus groups were subsequently organised with the drivers and chairman of the waiting point's association at the two waiting points showing favourable conditions (connectivity to the BRT, bajaj demand, road condition, etc.) and a particular interest in the project.

Figure 7: Bajaj at Mbezi Mwisho (southern part)

3.2. GPS tracking of ICE bajajs

A GPS survey with 20 drivers of ICE bajajs identified at the waiting points was conducted between March 19 and April 23, 2022. Tracking devices from the company Develogix Technologies specialising in GPS data collection, were used and installed in the ICE bajajs (Figure 8). Mileage patterns for all bajajs were retrieved from an online platform and validated using the collected GPS tracks.

Collecting and analysing GPS data from bajajs can help capture and evaluate local needs and assist in identifying appropriate solutions to enable the transition to e-three-wheelers. The purpose of the analysis was to provide insights into daily distances, movement, and parking patterns. This helps assess the needed characteristics of e-bajajs with regards to battery size, charging infrastructure at day and night, charging times. In addition, an overview of frequently used night parking areas can help assess, for instance, suitable locations for overnight charging parking areas if not parked at home.

Figure 8: GPS installation on one ICE bajaj.

3.3. Boarding and alighting survey

Surveyors used the Locus (Android) and MyTracks (iPhone) applications for boarding and alighting surveys. The purpose of the study is to capture the following information:

- For each stop:
  - Number of passengers boarding
  - Number of passengers alighting
  - Stop location (captured automatically by the device)
  - Time.

- For the route:
  - Route number
  - Fare paid
  - Direction (i.e., inbound or outbound).

Surveyors captured information in both directions along each route. The team collected data during the morning peak from 6:00 to 10:00 hours and the evening peak from 15:00 to 19:00 hours.

3.4. Frequency-occupancy survey

For the frequency occupancy (FO) survey, the surveyors counted the number of passengers in each vehicle during the peak period at selected locations.

The surveyors stood where they could observe the three-wheeled vehicles and the number of passengers inside. The surveyor recorded each three-wheeled vehicle that passed, its registration number, seating capacity, and the number of occupants inside the vehicle. Surveyors collected data from 6:00 to 10:00 hours and from 15:00 to 19:00 hours.

Figure 9: Frequency-Occupancy survey locations

3.5. Transfer survey

Surveyors conducted the transfer survey using the Device Magic smartphone application. The survey aimed to understand the passenger's journey, including trips involving more than one segment. Surveyors spoke with passengers getting off vehicles at transfer stations. A total of 260 respondents participated in the survey, including 131 females and 129 males. Figure 11 shows a screenshot of the questions in the Device Magic phone application, and Figure 11 shows the surveyors interviewing one of the passengers.


Figure 10: Surveyor interviewing a passenger at Kimara North.

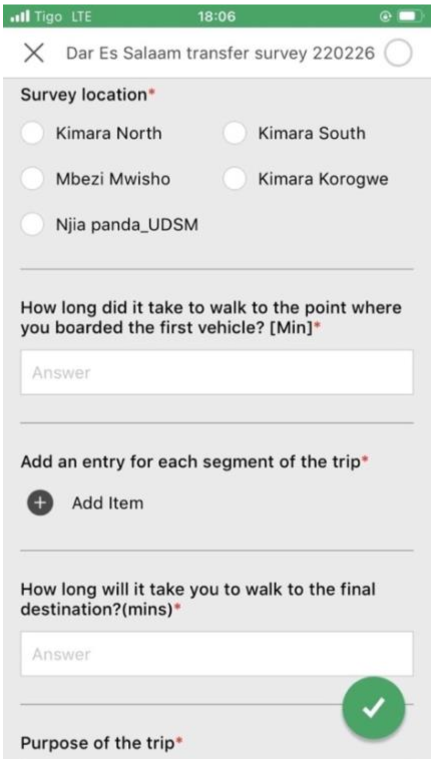
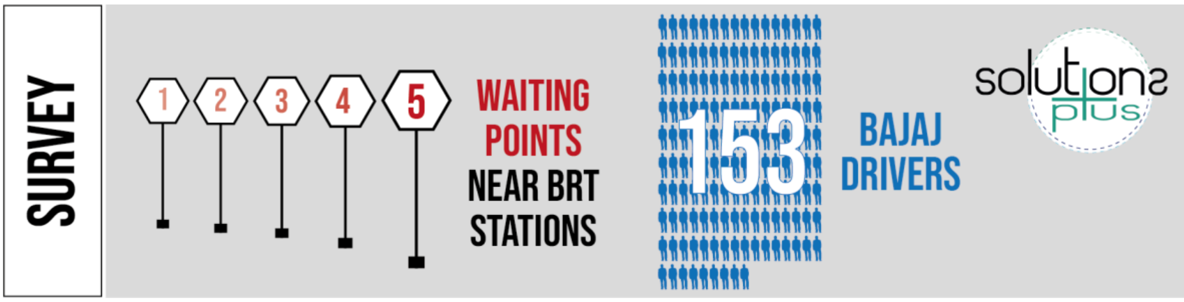


Figure 11: Transfer survey form in the Device Magic application.

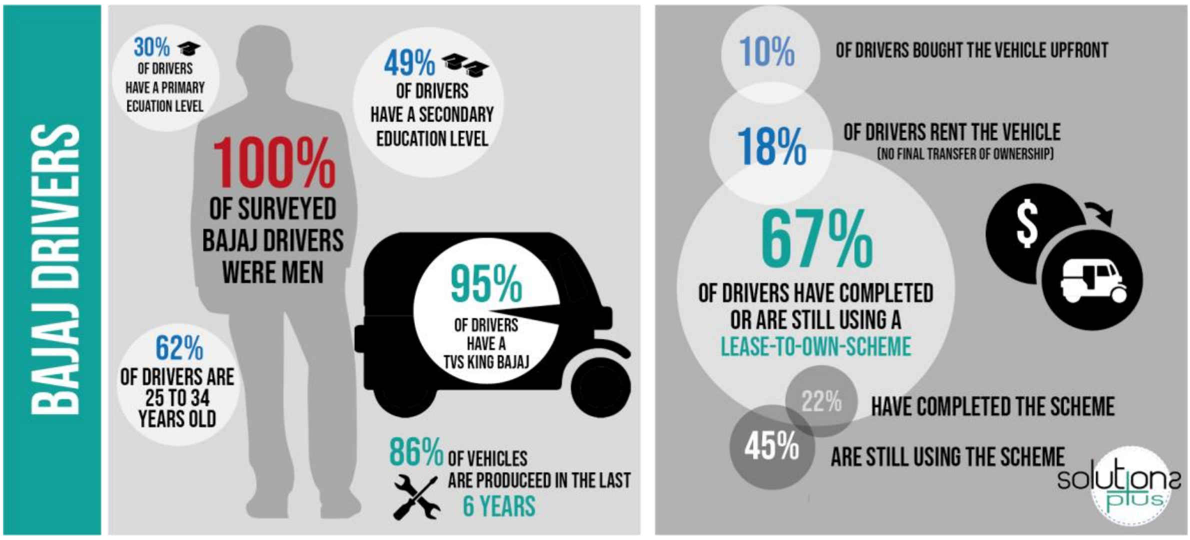
4. Results

4.1. Technical, financial, and organisational patterns of ICE bajajs

A total of 153 drivers were interviewed, exceeding the initial target of 100 drivers. This represents an unprecedented number in terms of data collection with bajaj drivers in Dar es Salaam. After cleaning the data, the sample size is 152. The infographics and comments below indicate key takeaways; detailed results are indicated in Annex I.1.

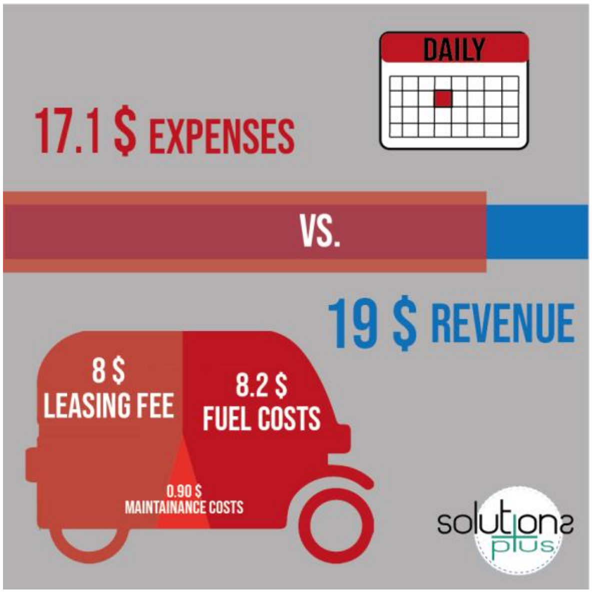


The survey revealed the significant concentration of ICE bajajs on a single brand (TVS King), vehicles mostly not older than six years, and the dominance of a lease-to-own scheme (renting combined with final ownership transfer).



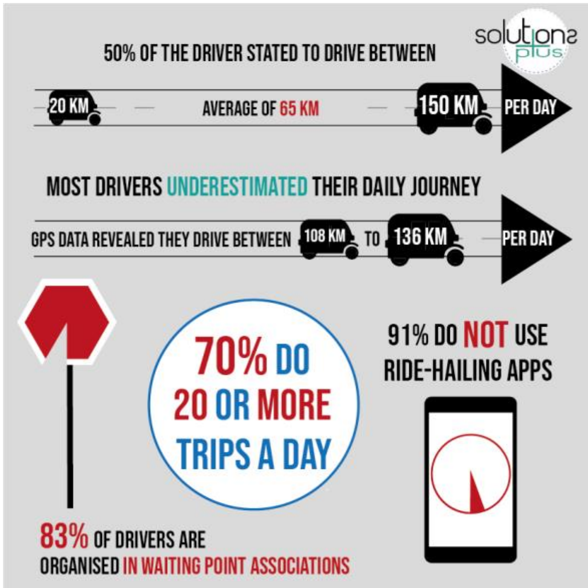
Drivers of current ICE bajajs face high expenses (leasing fees, fuel costs, maintenance costs). These high costs only enable an average take-home income of approximatively 1.9 USD.

Leasing fees of the ICE vehicles represent nearly half of their operational costs. The high fuel costs paid could provide an incentive to switch to electricity.

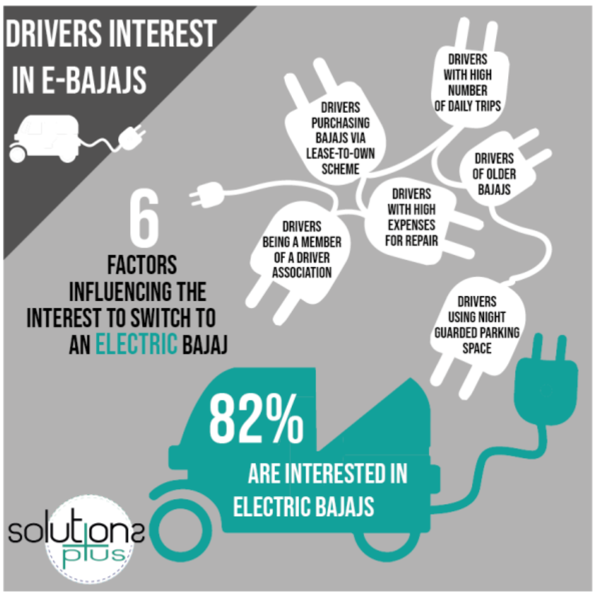


Most drivers estimated to drive between 20 and 150 kms every day, with a median value of 65 kms. This assessment was subsequently lower than the results of the GPS data showing significantly higher average daily mileages (see section 4.2.).

The large majority of drivers make more than 20 trips per day. Most of them are organised in waiting point associations. Only a few of them use a ride-hailing application.

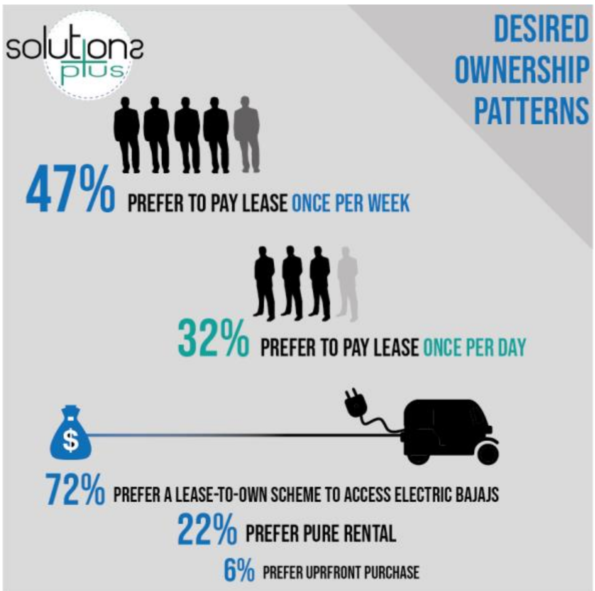


A vast majority of drivers stated to be interested in switching to an electric bajaj. Six factors were identified as increasing the likelihood of the stated intention to change to an electric bajaj.



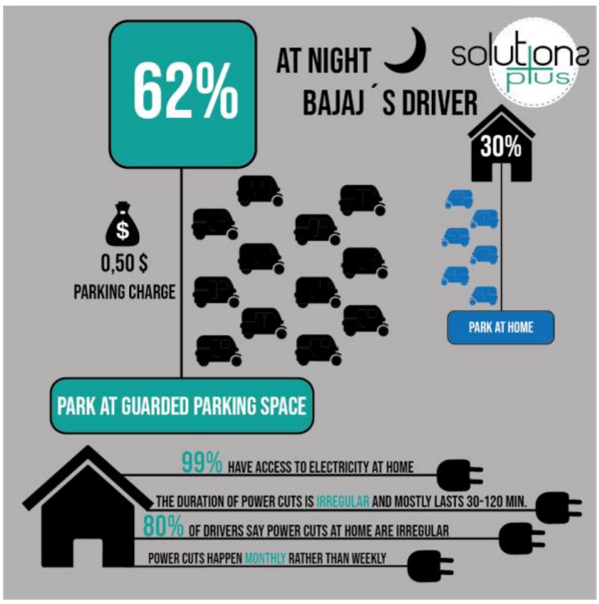
Subsequent focus groups enabled to identify a series of characteristics that electric bajajs should have (robustness, availability of spare parts, sufficient range) and the key aspects that the transition to electric mobility transition must consider, in particular the need for economic benefits and the reduction of operational costs.

A very large majority of drivers would prefer a lease-to-own scheme to access electric bajajs, in continuity with current practices with ICE bajajs (see above).



With regards to night parking, most drivers park their bajaj at night in a guarded parking space (62%). On average, drivers pay approximately USD 50 cents to park their bajaj at night in a protected area. Others (30%) park the bajaj outside of their home.
This information is key to organising overnight charging and selecting a suitable charging strategy.

Nearly all drivers stated having access to electricity at home, yet with irregular power cuts, mostly lasting between 30 to 120 min.



To refine the findings, small focus groups were organised with the drivers and chairman of the waiting point's association at two locations.

Table 1: Focus group discussions at Kimara Korogwe.

Dimension	Kimara Korogwe
	Parking During the day, drivers park at Korogwe waiting point, spending most of the time there. Trip demand is high from the early morning hours to 8 am and 3 pm to 8 pm. Non-peak hours occur from 8 am to 3 pm and 8 pm to midnight, where drivers can wait an average of 2 hrs before getting customers. The area where bajaj drivers park to wait for customers at Kimara Korogwe is owned by TANROADS. Regarding night parking, most drivers park in a guarded space (CCM office, i.e. main party's office, usually providing space as an income-generating activity). They also park at kwa Mzaire or Mkua, a distance of 3.5 km from the Korogwe waiting point, where they pay a fee. Only a few drivers park at home.
	Ownership and business models Most drivers get contracts from individuals, not from companies. Contracts with individuals are considered to work well because most drivers come owners the vehicles at the end of the contract period. This arrangement is seen as giving the driver an incentive to take care of the vehicle. Mkombozi bank has a longer payback of 4 years for the bajaj loans; however, drivers must deposit 2 million Tsh at the beginning of the contract. Most drivers prefer getting into agreements with individual owners because they can't give this deposit at the beginning of the contract.
	E-mobility transition: key aspects for the drivers • *Space*. Drivers asked how much space charging would take. Drivers were wondering if having charging infrastructure will still allow all vehicles, including non-electric ones, to park in the same place. They stress that the space taken for charging equipment should be proportionate to the number of e-bajajs ("we hope it won't take too much space if there are too little three-wheelers using it") and allow other ICE bajaj drivers to still use the area. • *Charging ease and range*. Drivers mentioned the need for flexibility of charging and allowing long trips. The drivers suggested that having a charging point at Kimara Korogwe is the best option for them, but DART will have to consult TANROADS. • *Robustness of the vehicles*. Most drivers currently pay off the contracts at one year and ten months. Drivers would like to see the e-bajaj still in good condition at the end of repayment and working for another 2 to 3 years. Otherwise, if they finish the contract time and the vehicle cannot be used anymore, that would not "work for" them. They want to be able to make a profit out of it. • *Ease of getting spare parts* in terms of price and availability. Some three-wheeler brands failed due to the unavailability of spare parts – waiting times of 2 to 3 days to get the parts - and their high costs. TVS managed to address this challenge, which explains its market domination. • *Seating capacity*: drivers would prefer to have five passengers per vehicle. When SOLUTIONSplus indicated that it would not be allowed by LATRA as verbally indicated by the authority in 2022, drivers insisted, saying that they see three-wheelers operating with a five-passenger seating capacity.

Table 2: Focus group discussions at Njia panda ya Chuo (Sam Nujoma/University Rd).

Dimension	Njia panda ya Chuo (Sam Nujoma/University Rd)
	Parking During the day, drivers spend most of their time at the waiting point. Drivers are usually very busy between 6 am -10 am and 4 pm - 10 pm. On good days, the typical waiting time on off-peak hours, between 10 and 4 pm, is 10-15 minutes. On not-so-good days, the waiting time in off-peak hours is 30 minutes. Most of the time, the drivers wait for 10-15 minutes. At night, most drivers park in one location every night. Drivers may change parking location, but it is infrequent. Among the 80 drivers operating at the waiting point, the chairman estimates that half of the drivers park at home at night while the other half park in different spaces (CCM office, supermarkets).
	BRT connection The chairman confirmed that most users of the three-wheelers connect to the BRT either by walking or, when in a hurry, by a motorcycle with a fee of 1,000 Tsh.

	Ownership and business model The chairman estimates that half of the drivers are currently on contract (paying for lease-to-own or renting), and half already own the bajaj. Pay off times for contracts depend on the terms but usually vary between 1.5 to 2 years. Contract conditions differ from one driver to the other, depending on negotiations. If the driver shares maintenance costs with the owner, the contract becomes longer; when the driver pays for all maintenance costs, the contract is shorter. In most contracts, drivers pay every day except for Sunday. The mode of payment could be daily or weekly, depending on the agreement with the owner.
	E-mobility transition: key aspects for the drivers • Charging. The chairman suggests the charging points to be at the waiting point, but he is unsure regarding who owns the area. Regarding overnight charging, he is unsure whether charging is possible at CCM but suggests the flexibility of charging from home. • Long-lasting charge. • Robust engine and vehicle.

4.2. Daily mileage

Data Analysis

- 4.85 Mio data points provide insights on daily distances, movement, and parking patterns to assess the needed characteristics of e-bajajs (battery size, charging infrastructure at day and night, charging times).
- The number of observations per bajaj varies significantly. While the transmitted data for most GPS trackers amounts to more than 200,000 observations, data from four bajajs show fewer than 50,000 observations for the entire period.
- Data-related challenges included inconsistencies and missing values due to tracking interruptions, technical/connection issues, and GPS device failures. Systematic errors may occur in GPS monitoring due to factors beyond our control (e.g., tracker calibration).

Daily mileage patterns

- The results show that the average daily mileage of all observed bajajs (n=20) is about 120 km. As figure 12 shows, half of the observations (interquartile range, IQR) are between 108 km and 136 km daily (for more information, see Annex I).

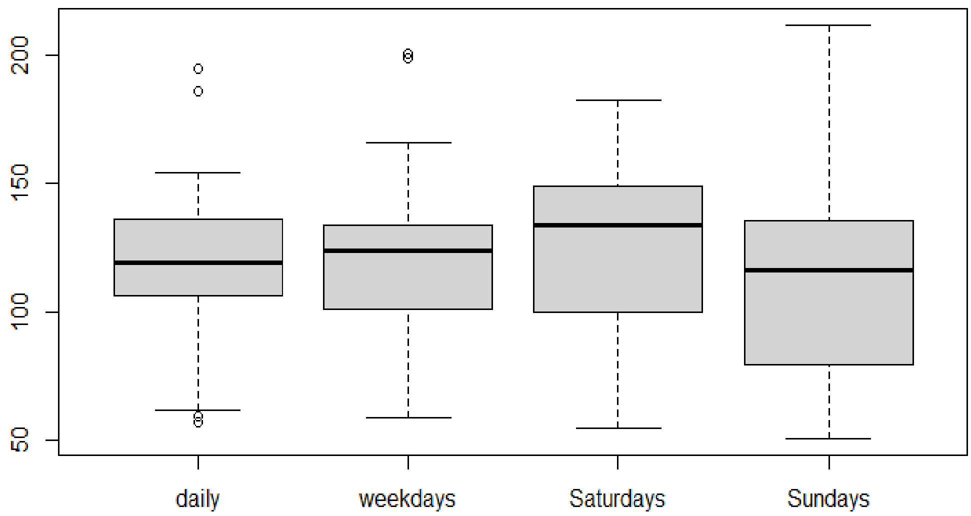


Figure 12: Boxplot of average mileage in km (n=20)

This average daily mileage is higher than findings in previous studies, such as Goletz et al. 2021. This difference may stem from differences between urban areas assessed: while previous

studies looked at bajaj waiting points closer to the city centre, our study focused on waiting points located near BRT stations further away from the centre, where bajajs are used, among others for feeder services and connecting to peri-urban areas, which may explain the longer distances driven every day.
In addition, the difference in the range estimated by the drivers in the driver survey may result from the possible imperfect relationship between the distance perceived by the drivers and the actual (measured) distance.

- The breakdown of average daily mileage by weekdays, Saturdays, and Sundays suggests differences in usage patterns regarding the days of the week. While the daily mileage of all tracked vehicles is relatively close to each other on a daily and weekday basis, the variation seems to be more considerable for the Saturdays and Sundays calculation.

  The average mileage remains relatively robust for all categories (between about 111 km and 125 km); however, notable differences can be observed in the data extremes. For the daily calculation, we obtain an upper 1.5 IQR value of about 154, which increases to about 166 for weekdays, 182 for Saturdays, and 212 for Sundays, respectively.

  Reasons for the difference between weekdays and weekends may include:
    - Less idling time (e.g., due to less traffic or waiting time for passengers),
    - Private hires for out-of-town trips,
    - Or other personal trips of drivers without passengers.
    - Also, the shorter period and the small(er) number of observations in the respective sub-samples could be a reason.

- Considering this, higher daily mileage is critical when designing the battery size and charging modalities. Sufficient battery size will be needed to cover a similar daily range of circa 120 kilometres, potentially requiring a combination of overnight charging and opportunity (daily) charging or a swapping option. This will be further detailed in Part 2, section 3 on available e-three-wheelers and charging equipment, and the final recommendations in Part 3.

4.3. Night parking patterns

- Using GPS data, the main objective is to determine the spatial distribution of night-time parking and investigate if patterns are apparent. The analysis examines locations where units are parking during the night for time windows between 12 and 3 am. The spatial clusters presented in this report refer to the geometric coordinates where the vehicles are located during the identified time windows. Hierarchical clustering is used to identify all data points within 500 m next to each other.

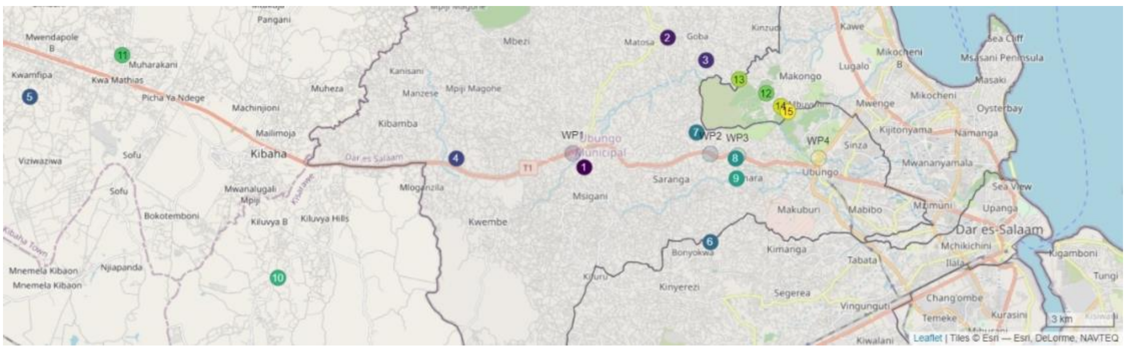


Figure 13: Locations of night parking clusters.

- While three of the clusters are located outside the city boundary, several are located close to the surveyed waiting points.

- The analysis identified a total of 15 locations. Three are near Kimara Mwisho (WP2) and Kimara Korogwe (WP3), and one is on the south side of Mbezi Mwisho (WP1). Three clusters are located along the potential corridor from University Road/Sam Nujoma (WP4) to Changanyikeni.

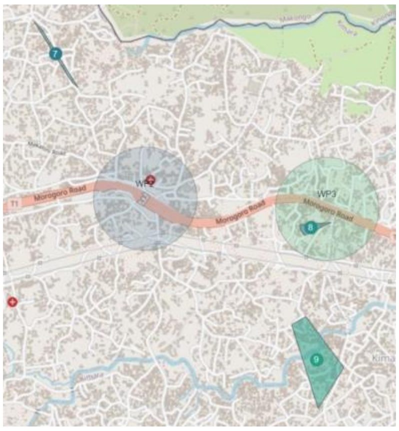


Figure 14: Clusters around WP2 & WP3

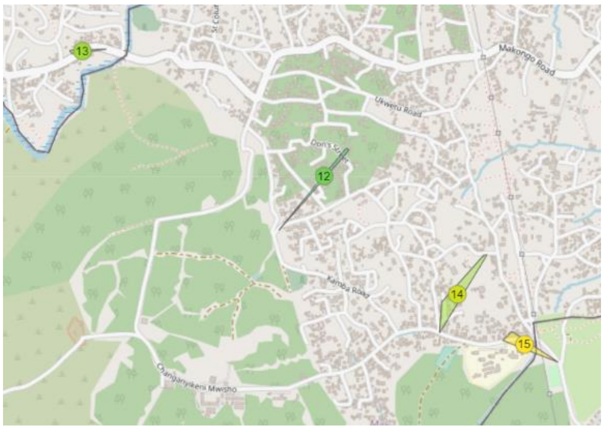


Figure 15: Cluster along the WP4 to Changanyikeni corridor

- The analysis shows that some vehicles exhibit a pattern of parking near the waiting point where they are stationed at night, as shown in clusters 12, 13, and 14 (as depicted in Figure 15). In addition, there are cases where units from different waiting points park close to each other, such as in clusters 7, 8, and 9 (Figure 14).

- The hypothesis that interrelationships between night-time parking locations exist and that drivers from different waiting points park in the same parking spots could not be verified. The distance chosen between the points (500m) or the small sample size, among other factors, may be a reason for this. Nevertheless, the results allow us to conclude the tendency of many bajajs to park at a regular location.

- To refine the identification of suitable locations for overnight charging (such as a guarded parking space or at home), further research is necessary to identify night parking patterns at selected corridors for the pilot study. This could be accomplished through additional focus groups.

4.4. Passenger volumes

Based on the frequency-occupancy data, the highest volume occurs during the 7:00 (morning) and 16:00 hours (evening). Figure 16 shows the passenger volumes during the 7:00 hours and Figure 17 shows the same for the 16:00 hours recorded as passengers per direction per hour (pphpd).

Generally, more passengers travel toward the BRT corridor in the morning and away from the corridor in the evening. During the 7:00 hours, the highest demand was observed from Maji Chumvi towards Korogwe (estimated at 440 pphpd). During the 16:00 hours, the survey revealed the highest passenger volume from Kimara to Bonyokwa (estimated at 340 pphpd).

The residents residing along the Korogwe-Maji Chumvi route depend mostly on two modes of transport: three-wheeled vehicles and motorcycles. In other areas, passengers can use dala-dala minibuses and private taxis; hence a lower volume of three-wheeled vehicles on those routes compared to the Korogwe-Maji Chumvi route.

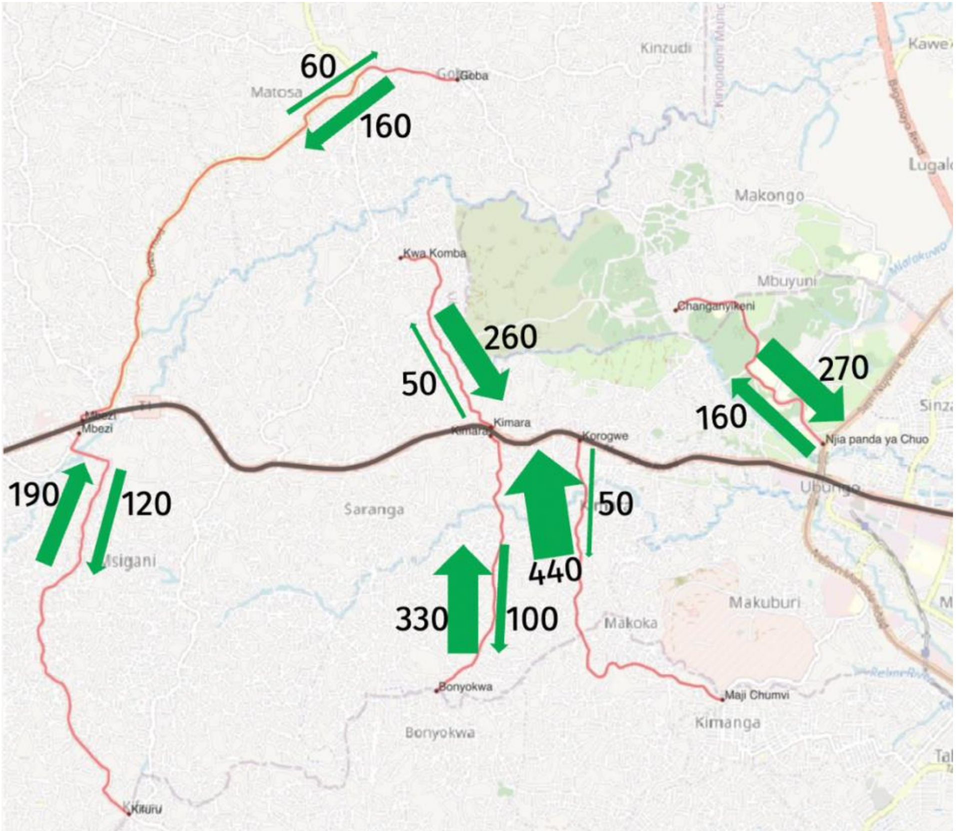


Figure 16: Passenger volumes during the 7:00 hour (passengers per hour per direction).

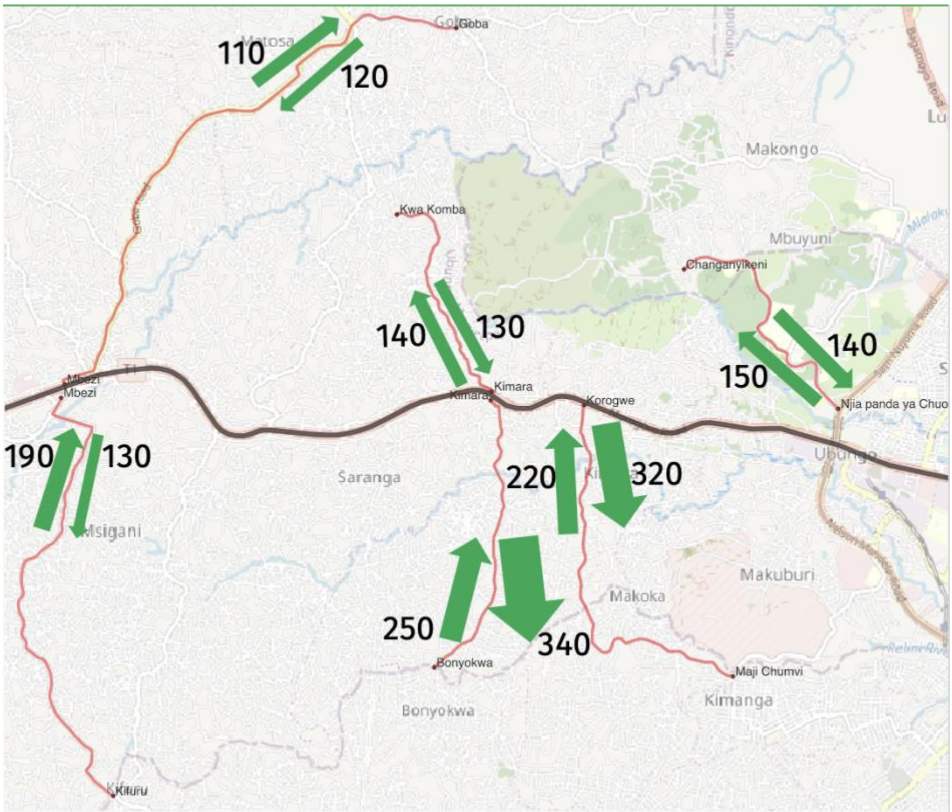


Figure 17: Passenger volumes during the 16:00 hour (passengers per hour per direction).

4.5. Vehicle types

During the survey, other types of three-wheeled passenger vehicles were observed operating in Dar es Salaam; the three-seater and six-seater 3-wheeled vehicles. According to the Land Transport Regulatory Authority (LATRA) as communicated to the SOLUTIONSplus in February 2022, the 3-seat three-wheeled vehicles are licensed, but six-seat vehicles are not.

In the FO surveys, the team observed only 23 six-seat vehicles (0.4% of the total), while the remaining 5,690 vehicles (99.6% of the total) were three-seat vehicles, as indicated in Figure 18. The drivers' survey revealed that 95% drove a TVS King bajaj (section 4.1).

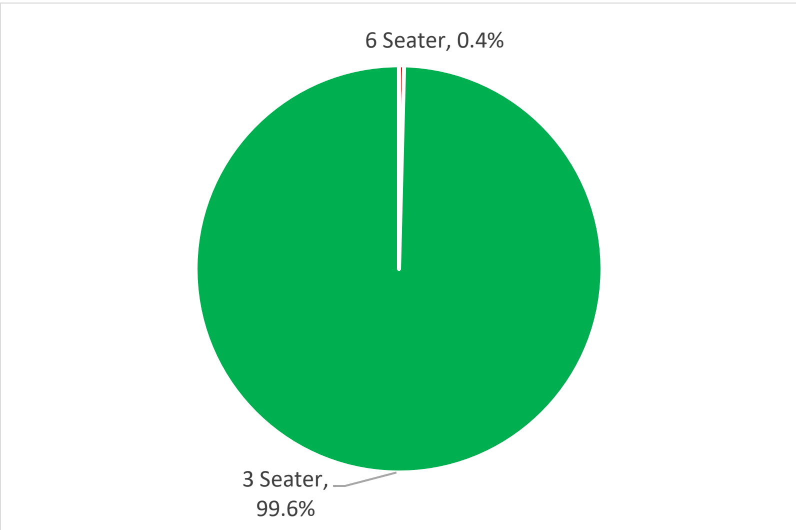


Figure 18: Vehicle types observed in the FO survey.

4.6. Boarding and alighting patterns

Figure 19 and Figure 20 show the expanded boarding and alighting data for the observed routes. The boarding and the alighting survey revealed heavy alighting at the end of the routes towards Morogoro Road during morning hours and heavy boarding along the BRT line towards the outskirts during the evening hours. Along the Korogwe-Maji Chumvi route, there is an intermediate waiting point surrounded by residential and commercial land use, and that is why the volumes are much higher at that point.

Figure 19: Boarding and alighting volumes of three-wheeled vehicles during the 7:00 hour.

Figure 20: Boarding and alighting volumes of three-wheeled vehicles during the 17:00 hour.

4.7. Fleet size

Using the frequency survey and the boarding and alighting survey, the team obtained the demand volumes and speed, which informed estimates for the fleet that may be required to operate these routes. The Korogwe-Maji Chumvi route, which has the highest demand of 440 pphpd, would require a fleet of 67 electric-three vehicles, including a reserve fleet. This information may be useful when determining the number of electric 3-wheeled vehicles that will ultimately operate the pilot route. Table 3 shows the fleet size requirements for the six routes.

Table 3: Fleet sizes

Corridor	Length (Km)	Max load (pphpd)	Average speed (km/h)	Time to make a round trip (hr)	Capacity (pax)	Fleet size (no reserve)	Fleet size (with reserve)
Korogwe-Maji Chumvi	5.7	440	27.6	0.4	3	61	67
Mbezi Mwisho-Kifuru	7	190	28.8	0.5	3	31	34
Mbezi Mwisho-Goba	8.5	160	27.4	0.6	3	33	36
Kimara North-Kwa Komba	3.4	260	9.6	0.7	3	62	68
Kimara South-Bonyokwa	3.8	340	13.1	0.6	3	66	72
Njia Panda ya Chuo-Changanyikeni	3.9	270	26.0	0.3	3	27	30

4.8. Transfer patterns (rates, modes, combination, fares, trip purpose)

4.8.1. Transfer rates

The transfer survey results provide insight into the entire journey, from the time taken to walk to the point where the passenger boards the first vehicle, the mode of transport used, fare paid, the purpose of the journey, and the number of trips a person has to make to complete their journey. Figure 21 shows that 6% of the respondents did not make a transfer, 40% made one transfer, 43% made two transfers, and 10% made three transfers to get to their destinations.

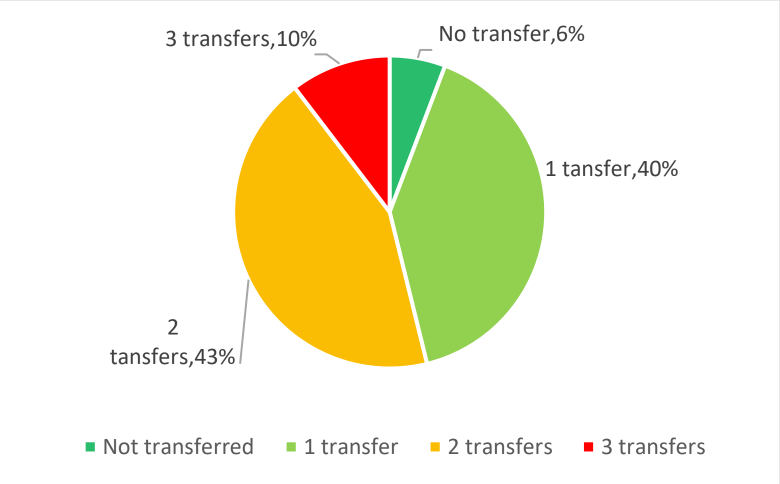


Figure 21: Number of trip segments

4.8.2. Mode used

The survey results reported different combinations of modes of transport that the respondents made throughout their entire trip segments. As indicated below in Figure 22, the bajaj (also bajaji) trips were the most dominant, with a trip combination of bajaj to dala-dala the highest, followed by bajaj to BRT trips.

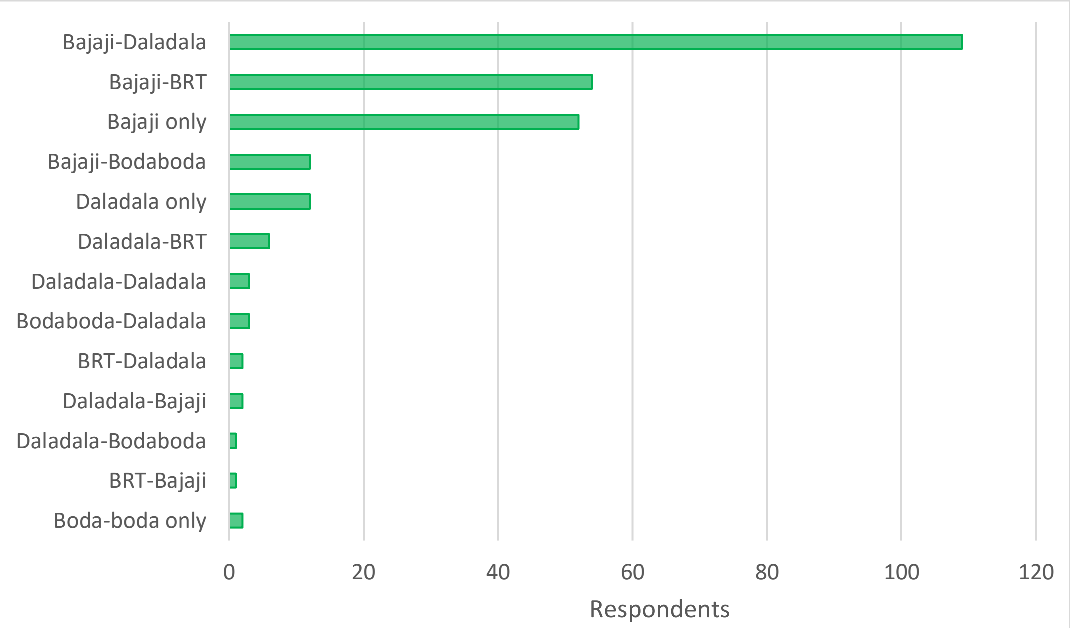


Figure 22: Frequency of transfer combinations.

4.8.3. Bajaj-BRT combination at all waiting points

The survey reported the number of respondents connecting to BRT when getting off the bajaj. 35% of the respondents from Kimara Korogwe connect to BRT as a second mode of transport. At Kimara North and Kimara South, 22% and 24%, respectively, reported connecting to the BRT, while at Mbezi Mwisho_North, only 11% of the respondents transferred to the BRT. 4% of the respondents from Mbezi Mwisho_South and Njia panda_UDSM reported connecting to BRT.

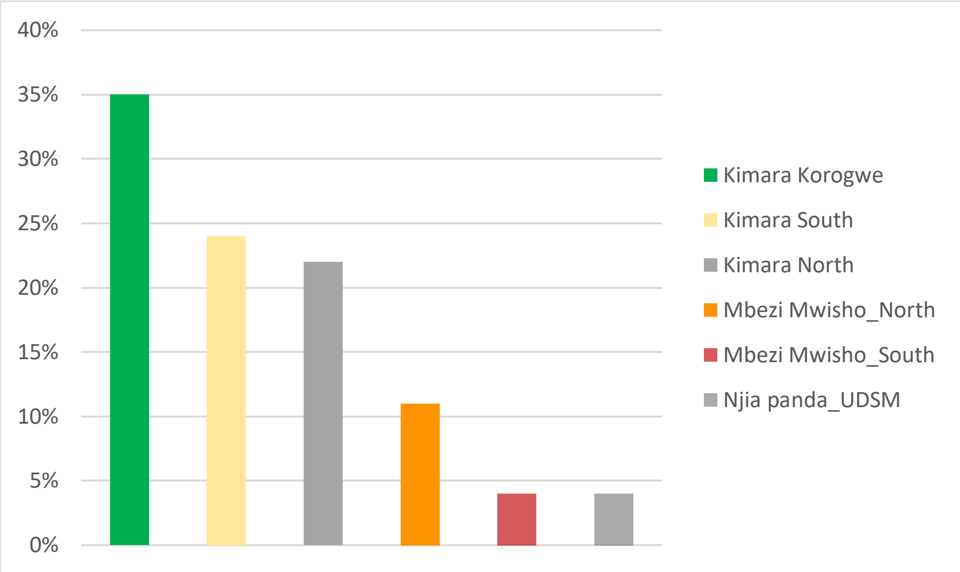


Figure 23: Number of people connecting to BRT (percentage).

4.8.4. Fares

Figure 24 shows the fares for the trip segments made by the different modes of transport. The survey revealed that most trips are made using bajaj and dala-dala, and they mostly pay less than 1,000 TZS. Most of the BRT trips cost between 550 to 1,000 TZS. Very few trips pay more than 2000 TZS.

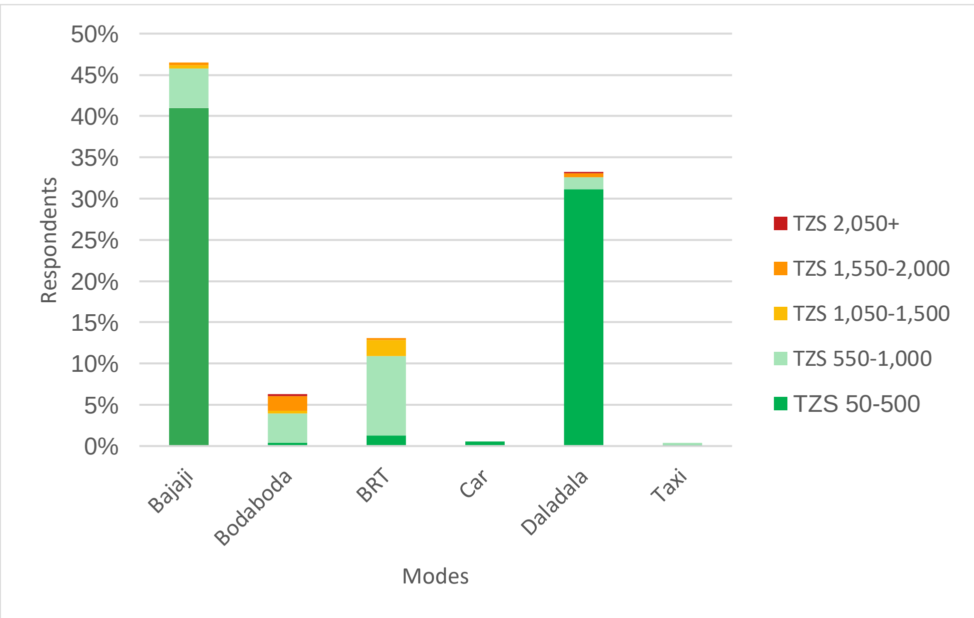


Figure 24: Fares

From the boarding survey, the surveyors also collected the total fare paid per route. As indicated in Figure 25, the survey reported that passengers that travelled up to approximately 4 kilometers using bajajs paid 500 TZS. Beyond that distance, most of the passengers paid 1,000 TZS.

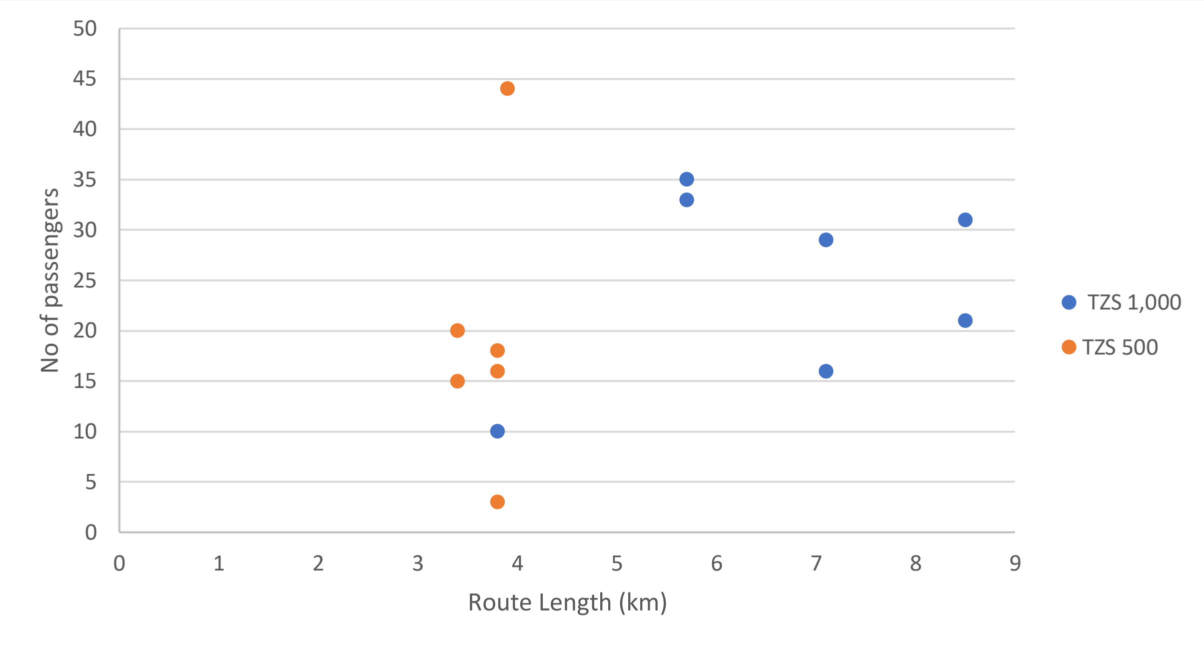


Figure 25: Fare and Distance.

4.8.5. Trip purpose

The survey results in Figure 26 show that most of the entire journey - not only the bajaj segment - were for work purposes, followed by shopping. Only a few mentioned making their trips for accompanying, education, medical, or recreational purposes. This may indicate that passengers will use electric three-wheeled vehicles most days of the week to help them reach their working areas.

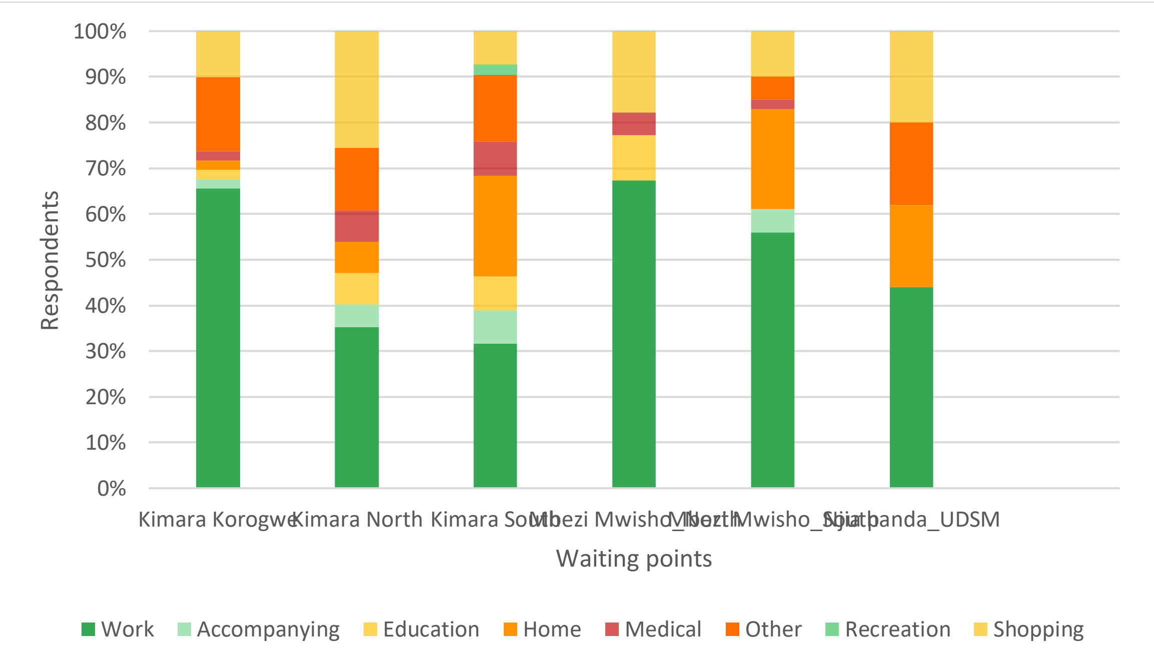


Figure 26: Trip purpose.

5. Intermediary recommendations for the e-bajaj pilot

5.1. Key aspects to consider in the feeder e-bajaj pilot

The various data collection methods show us different key facets of the current provision of transport services by bajajs, in the selected corridors. They also provide key insights for the transition towards electric bajajs as detailed in table 4.

Table 4: Insights for the pilot

Source	Results	Insight for the e-mobility pilot
Interest of drivers		
Drivers' survey Focus groups	A vast majority of drivers stated to be interested in switching to an electric bajaj. Several identify an opportunity to reduce operational costs. However, drivers at the Mbezi Mwisho waiting point (direction Goba) were less interested.	➲ The general interest is a positive factor for the project. ➲ Selecting waiting points where drivers showed clear interest in the pilot is important for local ownership of the project and continuous dialogue.
Organisational modalities		
Drivers' survey	The large majority of drivers are organised in waiting point associations.	➲ The waiting point association and its chairman should be tightly involved in the transition, as done throughout the surveys and focus groups. ➲ Additional individual contacts with drivers are desirable to cater for the theoretical possibility of the evolution of governance patterns between the survey and the start of the pilot.
Drivers' survey	The very large majority of drivers surveyed (91%) do not use a ride-hailing app to find customers.	➲ Using a privately provided ride-hail app seems less of a facilitating lever. ➲ If considered, the reasons for drivers not to use such apps should be better understood (potential factors: low level of digital apps in general, sufficient trip demand without the need for apps, financial impact, trust, etc.).
Financial modalities		
Drivers' survey	High operational costs enable an average take-home income of only 1.9 USD; fuel costs represent half of these daily costs. The median daily fuel cost has increased compared to a previous study conducted 3 years ago, probably reflecting the inflation.	➲ There is an opportunity to reduce operational costs for drivers by removing high fuel costs when shifting to e-bajajs. ➲ The extent of benefits will depend on the level of electricity fees and require an analysis of the total cost of ownership (TCO). This should be

		further assessed and communicated to drivers and associations.
Drivers' survey	Leasing fees represent nearly half of the other daily operational costs.	➲ Considering a reasonable level of leasing fees for the e-bajajs will give the opportunity to ensure a just transition, possibly even fairer conditions compared to the existing situation.
Drivers' survey	A very large majority of drivers would prefer a lease-to-own scheme to access e-bajajs, in continuity with current practices with ICE vehicles.	➲ Considering the preference of drivers for a lease-to-own scheme to access the e-bajajs is key.
Vehicles and charging modalities		
Drivers' survey Focus groups	Drivers identify key characteristics that e-bajajs should have: robustness, spare parts (reasonable costs and speedy availability), and sufficient range.	➲ Considering that these three key needs and characteristics (vehicle robustness, availability spare parts, sufficient range) are addressed in the pilot is key for its acceptability and success.
Daily range		
GPS data Drivers' survey Focus group	The GPS data of ICE bajajs indicated a daily mileage of about 120 km, with an interquartile range (Q1 to Q3) between 108 and 136 km. This daily mileage may be specific to the selected locations where bajajs are used for feeder services and connecting to peri-urban areas, hence possibly driving longer distances than central locations surveyed in a previous study.	➲ Drivers stated their desire for e-bajajs to provide a sufficient daily range compared to ICE vehicles. The combination of the e-bajajs specifications (battery size, drivetrain power) and the charging strategy and frequency should be designed to match at least an average of about 120 km, considering the need to possibly go higher as the interquartile range goes up to 136 km. ➲ This important daily range may be achieved via different options: a large battery size, a combination of overnight and day charging (plug-in, detachable battery, or battery swapping), or an additional energy source via solar panels on the roof. ➲ The market analysis scrutinises available vehicles and charging options in Part 2.3. will assess various options against this desired daily range and factors influencing energy consumption (number of passengers, elevation, etc.).

Overnight charging strategy and modalities		
GPS data Drivers' survey Focus group	Parking at night. 62% of drivers surveyed stated to park in a guarded, protected space at night (not at home) and 30% at home. Most drivers waiting at Kimara Korogwe park in a guarded area at night, and only the half of drivers at Njia panda ya Chuo do so. Drivers indicated the party's office and supermarkets as protected night parking spaces. The GPS data shows a tendency for many bajajs to park at a regular location at night. Units based at one waiting point tend to use nearby night-time parking locations.	➲ Selecting an overnight charging strategy (plug-in, detachable battery/portable charger) should be done carefully to ensure that it is feasible with regards to current night parking patterns and acceptable for drivers. ➲ If a third party is currently involved in providing guarded space for night parking (e.g. party's office, supermarket), it is desirable to involve this entity in the pilot. ➲ In both cases of charging at home or a protected parking space, when selecting a corridor and waiting point, further discussions are needed with the drivers and the association to refine the identification of night parking patterns as well as ensure the feasibility and acceptability of the proposed charging strategy.
	Access to electricity at home. Nearly all drivers stated having access to electricity at home, yet with irregular power cuts, mostly lasting between 30 to 120 min.	➲ Further discussions are needed with the association and chairpersons to refine the understanding of power cuts (frequency and duration).
Day charging modalities		
	The large majority of drivers make more than 20 trips per day. Demand strongly varies during the day between peak and low demand periods.	➲ Day charging should allow a comparable number of trips. To avoid disrupting current operational patterns and ensure acceptability, periods of low demand should be used for day charging.

5.2. Evaluation of waiting points and corridors for the e-mobility pilot

To identify the best location(s) to deploy the pilot, the information collected through the various studies was evaluated to establish a desirability profile for each waiting point and the corresponding corridor. Field observations further provided key input on the quality of the road infrastructure, the degree of organization at the waiting point and the availability of space for parking and charging. Lastly, an analysis of the topography and elevation of the corridors was performed. The detail of this topography analysis is available in Annex II.

Methodology

The profile of each waiting point and route consists of 8 criteria:

- Analysis of the existing demand for ICE bajaj services (frequency occupancy)
- BRT connectivity (transfer survey, field observation)
- Delimited area for bajaj services at the waiting point (field observation)
- Road condition at the waiting point (levelled/unlevelled, paved/unpaved) (field observation)
- Available space for parking and charging at the waiting point (field observation)
- Interest in an e-mobility pilot (drivers' survey, focus group)
- Topography of the corridor (elevation, Google Earth)
- Road condition of the corridor (field observation)

Two elements were not included in this analysis: first, power availability at the waiting point. Connecting the waiting point to the electric grid will likely be required for the pilot, as the infrastructure of the waiting points is currently not planned. Discussions between DART, the provider of e-bajajs and/or charging equipment, and TANESCO will be needed. Secondly, the ownership of the area is neither a positive nor negative factor since discussions with either TANROADS or TARURA, owning these areas, will be needed in all cases.

To allow straightforward analysis and comparison of the strengths and weaknesses of the waiting points, the resulting score is presented in spider diagrams. The scores were assigned on a scale of 0 to 10, with 0 representing the lowest possible rating and 10 representing the highest possible rating. As described in the sections above, various methods were used to determine the rating, including on-site observations, the drivers' survey, focus groups, the frequency occupancy and transfer surveys, and the analysis of elevation profiles. The final evaluation of each waiting point was done by assigning a score to each of the eight criteria based on its relative importance (for instance, bajaj demand) or quality (for example, organisation of the waiting point, WP). The results are presented in figures 27 to 32 below.

Results

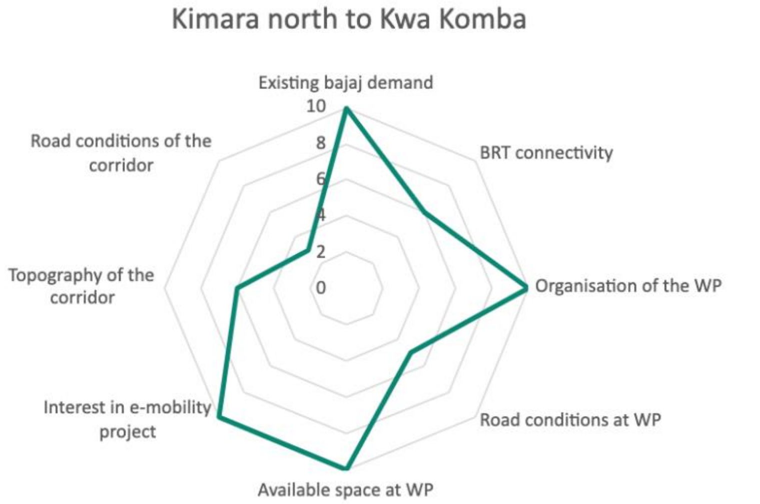


Figure 27: Concluding profile of Kimara North to Kwa Kwomba

Kimara North - Kwa Komba
The waiting point at Kimara "north" leading to Kwa Komba scores well in terms of existing demand for bajaj services, delimitation of the area for bajaj services (former market area; reuse of the former stands to park the bajajs; visible organisation in circulation paths although unpaved). Space is available to park and seemingly to charge. Drivers are interested in the e-mobility pilot.

However, this corridor is marked by the limitations of the road conditions (unpaved, potholes). There is also uncertainty on the area's future as TANROADS is implementing a renovation project involving lane extension. For the SOLUTIONSplus pilot which needs to be implemented in a shorter timeframe, this would mean installing temporary charging installation only.

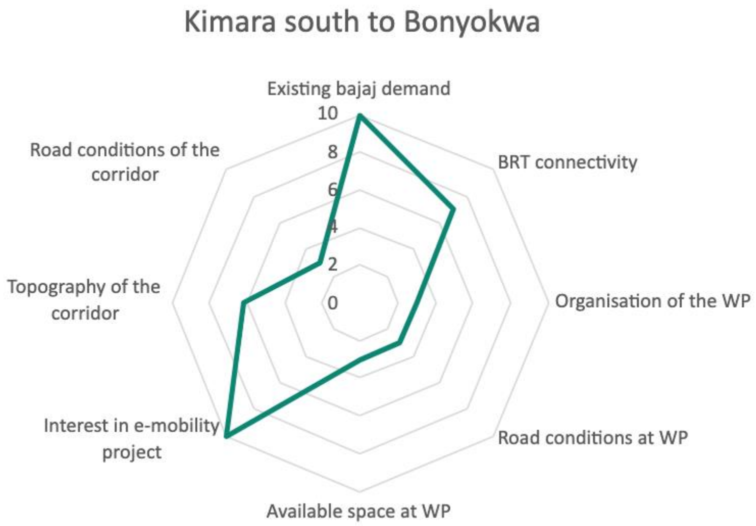


Figure 28: Concluding profile of Kimara South to Bonyokwa

Kimara South - Bonyokwa
The waiting point at Kimara leading to Bonyokwa scores well for the existing bajaj demand and interest of the drivers in the e-mobility pilot.

However, this option presents a series of important flaws: the uncertainty pertaining to the TANROADS project mentioned above; poor road conditions of both the route (unpaved, potholes) and at the waiting point; no delimitation of a specific area for the provision of bajaj services, which are merged with other uses cases, such as a market. Installing charging stations and finding sufficient space seem challenging.

Mbezi Mwisho - Kifuru

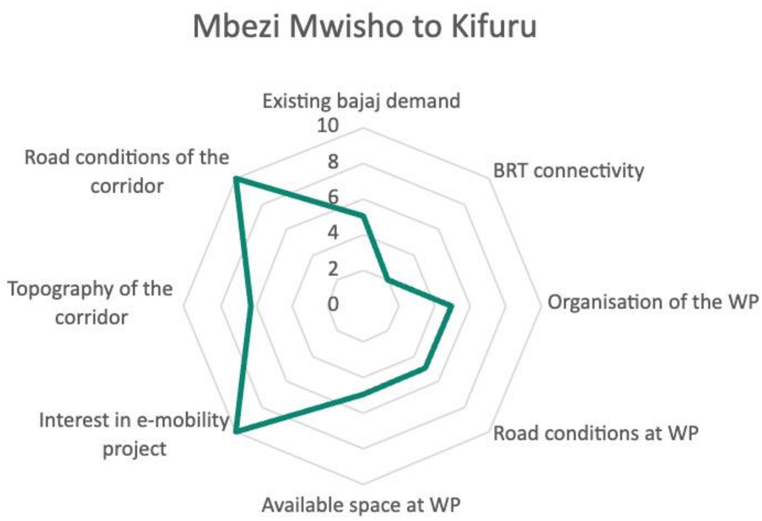


Figure 29: Concluding profile of Mbezi Mwisho to Kifuru

Field observations at the Mbezi Mwisho waiting point show a very high number of bajajs, going to four different destinations. For the route leading to Kifuru, the demand is medium compared to other analysed routes, as passengers can also use dala-dala minibuses and private taxis.

The interest of the drivers is a plus, showing a high level of organisation via their leadership and keenness to participate in the project. They also asked many questions about the availability and affordability of spare parts and business models.

However, the space at the waiting point may be a limiting factor as a high number of bajaj park extremely close, raising questions on the space for charging. Organisation patterns are unclear.

Mbezi Mwisho - Goba

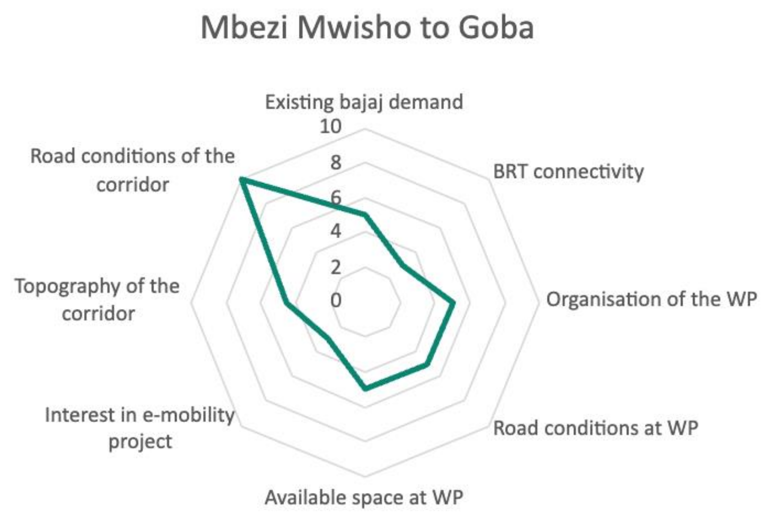


Figure 30: Concluding profile of Mbezi Mwisho to Goba

The waiting point at Mbezi Mwisho where drivers park to drive to Goba is marked by the same limitations mentioned above: crowded conditions and lack of apparent structuration of the space at the waiting point.

In addition, there are two further limitations. First, drivers seemed less receptive to the project, with only three individuals interested in participating in the GPS data collection. Second, the road is characterised by slopes upwards and is one of the two least-ranking routes in terms of topography profile.

Njia Panda ya Chuo - Changanyikeni

The large bajaj waiting point at the Njia Panda ya Chuo (intersection between University Road and Sam Nujoma Road), with a corridor towards Changanyikeni, scores well on several levels. There is essential existing bajaj demand, both observed and confirmed in the surveys. Bajajs are used either as collective mode or for private hire. Space at the waiting point is available; there are no visible conflicts with other transport services or uses. Space is sufficient to deploy charging infrastructure if needed. Drivers were very enthusiastic and volunteered to participate in the pilot. The road to Changanyikeni is paved and in good condition.

One limitation is the lower connectivity to the BRT Phase 1 compared to other waiting points surveyed. However, the connectivity is good with regard to the upcoming BRT Phase 4 (Sam Nujoma Road), as well as to dala-dala stops.

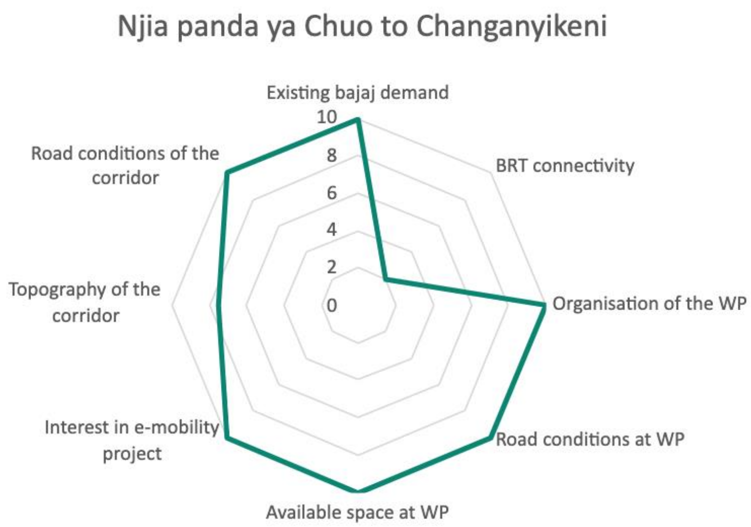


Figure 31: Concluding profile of Njia Panda ya Chuo (also known as the intersection University Road/Sam Nujoma Rd) to Changanyikeni

Kimara Korogwe - Maji Chumvi

The bajaj waiting point at Kimara Korogwe leading to Maji Chumvi presents positive characteristics in terms of existing bajaj demand, BRT connectivity, organisation of the point, paved road conditions at the waiting point and the road going to Maji Chumvi. The drivers were very interested in the e-mobility pilot and asked in-depth questions.

On the negative side, this corridor has the steepest

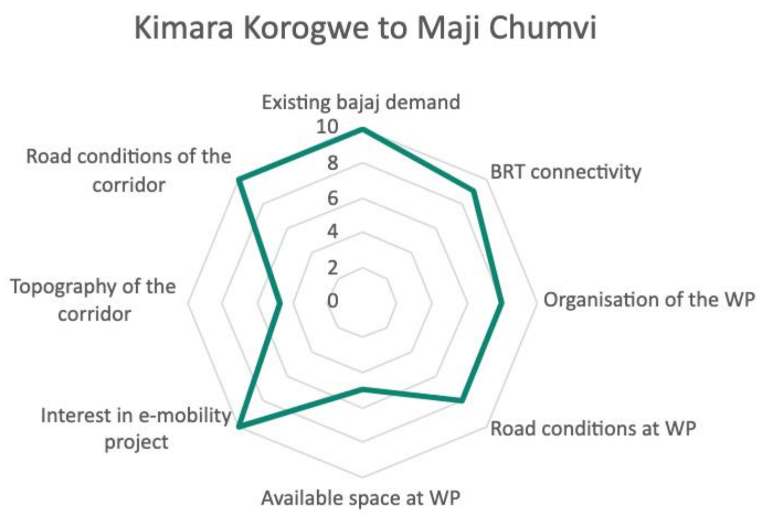


Figure 32: Concluding profile of Kimara Korogwe to Maji Chumvi

maximum slopes among all surveyed waiting points. However, electric three-wheelers with gradeability allowing them to operate on both maximum and average slopes, are available on the market (see Part II.3 and Annex II). When selecting equipment for the pilot, it will be essential to ensure that it has sufficient gradeability to navigate this corridor.
Secondly, limited space availability may challenge the deployment of charging infrastructure.

In conclusion, the two locations comparatively scoring better on the highest number of criteria are Kimara Korogme-Maji Chumvi and Njia Panda ya Chuo-Changanyikeni.

On the 10^{th} of January, the SOLUTIONSplus team discussed the results of the profiles for all routes. A discussion arose on potential competition between dala-dalas and bajajs on some routes; it was concluded that selecting e-bajajs with a low seating capacity such as three seating passengers, as verbally mentioned by LATRA, would not create competition to larger capacity commuter vehicles.

In conclusion, the team confirmed the preference for these two best-ranking locations (Kimara Korogwe-Maji Chumvi and Njia Panda ya Chuo-Changanyikeni), where the pilot should be deployed. The other four locations would be reconsidered only as fallback scenarios, in the case of unexpected legal or technical challenges in the two preferred areas.

Part 2: Environment assessment for the introduction of e-bajajs

1. Regulatory environment

1.1. Registration and standards of electric vehicles

SOLUTIONSplus partners (DART, UEMI, ITDP Africa) met several key Tanzanian government institutions between 2020 and 2022. In February 2022, key information was collected from the Land Transport Regulatory Authority (LATRA) and the Tanzanian Bureau of Standards (TBS).

LATRA indicated the following process to register electric three-wheelers.

- Vehicles and batteries must be first certified with TBS and respect TBS standards. TBS currently applies a series of standards from the International Organization for Standardization (ISO), and the International Electrotechnical Commission (IEC) identified as relevant for electric vehicle safety. Regional or national-specific standards would be adopted in a second step, if necessary.
- Vehicles can subsequently be registered with the Tanzania Revenue Authority (TRA) and receive a registration card and plate number. In early 2022, the registration seemed to be an issue as the TRA online registration form “Calculator & Tool for Motor Vehicles” was adapted to ICE vehicles and not electric ones, requesting information about the engine size in Cubic Centimetres (CC). Yet, one company importing electric three-wheelers communicated to the SOLUTIONSplus team to have received in mid-2022 a registration certificate. It remains to be assessed to what extent this was a bilateral agreement or a sector-wide evolution.
  An empirical test done on the 30th of November 2022 showed that it is possible to register an electric car on this portal, for instance, a Nissan Leaf, indicating “electric” as a fuel type and “0 CC”. However, it is less clear if the same is possible for motorised two- and three-wheelers as the portal does not include the leading bajaj brands.
- Vehicles can be consequently licensed by LATRA, responsible for licencing and regulating all land transport., as described below in section 1.2.

1.2. Bajaj operations

Table 5 lists key regulatory requirements discussed with LATRA on the 8th of February 2022.

Table 5: Regulatory overview

Dimension	Regulation
Classification and fares	LATRA does not currently set fares for bajaj services since these are classified as hire services. The service is not considered a commuter service, for which the commuter service operator must propose a fare to the regulator for approval.
Routes	Since bajajs are not a commuter service, no routes are identified for them. In the SOLUTIONSplus project, it is up to DART to identify the e-bajaj routes currently providing feeder services to the BRT.
Size	The existing regulation applying to motorised three-wheelers used as a hire service does not specify the size.
Carrying capacity	LATRA indicated that vehicles are regulated in terms of carrying capacity. LATRA stated that it will, in principle, not license e-bajajs with a large seat

	capacity, such as six-seaters, since bajajs are not classified as commuter services, which carry at least five people. LATRA will accept e-bajajs with the same capacity as current ones, namely a driver plus a maximum of three passengers. The six-seaters which can be seen on the streets of Dar es Salaam are not legal, i.e. operate without a license and will be tentatively removed. However, LATRA indicated that flexibility is possible in some specific cases, for instance, vehicles with a “special purpose”, such as the Bajaj Maxima.
Feeder services	LATRA stressed the importance of assessing the demand for bajajs to provide feeder services and avoid competition with buses currently operating as feeders.

A discussion with the team in January 2023 showed the difficulty of assessing the lack of competition between bajajs and dala-dalas, in a context where transport services change very frequently, and as doubts were raised on the approval for dala-dalas to operate on some routes, or their continuity in the near future. To limit competition, the selection of a lower seating capacity seemed a more appropriate criteria.

Lastly, there seems to be a need to further clarify the regulatory framework for other types of vehicles. Regarding personal pedal-assist electric bicycles (“e-bikes”), LATRA indicated that they would not need to be registered licensed by LATRA. However, e-bikes imported within SOLUTIONSplus in October 2022 were submitted to a vehicle registration tax. With regards to e-bikes used for commercial purposes, LATRA indicated that there is no regulation yet. The overall sentiment given was that it should not be an issue. The SOLUTIONSplus team made a case for enabling regulations and favourable tax regimes on active electric modes such as e-bikes to facilitate their uptake.

2. Fiscal environment

Table 6 displays taxes applying to conventional and electric three-wheelers, as per information collected with the Tanzania Revenue Authority (TRA) met in March 2022, and electric mobility companies and freight agents active in Tanzania interviewed at several intervals in 2021 and 2022.

Table 6: Applicable taxes and tax levels

Tax	Level	Details
Import duty	25% or 10%	The percentage of this tax depends on the extent of local assembly of the vehicles, coming as Semi Knock Down (SKD) or Complete Knock Down (CKD). A SKD option is the dominant practice and attracts an import duty tax level of 25%. We found diverging information regarding CKD: a person met at TRA in March indicated to the SOLUTIONSplus local team the absence of a favourable tax regime for CKD. However, the East African Community (EAC) enables a duty remission scheme for CKD with an import duty rate reduced from 25 to 10% (East African Community Gazette Vol. AT 1 – No. 23). This should supersede national regulations. A freight agent interviewed confirmed that importing as CKD should be possible and would attract a 10% rate. Yet, the conditions to apply CKD would

		be challenging; the following steps would be required: registration as a business entity and application of the remission scheme to the chamber of commerce, which would be submitted to the EAC before being gazetted. This process would take up to 3 months. These challenges could explain why TRA did not mention the possibility of a lower custom duty rate and why most vehicles are imported as SKD. E-mobility companies active in Tanzania confirmed during interviews between February and December 2022 that the EAC CKD tax incentive is currently not recognised. Companies currently import SKD vehicles, but some are considering moving to CKD. In general, a lack of clarity in the regulatory framework was identified, and varying tax levels were applied depending on practices, for instance, by importing the vehicle as separate parts or as a unit in separate parts.
VAT	18%	Value Added Tax
CPF	0.6%	Custom Processing Fee
RDL	1.5%	Railways Development Levy
Wharfage	1.6%	
Addition: Other costs such as port charges, shipping charges, and freight agent's commission apply.		

Adding these various taxes gives the following total rates:

- **SKD: total tax level of 46.7%** (25% import duty, 18% VAT, 0.6% CPF, 1.5% RDL, 1.6% wharfage),
- **CKD: total level of 31.7%** (10% import duty, 18% VAT, 0.6% CPF, 1.5% RDL, 1.6% wharfage),
- plus other costs such as port charges, shipping charges, and freight agent's commission.

Other aspects are essential to consider:

- Electric vehicles: the person at TRA indicated that there is no different or incentivised taxation for electric vehicles. The question on a differentiated tax regime for charging equipment, as well as spare parts, remains to be clarified.

- Excise duty: according to TRA, is not applied to motorised three-wheelers, only to cars.

- Tax levels on batteries: a freight agent indicated the possibility of declaring batteries as solar PV batteries incurring 0% import tax and 0% VAT, which has been confirmed by one mobility company. There seems to be regulatory uncertainty on this incentive.

- Tax reductions: donor-based projects may benefit from a VAT exemption; however, under strict conditions and from the early stages of project planning (TRA, n.d.), this may not be feasible in the context of the SOLUTIONSplus pilot.

3. Market environment

An overview of vehicles available internationally and locally, of their specifications and costs, is needed to make an informed decision on the type of vehicles to procure. Therefore, a desk-based market analysis was conducted.

Since the Tanzanian Land Transport Regulatory Authority (LATRA) verbally indicated on the 8th of February that it will only accept three-wheelers with three passengers seating capacity, the desk research only focussed on corresponding vehicles.

In addition, the analysis concentrates on vehicles with lithium-ion batteries to avoid environmental pollution from lead-acid batteries with lower energy efficiency. Regarding charging technology, both plug-in and battery-swapping options were considered.

The costs indicated below are to be taken as an indication, as they vary depending on the quantity ordered, specific features of the equipment, and any additional parts or accessories. Additionally, exchange rates and taxes also affect the final cost.

The main findings of the market analysis are the following:

- There are three-wheelers from India or China with a sufficient range, speed and design comparable to current bajajs in Dar es Salaam. These use predominantly plug-in charging and are priced at circa USD 3,500-3,800. Cheaper vehicles, around USD 2,500, were found in India and China, but they show issues of either seat capacity above three passengers or a too-low battery price, raising safety doubts. Tax levels presented in Part 2.2 would come in addition to this cost.
- Alternatives to new vehicles and plug-in charging were analysed. Swapping models with good specifications seem more expensive than plug-in options, at circa USD 4,000. Costs of retrofitted ICE three-wheelers (plug-in) vary widely between USD 2,100 and 4,000 depending on the depreciated value of the used vehicle.
- Another category of three-wheelers from India or China, with a lower price range of around USD 1,500 to 2,000, exists. However, these vehicles present several key disadvantages such as the use of primarily lead-acid batteries, speeds below 25 km/h, shorter ranges of less than 50 km, designs that differ from current bajaj models, and seating capacity of mostly up to six passengers, making them incompatible with LATRA's requirement of a maximum of three seating passengers. Hence, these vehicles do not seem relevant for the SolutionsPlus pilot.
- A limited number of providers are based in East Africa as of the end of year 2022. SOLUTIONSplus has provided seed funding to Auto Truck, which is assembling two new electric bajajs and retrofitting one ICE bajaj at the Dar Institute of Technology (DIT) in Dar es Salaam. TRI is a company based in Dar es Salaam that has already imported 24 electric three-wheelers from China with two detachable batteries and exploring various options, such as adding solar roofs to extend the range. ELICO and SESCOM are two further options. In March 2022, costs ranged from USD 4,200 to 5,000 for new electric bajajs and approximately USD 5,000 for a retrofitted one, including Tanzanian taxes. These costs need to be frequently updated as they may vary depending on international supply chains, iteration of the vehicles such as the battery size and engine power, and second-hand ICE vehicles bought for retrofit purposes.

The following sections provide information about electric three-wheeled vehicles from India, China, and other Asian countries, which are also available in the East Africa region.

3.1. Electric three-wheelers from India

Two main vehicle types

Two main electric three-wheeled types are found:

- e-rickshaws,
- electric auto-rickshaws, also commonly and hereafter named "e-autos".

Most of the vehicles in India are e-rickshaws, which gained traction for the following reasons: limited upfront cost since low power motor and lead acid batteries, no registration and regulation, and lower operating costs. Yet, these e-rickshaws showed safety issues, partly stemming from the assembly of components imported from China. They have low speed and range. They are often used for the first and last mile (Das et al, 2020).

S. no	Parameter	E rickshaw	Electric auto rickshaw
1	Battery Technology	Both Lead Acid and Lithium	Lithium
2	Load bearing capacity	Low- speed decreases with increase in load	Comparatively high
3	Braking system	Normal	Regenerative braking system
4	Speed	Slow speed Less than 25 km/hr	Speed more than 25km/hr
5	Occupancy	4	3
6	Type of service	Shared- operates only with full occupancy	Personalized
7	Routing Fixed	They are usually not allowed on arterial roads	Area based- no restrictions
8	Fare	Not fixed fare	Regularised fare system
9	Trip length	Mostly short trips less than 5 km	Both short and long trips

Figure 33: Classification of e-rickshaws and electric auto-rickshaws (Thakur & Pal, 2019)

The current classification in the Central Motor Vehicle Rules (CMVR) is:

- E-rickshaw: An e-rickshaw is a special-purpose battery-powered vehicle with power not exceeding 4 kW, having three wheels for carrying either goods or passengers (Ministry of Road Transport and Highways, 2015) (Shandilya, Saini, & Ghorpade, 2019). These vehicles are not mandated by law to be equipped with regenerative braking systems (Ministry of Heavy Industries and Public Enterprises, 2019).
- E-cart: E-rickshaws for goods transport are called e-carts (Vahan, 2020).
- E-auto: A three-wheeled motor vehicle with a maximum speed exceeding 25 km/h and motor power exceeding 0.25 kW, if fitted with an electric motor, is an e-auto (ARAI, 2018). E-autos for passenger transport are classified as L5M.

The design significantly varies between both types. E-rickshaws have an open front for the driver and a lighter chassis, while the front is closed for e-autos, as shown in Figure 34. The design of electric auto-rickshaws is comparable to the tuk-tuks found in Dar es Salaam.

Figure 34: Design of e-rickshaws and electric auto-rickshaws (Patel, 2020)

Patel (2020) operated a classification of key characteristics of both vehicle types (Figure 35).

	E Rickshaw	E Auto
Battery	Lead Acid	Lithium Ion
Max Speed	25 Km	Higher
Battery Size	4000 w (Earlier 2000 w)	4000 w +
Range in Single Charge	40-50 km	70-80 km
Body	Light body with uncovered or fibre glass top	Hard covered metal body
Licensing for operation	With Municipal Corporation or as per State Policy	With State Transport Dept. like any Auto
Safety Features	Required as per design and safety standards by four approved agencies	Higher stability, approved designs by stipulated Agencies for all vehicles
Price Range per Auto	Rs. 80,000/- to Rs. 1,20,000/-	Rs. 1,50,000/- to Rs. 2,00,000/-
Battery Warranty	Usually one year	Three years in most cases. (Vehicles taking FAME Benefit must mandatorily have 3 year warranty).
Life cycle cost	Approx. Rs. 2,35,000	Approx. Rs. 4,00,000
Environmental Implications	- Lead acid batteries require many times more raw material to achieve the same energy storage as Lithium-ion - The lead processing industry is also very energy intensive, leading to large amounts of pollution. Although lead is highly hazardous to human health, the manufacturing methods and battery packaging make the human risk negligible.	- Requires comparatively less raw material than Lead acid batteries. Thus it has less impact on environment during mining process - Lithium mining specifically is resource intensive, but lithium is only a minor portion of the battery cell by mass. - It is considered less hazardous and more environmental friendly alternative as compared to lead acid.

Figure 35: Characteristics of e-rickshaws and electric auto-rickshaws (Patel, 2020)

Since this classification, the performance of vehicles has evolved:

- Many e-autos now have a battery of a larger size, for instance, 7.37 kWh for the Mahindra Treo, a corresponding more extensive range reaching more than 120 km per charge, and corresponding higher costs.
- Battery capacity is mainly found between 2.8 to 6.6 kWh for e-rickshaws (interquartile range) and 4.6 and 7.4 kWh for e-autos. The standard voltage is 48V per guidelines, but vehicles are found with 60 and 72V battery packs.
- Differences between these two types are getting less clear. For instance, some e-rickshaws are being equipped or retrofitted with li-ion batteries (Patel, 2020; Das et al., 2020).

Examples of electric autos

For the Dar es Salaam project, electric autos seem more appropriate than electric rickshaws for the following reasons:

- Higher range enabled by e-autos to reach sufficient daily range found in Part 1;
- Vehicles allowing an adequate speed, being a success factor for uptake (Goletz et al. 2021);
- Li-ion batteries instead of lead acid;
- Vehicle design closer to current e-bajajs, possibly facilitating acceptance by the drivers.

Table 7, therefore, focuses on examples of electric autos. This is an indicative list giving a few examples. Discussing with vehicle importers outside of Tanzania may enable enriching this list.

Table 7: Few examples of e-autos

Vehicle		Main specifications (source: OEM)
Mahindra Treo		Seating capacity: 3 passengers + drivers Mileage: 130 km/charge typical driving range; a certified range of 141 km. Top speed: 55 kmph Battery: Li-ion, 48V, 7.37 kWh, charging time 3 h 50 min Motor: 8 kW motor Dimensions (L x W x H mm): SFT (flex canopy): 2769 x 1350 x 1750; 377 kg HRT (hard top): 2766 x 1350 x 1757 ; 387 kg Torque: 42 Nm Gradeability: 12.7 degree Warranty: 36 months (More in brochure) Mahindra Treo *Yaari:* seat capacity of 4 passengers Mahindra e-Alfa Mini: e-rickshaw with lead acid battery
Kinetic Safar Smart		Seating capacity: 4 passengers + drivers Mileage: 100 km/charge on the website, 70 km in brochure confirmed by Patel (2020), but going down to 40-45km if overloading Battery: Li-ion battery 4 kWh, 2 hours full charge Motor: 1.2 kW BLDC Type Motor Dimensions (L x W x H mm): 2785 x 998 x 1790 ; 679kg Gradeability: 10.2 degree Warranty: 3 years Super DX, another Kinetic Green vehicle: an e-rickshaw
Piaggio Ape E-City		Seating capacity: 3 passengers + drivers Battery: swappable battery, li-ion 48V, 4.5 kWh Certified range 68 km/swap Peak power 5.4 kW, Peak torque 29 Nm Dimensions (L x W x H mm): 2700 x 1370 x 1725 Gradeability: 19 % (More in brochure)
Adapt motors, Sweekar		Seating capacity: 4 passengers + drivers Mileage: 87 km/charge Battery: 48V 100 AH, *lead acid* battery Motor: 1 kW Dimensions (L x W x H mm): 9 x 3 x 6 (ft)
Gayam Moto Works		Seating capacity: 3-6 passengers + drivers Mileage: 60-110 km/charge Battery: li-ion, 6-10 kWh Motor: 4.5 kW Dimensions (L x W x H mm) : 2700 x 1280 x 1740
Singham Li-Ion		Seating capacity: 4 passengers + drivers Mileage: 100 km/charge Battery: li-ion battery (no data about kWh) Motor: 1.5 kW, voltage 28v Dimensions (L x W x H mm): 2,575 x 1,740 x 998

Hykon India Ltd, Hetto		Seating capacity: 3 passengers + drivers Mileage: 200 km/charge Battery: 10 kWh Motor: 5.5 kW Gradeability: 18 % Dimensions (L x W x H mm): 2730 x 1350 x 1805
Volta EV – Model 80X and Retro		Seating capacity: 3 passengers + drivers Battery: 5.1 kWh Motor: 60v, 2.2 kW Dimensions (L x W x H mm) Gradeability: 9 degree
Kerala Neem G		Seating capacity: 3 passengers + drivers Mileage: 80-90 km/charge Battery: li-ion, 5.4 kW, 90 Ah Motor: 2.2 kW, 60 V Gradeability: 7 degree

In addition, some models have the flexibility or can be customized to add solar panels on top to charge the batteries and add extra mileage. The excess mileage will depend on the area on top that can be covered.

Price. Indicating the cost of the vehicle is challenging as prices vary based on ordered quantities, characteristics selected and battery types. In addition, online sources do not always specify clearly whether the cost already deducts the FAME II subsidies provided by the government. Approximative cost estimation can be given, ranging from circa 2,500 USD for a model with a comparatively smaller battery size, such as Kinetic Green Energy & Power, increasing to higher prices for more powerful vehicles, such as Mahindra Treo for circa 3,600 USD or for models allowing swapping such as Piaggio Ape E-City ranging between circa 3,800-4,100 USD. In addition, all these costs are before the imposition of Tanzanian taxes.

Range per charge. Kumar and George (2020) indicate that a battery capacity of 1 kWh enables a mileage of 17 km per charge. This indication is consistent with the mileage per single full charge shown by manufacturers above: 17.6 km for the Mahindra Treo (battery of 7.37 kWh allowing a typical 130 km range), 17.5 km for the Kinetic Safar Smart (battery of 4 kWh with a range of 70km per charge), 15.1 km for Piaggio (smaller battery of 4.5 kWh as can be swapped, for 68 km range). This remains an approximative figure as the range will vary on additional endogenous parameters (e.g. vehicle weight) and exogenous parameters (e.g., number of seating passengers, road conditions, topography). Yet, it can give a starting point to refine.

Retrofit alternative. A new vehicle is not the only option: it is possible to convert an existing ICE vehicle into an electric one. Discussions with Indian stakeholders enabled identifying the following costs:

- Cost of the used vehicle: depending on the vehicle condition and depreciated value, it could range between USD 500 and 2,000.
- Cost of the retrofitting kit, including the battery: USD 1,600 -2,000.
- Cost of the retrofitting, excluding the battery, found for swapping models, for instance, by the company RACenergy: USD 656-787.

- Total: a retrofitted vehicle with a plug-in charge may range between USD 2,100 and 4,000 depending on the vehicle depreciated value and battery size**.** The costs of retrofitting to a swapping model are difficult to assess and will depend on the costs of the batteries.

Typical charging options

A fixed battery model is dominant, according to Patel (2020) and ITDP (i.e. only plug-in charging is possible). Das et al. (2020) have the opposite analysis of the market, identifying a majority of electric three-wheeler vehicles with a detachable battery (DOT, Gayam Motor Works, Save Electric, SmartE, Lithion Power, Omega Seiki) versus electric three-wheelers with a fixed battery (SmartE, Technigence, eFleet Logix). Das et al. (2020) only find a minority of electric three-wheelers with an on-board charger (Ultraviolet, Ather, Emflux Motors) and a majority of three-wheelers without on-board chargers, in that case with portable chargers. This can be explained by the fact that Das et al. (2020) focus on B2B segment players, including cargo and aggregators who prefer swapping, hence a detachable battery; this must therefore be taken with caution.

Thakur & Pal, 2019 give an example in Kochi, based on home-based and slow charging late at night or early morning, complemented by a top-up during the day. In this example, the battery size is of 4 kWh, charges for two hours, and enables a theoretical range of up to 70 km per single charge. Another example mentioned by Das et al., 2020 indicate a similar combination of charging overnight and charging midday (both slow charging) for SmartE e-rickshaws with a smaller battery size of 2.8 kWh.

Battery swapping is implemented by some private companies (Patel, 2020). Key advantages are identified, such as the separation of ownership of the vehicle and batteries, control of the pool of batteries by the company, and potential economic gains for the driver from the start. Yet, issues are identified, including the need for a vast pool of users for financial viability, limited experience in India, and higher investment costs for the company, slowing down its uptake.

Das et al. (2020) identify the following swapping models:

ES 12: DIFFERENT CHARGING PRACTICES ADOPTED FOR COMMERCIAL E-2WS AND E-3WS IN INDIA

Operating Entity	Plug-in EV Charging	Battery Swapping	Vehicle Category	Operational Category	Charging Service Operating Model
Ather	Distributed EV charging		e-2W	Passenger	Subscription model for customers; tie-ups with shops
Bounce		Individual battery swapping	e-2W	Passenger	Tie-up with kirana stores
Dabadigo		Individual battery swapping	e-2W	Passenger	Swapping facilities set up by fleet operator
DOT	Centralised EV charging		e-2W, e-3W	Logistics	Captive charging facilities set up by fleet operator
eFleet Logix	Centralised EV charging		e-3W	Logistics	Captive charging facilities set up by fleet operator
Gayam Motor Works		Stack battery swapping	e-3W	Logistics	Captive swapping facilities set up by fleet operator
Lithion Power		Stack battery swapping	e-3W	Passenger, Logistics	Battery charging and swapping
SUN Mobility		Stack battery swapping	e-2W, e-3W	Passenger, Logistics	Provides swapping service to vehicles using its proprietary batteries
SmartE	Centralised EV charging		e-3W	Passenger	Captive charging facilities set up by fleet operator
Ola Electric		Individual and stack battery swapping	e-3W	Passenger	Swapping facilities set up by fleet operator

Figure 3: Swapping models (Das et al., 2020)

Standardisation

Contrary to large electric four-wheelers such as cars and buses, and the exception of the UN Regulation No. 136 vehicles of category L, “there are hardly any *international* standards governing the design of e-2Ws and e-3Ws” according to Das et al., 2020, therefore little standardization of charging. India has developed its own standards for low-voltage E3Ws and E2Ws: Bharat AC 001 (plug-in or conductive charging, AC power) and Bharat DC 001 (plug-in or conductive charging, ADC power).

3.2. Electric three-wheelers from China

Vehicle types

A similar schematic variation in vehicle design and characteristics seems to exist in China.
On the one hand, there is a broad category of cheaper three-wheelers allowing for more than three passengers, with a different design than current bajajs and less rain protection, mostly with lead-acid batteries.

On the other hand, more expensive vehicles with a design approaching those of current bajajs, larger motor, larger battery capacity and subsequent larger range, equipped with lead-acid or lithium-ion batteries, are found. Some models are presented in Table 8 below.

Table 8: Few examples of electric three-wheelers produced in China

Vehicle		Main specifications (source: OEM)
Changzhou Yufeng Vehicle	Model KV-DDC  	Motor: 4 kW Battery: 48V100AH Options: lead-acid and lithium-ion battery Charging: 6-8h Range/charge:100km Max speed: 45 km/h Grade ability: 30% Max Loading weight: 500 kg Max 4 passengers Weight: 280 kg Size: 2.600 * 1250 * 1750 mm USD 3,000 with a lead-acid battery; USD 3,650 with a lithium-ion battery. Based on an order quantity of 27 vehicles
	Model Yu Hang 	Same specifications USD 3,200 with a lead-acid battery; USD 3,850 with a lithium-ion battery. Based on an order quantity of 27 vehicles

Qiangsheng Group	Model JOY1 	Motor 48v 4kW 48v 25a onboard charger; charging time 4h 48v 86ah lithium battery (i.e. 4,128 kWh) 3 seating passengers Max speed: 45 km/h Vehicle size 2700 * 1300 * 1780 mm Ground clearance 16-28cm Gradeability: 15% USD 2,375, incl. a lithium-ion battery at only USD 786, which is significantly lower than usual prices. This can may raise caution for quality and safety reasons

3.3. Electric three-wheelers from other Asian countries

Further models are identified in Table 9.

Table 9: Few examples of electric three-wheelers produced in China

Vehicle		Main specifications
Onion Mobility, ONiON T1		Range 100 km Nominal power 5 kW, peak power 10 Battery Lithium-ion, 72V, 7.5 kWh, swappable Typical driving range: 90~112 Max speed: 50 km/h Dimensions 2,685 * 1,370 * 1,700 mm Gradeability: 30% Cost: USD 3,999 Currently only available in Phnom Penh; plans to expand sales to other regions after 2022
BEMAC, Philippines 68 VM		Battery capacity: 5 kWh Battery type: li-ion Max range/charge: 60 km Top speed: 50 km/h Country of origin: Japan, operated in the Philippines
Terra Motors T4		Battery capacity: 5 Battery type: li-ion Max range /charge: 100 km Top speed: 45 km/h Country of origin: Japan, operated in the Philippines
BIZ NEX Motor NEX1		Battery capacity: 7.4 Battery type: li-ion Max range /charge: 80 km Top speed: 70 km/h Country of origin: Thailand, operated in Thailand

With regards to the range per charge, we find 12-14.3 km for 1 kWh (ONiON T1), 12 km (BEMAC), 20 km (Terra Motors), and 10.8 (BIZ NEX Motor).

3.4. Electric three-wheelers available in Tanzania

In Dar es Salaam, at least four companies are identified as introducing electric three-wheeled vehicles for passenger services. Freight services will not be detailed here.

Two models of electric three-wheeled vehicle are already available, imported and assembled locally (TRI) and ELICO Foundation. Another company is assembling a new electric three-wheeled vehicle prototype with an important share of local materials (Auto Truck). Two companies are exploring retrofitting (Auto Truck, SESCOM).

The information contained in Table 10 shall be taken with great caution as vehicles are evolving, either via a regular process of research and development (Auto Truck, SESCOM), or via continuous iterations following feedback from drivers and the market (TRI). The information in this Table is not exhaustive; for instance, it does not include information on ELICO's vehicles being deployed.

Table 10: Examples of electric three-wheelers in Dar es Salaam

Vehicle		Status and main specifications
TRI		• Some specifications as of early December 2022: ○ 2 battery packs of 3.4 kWh each (initial prototype of 2.5 kWh ensuring a range of 40 km per pack, amended); LFP batteries ○ 4 kW motor ○ 2 further vehicles with solar panels on the roof to increase the range ○ Charging: combination of slow overnight charging (detachable batteries) and fast charging during the day to ensure a top-up to 40 km • Cost as of mid-2022: circa 5,000 USD, including taxes
Auto-Truck		• Maturity: currently developing vehicles in the context of a SOLUTIONSplus grant • Manufacturing two new electric three-wheelers: ○ Planned completion of activities by January 2023. ○ Locally sourced materials for the body and chassis ○ Specifications as of the last iteration, May 2022: - Industrial design developed by Auto Truck - Motor 3 kW, 28V (China) - Battery: 51.2 * 105A (China) - Onboard chargers: 48V 25A onboard single-phase input, 220V 50HZ; standard (EAC) three pin socket • Retrofitting one existing ICE bajaj ○ Planned completion by January 2023 ○ Retrofit of a TVS King, year 2013, two-stroke ○ Motor 3 kW, 48V (China) ○ Battery: 51.2 * 105A

		• Costs indicated as of May 2022: 4,500 USD + for a new one (including taxes), tentative USD 5,000 USD for a retrofitted one
		
		• Conditions of operations
		  ○ Pilot phase at the DIT
		  ○ Followed by real-world deployment aligned with DART

SESCOM		• Maturity: current design of retrofitted ICE bajajs to electric, in the context of a SOLUTIONSplus grant. Expected completion: Q1-Q2 2023

Costs of conventional bajajs in Dar es Salaam
Costs for new ICE bajajs operating on the ground have been assessed by various stakeholders.
A spectrum ranging between approximately USD 2,800 and 3,500 is found.

- TSH 7,400,000 to 7,700,000 (USD 3,190 to 3,320) according to DART, January 2022.
- Ranges between USD 3,090 -3,200 when readily available from a show room and between USD 2,920-3,004 when ordered from abroad, according to UEMI research in March 2021.
- USD 2,800 to 3,500 (Goletz et al., 2021 according to "local stakeholders").

Final recommendations

Transparency of data

- This report shall be made publicly available to transparently provide information to innovators interested in providing electric three-wheeled vehicles and related equipment. Making it available to a wide range of stakeholders, including decision-makers, government authorities, research institutions, and international organisations interested in scaling-up the pilot will allow widely sharing of findings and opening the discussion.

General requirements for the pilot

- Integrating the views and preferences of ICE bajajs drivers and their associations is key to ensuring a just and efficient transition. In particular, the pilot needs to include the following three key needs identified: sufficient range, vehicle robustness, and availability of spare parts.
- Disruptions should be avoided as much as possible, for instance, by limiting immobilisation to charge during the day or avoiding designs varying too significantly from current models.
- Opportunities should be reaped as much as possible, for instance, by reducing operational costs for drivers and increasing net revenues.

Daily mileage in the pilot

- Surveyed drivers want electric bajajs to allow them to operate with a similar mileage compared to current ICE vehicles. The average daily mileage with ICE bajajs in the specific areas studied is found to be 120 km going up to 136 km (upper value of the interquartile range).
- The e-bajaj specifications and the charging strategy should be designed to allow a similar daily mileage while disrupting at little as possible current operational patterns of drivers and limiting the extent of costs.

Key characteristics for e-bajaj and charging in the pilot

- The global and local market analysis of electric three-wheeled vehicles shows that nearly all models enable *less* than 120-136 km on a single full charge. Only a few models come close to this range, such as the Mahindra Treo, with an indicated typical 130km on a single charge. Even in that case, the state range should be taken with caution as it may decrease in case of high loads, slopes or poor road conditions. Allowing for additional charging during the day would provide more flexibility and reduce range anxiety.

- Based on the market analysis, two options can be considered. It will be up to the innovators to suggest one option and detail it in their proposal. The pilot should not give strict vehicle specifications that the innovator should respect as different combinations of vehicle parameters, charging frequency, and strategies are possible, but instead request that the objectives stated above in “General requirements for the pilot” and “Daily mileage” can be achieved. SOLUTIONSplus industry partners will evaluate how the innovator’s proposal can match them.

  A. **Overnight charging combined with limited top-up during the day**.
  To avoid immobilisation as much as possible during the day, most of the charging should take place overnight. Charging during the day should serve as a limited top-up, not necessarily implying a full charge.

  Main charging: overnight. For this system to work, the battery should be sufficiently big to cover most of the needs on a single overnight charge. When looking at available products internationally and locally (large variation of 12-17 km enabled by 1 kWh depending on the vehicle parameters and OEM estimations), this would be best achieved with a battery of circa 7 to 8 kWh. Smaller batteries would involve more frequent or longer recharge times and corresponding immobilisation phases during the day. Larger batteries would unnecessarily increase vehicle costs, which are already high, especially when considering the 46.7% of taxes to add. Other options to add range via solar panels on the vehicle roof may be considered, yet with specific care, as they will incur additional weight.

Complementary day charging. Day top-up charging could be done either at a slow or fast rate. This choice will depend on the frequency and duration of power cuts: these have been reported as happening more frequently in the last trimester of 2022, which may not enable uninterrupted phases of access to electricity to allow for slow charging, hence a need for fast charging. On the other end, slow charging could be less costly in terms of equipment and have a lower impact on the battery.

Off-peak periods when drivers have fewer clients or during lunch breaks should be used to recharge the vehicle during the day. The focus group with drivers at two waiting points identified such phases of low demand, which should be refined with the drivers and their associations at the finally selected waiting points.

B. **Battery swapping**. Exchanging depleted batteries at swap stations could be an alternative option to limit the immobilisation of e-bajajs during the day. However, this option could be disadvantaged by a couple of inherent challenges. First, ensuring that batteries are available at a swap station requires a larger pool of batteries, which incur additional investment costs potentially disproportionate for a small pilot. Secondly, swapping large batteries would require dedicated staff at the swap station as they are heavy, as seen via various electric moto-taxis companies in the East African region. Lastly, there is less feedback on such schemes, although it is gaining traction in India. If selecting this option, the innovators should justify the choice and indicate how these challenges will be mitigated.

- Prices of circa 3,500 to 3,800 USD for imported plug-in vehicles can be expected, increasing to 4,100 USD for swapping vehicles, before importation. Import taxes and various other taxes amounting to a total of 46.7% plus different additional costs (shipping charges, port charges, freight agent's commission) will add to these costs. When adding taxes, total vehicle costs of 5,130 to 5,574 USD (plug-in) and 6,000 USD (swapping) are found. Locally products seem available for approximatively 5,000 USD, including taxes.

  To increase the number of vehicles to be deployed, it is recommended to consider the entire business model, integrating the leasing fees paid by drivers. Instead of financially supporting the full purchase of vehicles, the SOLUTIONSplus pilot should provide complementary funding to innovators planning to enter or already active in the market ("gap funding"). For instance, the funding can cover part or totality of the costs of deposits requested from drivers, or the cost of additional batteries required in the case of a swapping scheme.

Additional characteristics for e-bajaj and charging in the pilot

- **Seating capacity**: the regulatory environment set by the transport regulatory authority LATRA and the standardisation authority TBS needs to be respected, such as the limitation to three seating passengers verbally requested by LATRA in February 2022, except if a local innovator can prove that a vehicle with a higher seating capacity has obtained a legal authorisation to operate from a Tanzanian public authority.
- **Overnight charging**: selecting an overnight charging modality (plug-in, detachable battery, portable charger) should be done carefully to ensure its feasibility and acceptability with

regard to current night parking patterns. Depending on the waiting point, half or more drivers do not park at night at home but at a guarded parking space, for instance, at the political party's office or a supermarket. For these cases, and if a third party is currently involved in providing guarded space, it is desirable to involve this entity in the pilot. In both instances of charging at home or a protected parking space, when selecting a corridor and waiting point, further discussions are needed with the drivers and the association to refine the identification of night parking patterns to ensure the feasibility and acceptability of the proposed charging strategy. In addition, further discussions are needed with the association and chairmen to refine the understanding of the frequency and duration of night power cuts.

- **Availability and affordability of spare parts**: this is a key request from drivers and needs to be documented by innovators.
- **Maintenance and repairs**: this is a key element to ensure the pilot's sustainability and must be documented by innovators.
- **Local assembly**: this is a bonus for the selection of innovators.

Operational modalities

- Drivers and their waiting point associations should be tightly involved in the transition, as done throughout the surveys and focus groups.
- Using a ride-hail app seems less of a facilitating lever in the surveyed locations. If considering the introduction of an app, the reasons drivers do not use privately provided apps should be better understood (potential factors: low level of digital apps in general, sufficient trip demand without the need for apps, financial impact, trust, etc.).

Financial modalities

- Shifting to e-bajajs may reduce drivers' operational costs by removing particularly high fuel costs, which currently represent nearly half of their daily operating costs. The extent of benefits will depend on the level of electricity fees and require an analysis of the total cost of ownership (TCO). This should be further assessed and communicated to drivers and associations.
- Setting a reasonable level of leasing fees for the e-bajajs may give the opportunity to ensure a just transition. The pilot must integrate the preference of bajaj drivers for a lease-to-own scheme to access the e-bajajs.

Selection of areas to deploy

- Eight criteria were examined for each corridor and waiting point located near a BRT station: existing demand for ICE bajaj services, BRT connectivity, organised area for bajaj services at the waiting point, road condition at the waiting point, available space for parking and charging at the waiting point, the interest of drivers in an e-mobility pilot, the topography of the corridor, and road condition of the corridor.
- This analysis shows that each waiting point and corridor has different advantages and flaws. Some locations present more challenges, such as poor road conditions of the route and/or the waiting point or lack of space for charging purposes at the waiting point.
- The two locations scoring higher on most criteria, and selected by the SOLUTIONSplus team for the pilot, are Kimara Korogwe-Maji Chumvi and Njia Panda ya Chuo-Changanyikeni.

Interest of the drivers

- The general interest of the drivers in an e-bajaj pilot (82% of them) is a positive factor for the project. Selecting waiting points where drivers showed clear interest in the pilot is vital for local ownership of the project and continuous dialogue.

Policy environment

- Some elements of the regulatory environment are not fully clear, such as the maximum passenger seating capacity or the tax conditions. There is a need to clarify these with government authorities further.
- In particular, e-mobility start-ups face a challenge in receiving the incentive granted to semi-assembled vehicles in the East African Community, which should reduce the overall taxation level from 46.7% to 31.7%. Discussions to clarify this aspect will be necessary. Going forward, a debate on the level of taxes will be essential to identify pathways to facilitate the e-mobility transition and provide incentives compared to ICE vehicles.

Annex I. Detailed results of surveys

I. Drivers' survey – Descriptive statistics

1. Gender

	Drivers	Percentage
Male	151	99%
Female	0	0%
No answer	1	1%
	152	100%

All surveyed bajaj drivers were men.

2. Use of GPS trackers provided by SolutionsPlus

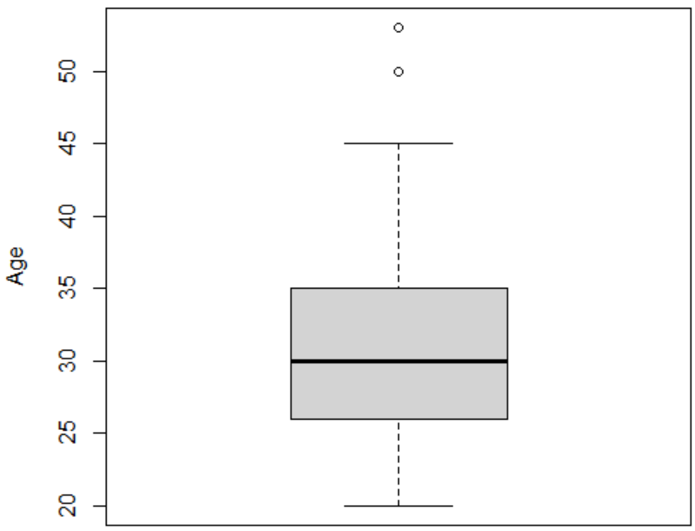
	Drivers	Percentage
yes	105	69%
no	43	28%
no answer	4	3%
	152	100%

The question aimed to identify drivers using a GPS tracker provided in the context of SolutionsPlus, to compare their survey answers with the data collected with the GPS tracking campaign. Given that 20 GPS devices were distributed, a total of 105 drivers answering "yes" is not realistic. Answers to this question may thus not be answered.

3. Drivers' age

The large majority of drivers (62%) were found to be between 25 and 34 years old. The median age is 30 years, with half of the drivers between 26 and 35 years old. The median is slightly lower than the age found by Goletz et al. (2021), with an average age of 34.6 years of drivers.

Age	Drivers	Percentage
<20	0	0%
20-24	16	11%
25-29	58	38%
30-34	37	24%
35-39	23	15%
40-44	12	8%
45-49	2	1%
>50	1	1%
no answer	3	2%
	152	100%

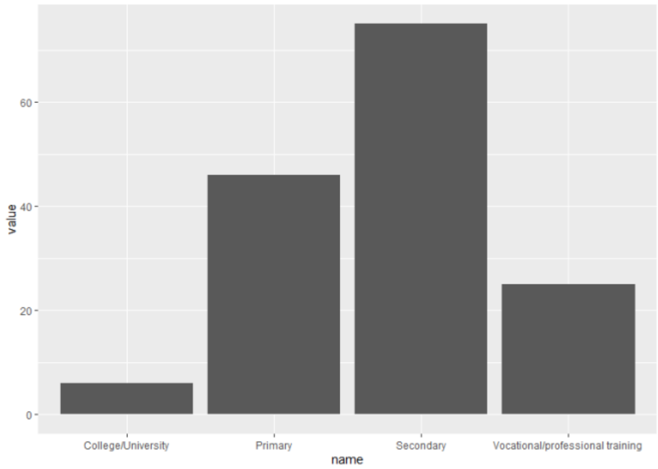


Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
20	26	30	30.66	35	53

4. Level of education

Most drivers (49%) have a level of secondary education, followed by 30% having reached primary education, 16% with vocational or professional training, and a small minority with a college or university degree. This economic activity may attract individuals with secondary education in the context of high unemployment. For further research, it would be desirable to compare these results with the average education level in Tanzania and Dar es Salaam.

	Drivers	Percentage
Primary	46	30%
Secondary	74	49%
Vocational/professional training	25	16%
College/university	6	4%
no answer	1	1%
	152	100%



5. Brand of the vehicle

An impressive portion of 95% of drivers has the bajaj model TVS King. Three-wheelers are still named according to the brand "Bajaj", although TVS and other brands are now more widely found in Dar es Salaam. The SolutionsPlus team discussed whether this imposing number could be inflated or unrealistic, possibly based on misinterpretation. The surveyors confirmed that the majority of vehicles at some waiting points, e.g. Mbezi Mwisho with a total of 200 three-wheelers observed, were TVS King vehicles, with only five vehicles being from the Bajaj brands. Similar patterns have been identified at the Kimara Korogwe waiting point. Drivers and association chairmen indicated that many people had bought TVS vehicles in recent years for the availability and low prices of spare parts.

	Drivers	Percentage
TVS King	145	95%
Lifan	2	1%
Toyo	1	1%
Piaggio	1	1%
Zongshen	1	1%
Nyingine (other)	1	1%
no answer	1	1%
	152	100%

6. Age of bajaj

Drivers were asked in which year the bajaj they were driving was produced ("x year ago"). Nearly all vehicles (86%) had been produced in the last six years. Within this six-year period, most of them (42% of all vehicles) were aged less than three years. This is coherent with data found by Goletz et al. (2021), identifying that 94% of vehicles were produced in the five years prior to data collection.

	Drivers	Percentage
Up to 1	3	2%
2	31	20%
3	30	20%
4	23	15%
5	29	19%
6	18	12%
7	5	3%
8	7	5%
9	0	0%
10	1	1%
11	1	1%
12 and more	2	1%
no answer	2	1%
	152	100%

7. Ownership

Different ownership models can be identified in Dar es Salaam and other mobility context in East Africa:

- a driver simply renting the vehicle,
- a driver renting the vehicle, with a planned transfer of ownership after a certain number of payments. This model is interchangeably named "hire-purchase" or "lease-to-own". The driver may still be renting the vehicle or having completed the agreed number of payments, thus owning the vehicle.
- a driver owning the vehicle after having purchased it upfront.

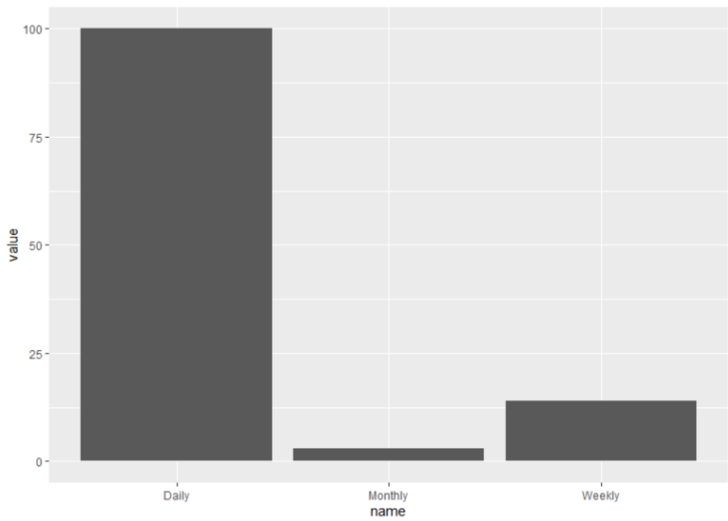
The survey showed that most drivers (45%) were still hire-purchasing the vehicle, while 22% of them had already completed a hire-purchase agreement, thus now being the owner of the vehicle. This means that 67% of drivers have used, or are still using, such a hire-purchase agreement. Less dominant models include pure vehicle rental without transfer of ownership (18%) and ownership with upfront purchase (10%).

Driver being the owner via upfront purchase	15	10%
Driver being the owner, via a completed hire-purchase agreement	34	22%
Driver still hire-purchasing the vehicle	69	45%
Driver purely renting the vehicle (no transfer of ownership)	28	18%
Other	4	3%
No answer	2	1%
	152	100%

Nb. The section "focus group and interview with drivers" provides more insights from drivers on ownership patterns with individuals, deposits, and alternative pattern via banks.

8. Leasing fees

Drivers were asked about the frequency and the level of fees paid to hire-purchase or rent the vehicle. Most drivers pay on a daily basis (100 drivers). Paying per week (14 drivers) and per month (3 drivers) is much less frequent. 35 drivers did not indicate the frequency of payments.
The analysis of fee levels was done for the majority paying on a daily basis only, in the absence of sufficient data for weekly and monthly payments. A mean value of 20,805 Tanzanian shillings (Tsh) was found, with a minimum of 15,000 and a maximum of 30,000. This value of Tsh 20,805/day – circa USD 8.1 – is coherent with the average 18,265 TZS /day – circa USD 8 – per day found by Goletz et al. (2021) during an earlier data collection in 2018/2019.



Daily= 100; Weekly= 14; Monthly = 3; NA= 35

Daily Rent	Tsh
Min.	15,000
Max.	30,000
Mean	20,805

9. Upfront purchase

Data on financial values of vehicle upfront purchase was not deemed usable as insufficient in number (only 10% of drivers) and with largely deviating numbers, possibly linked to the different conditions of purchase of the vehicle (new, second-hand, numbers of year of operation, etc.) where information was not available.

10. Preference of drivers for the electric three-wheeler business models

The survey did not only aim to better understand the current financial, organisational and socio-economic characteristics of ICE bajajs, but also to pave the way for the upcoming introduction of electric bajajs. To do so, it was very important to ask drivers about the models they would prefer to access e-bajajs, in order to ensure ownership and acceptability of the project.

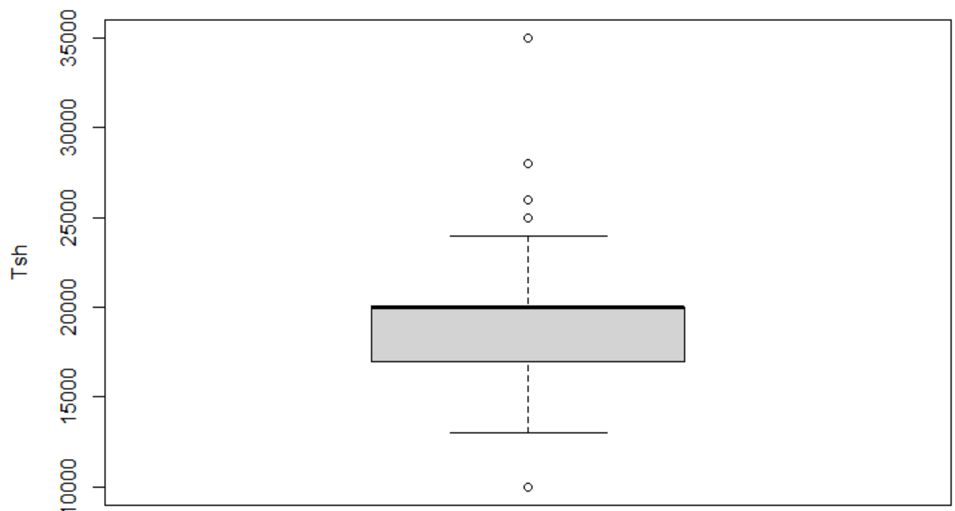
A large majority of drivers (72%) prefer the hire-purchase agreement model for electric bajajs. This is in line with current practices (67% of drivers have used or still using such a scheme).
When asked about the frequency they prefer for the payment of vehicle leasing fees for the e-bajas and additional charging fees if not charged at home, most drivers preferred to pay once per week (47%) or once per day (31%). This seems different from the current pattern based on daily payments. As two different opinions are expressed, refining the discussion with the drivers on preferred frequency is recommended.

If you were to change for an electric bajaj, what kind of system would you prefer?		
Hire to own	110	72%
Upfront purchase	9	6%
Pure rental	33	22%
No answer	0	0%
	152	100%

If you owned an electric bajaj via a leasing system, how would you like to pay for it?		
Every day	47	31%
Twice per week	4	3%
Once per week	72	47%
Twice per month	7	5%
Once per month	13	9%
No answer	9	6%
	152	100%

11. Average daily spending on gasoline

A median value of 20,000 Tsh (USD 8.6) spent on average on fuel was found, with half of the drivers paying between 17,000 and 20,000 Tsh (USD 7.3-8.6). This is more than the average 11,822 Tsh per working day (circa USD 5) found by Goletz et al. (2021).

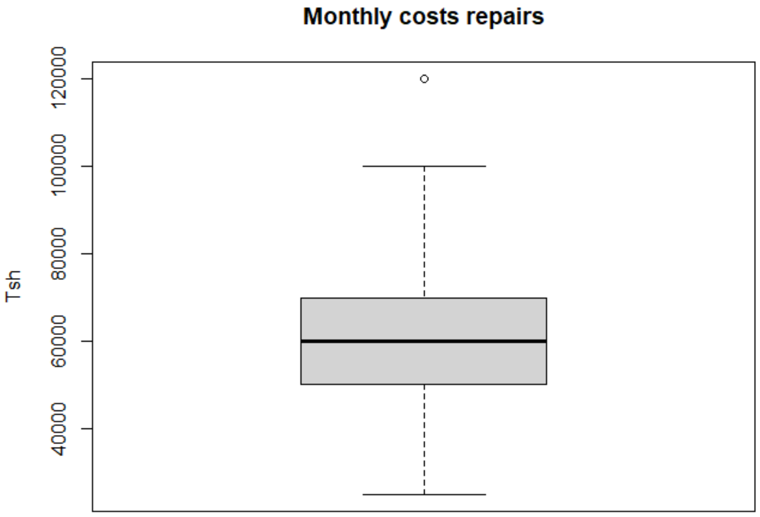


Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
10000	17000	20000	19086	25000	35000

12. Monthly spending on maintenance and repairs

Drivers were asked how much they pay for maintenance, including operational fluids (oil, hydraulics), wear and tear (tires, brakes etc..) and parts replacement, on average per month. A median value of 60,000 Tsh (approximately USD 26) was found, with half of the drivers paying between 50,000 and

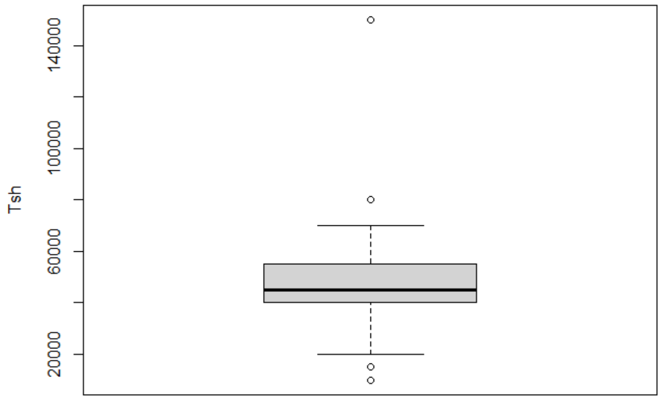
70,000 Tsh (USD 21-30). This is slightly more than the average Tsh 54,889 TZS per month (approximatively USD 24) found by Goletz et al. (2021) during a previous data collection in 2018.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
25000	50000	60000	57987	70000	1200000

13. Daily farebox revenue

Drivers were asked how much fare they receive from passengers per day. A median value of 45,000 Tsh (circa USD 19) was found, with half of the drivers receiving between 40,000 and 55,000 Tsh (USD 17-24). This is in line with Goletz et al. (2021) having found a median 45,000 Tsh/working day and 24,990 gross income.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
10000	40000	45000	44605	55000	150000

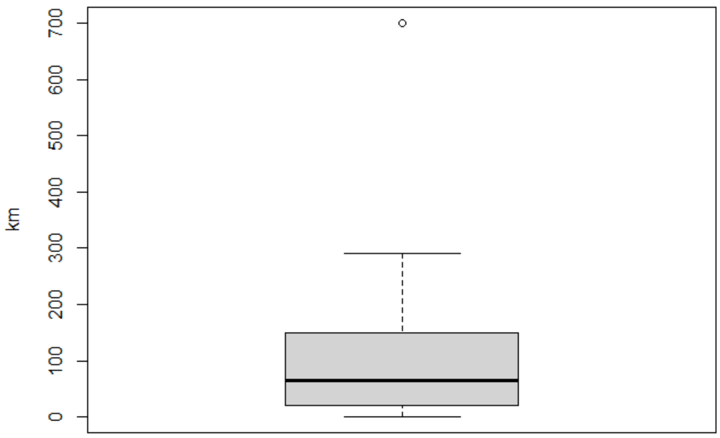
14. Number of daily trips

Drivers were asked how many passenger trips they do every day on average. The large majority of drivers (70%) do 20 trips or more every day. Only 3% of drivers make less than ten trips per day. Goletz et al. (2021) had found that 61% of drivers were doing more than 16 passenger trips per day in 2018 (details: 17% doing 6-10 passenger trips, 18% doing 11-15, 29% doing 16-20, 17% doing 21-25, 7% doing 26-30, 8% doing more than 30). The slight difference could be explained by the selection of other locations in the previous study, and the time difference between both studies.

	Drivers	Percentage
Up to 4	0	0%
5-9	4	3%
10-14	24	16%
15-19	18	12%
20 and more	106	70%
	152	100%

15. Daily mileage (km)

Drivers were asked how many kilometers they drive every day, including their trip to work. A median value of 65 kilometers was indicated, with important deviation as half of the drivers stated to drive between 20 and 150 kms every day. The previous study conducted by Goletz et al. (2021) had found that 50% of the drivers travel less than 75 km per working day and 75% of all vehicles travel less than 109 km.



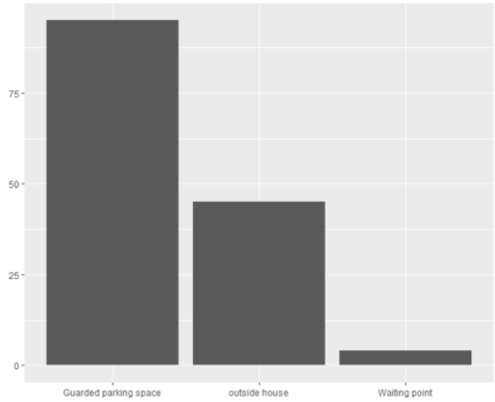
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
1	20	65	91.31	150	700	10

16. Night parking of bajaj

Drivers were asked where they park the vehicle at night since this information is crucial for the question of possible overnight charging of electric bajajs in the SOLUTIONSPlus project. This will inform the possibility and conditions of overnight charging, for instance, at the driver's place (need for a detachable battery or charging via a cable) or at a protected night parking space (need to involve the guarding entity).

Overnight, most drivers (62%) park their bajaj in a guarded parking space. This is coherent with the figure of 66% found by Goletz et al. (2021), parking in protected private parking areas. A further 30% of drivers park it outside their home, for instance, in the backyard or front of the house. Only a small minority (3%) parked the bajaj at the place for daytime parking. Lastly, 5% of drivers indicated other locations, for instance, four drivers parking at night in front of a mosque.

	Drivers	Percentage
In a guarded parking space	94	62%
Just outside your home (e.g. backyard, in front)	45	30%
At the waiting point where you operate during the day	4	3%
Another location	7	5%
No answer	2	1%
	152	100%



In addition, drivers were asked how much they pay to park in a protected space at night. Most of them paid per night, with a mean of 1,2229 Tsh, i.e. circa USD 50 Cents.

Fee for guarded parking (*n=106)*	
Min.	1,000
Max.	10,000
Mean	1,229
NA's	46

17. Availability of electricity at home

Nearly all drivers (99%) stated to have access to electricity at home.

	Drivers	Percentage
Yes	150	99%
No	1	1%
No answer	1	1%
	152	100%

18. Blackout frequency and duration

Reliability of electricity is critical to ensure the success of the e-mobility project, choose a charging option and avoid any negative impacts for drivers. Drivers were therefore asked how often they faced power cuts at home, on average, over the last year. Most drivers (80%) stated that these are irregular, thus without a specific frequency identified. When identifying a frequency, blackouts were identified as not happening too frequently: monthly (11%) rather than weekly (7%) or every day or night (1%) or several times per day or night (1%). Yet, it is essential to note that drivers were asked about home, not about the place where they park the bajaj at night, even if it is likely that these places are not far apart. Further work on access to electricity at these parking places will be required, if this option is selected.

	Drivers	Percentage
Several times per day/night	1	1%
Every day/night	2	1%
Weekly	10	7%
Monthly	16	11%
Irregular	121	80%
No answer	2	1%
	152	100%

In addition, drivers were asked about the typical duration of blackouts. Here again, the majority of drivers (57%) identify irregularity in the duration of blackouts. When quantified, most would last between 30 to 120 min (identified by 27% of drivers), while a minority of drivers remember them as lasting less than 30 minutes (6% of drivers) and more than 120 min, i.e. 2 hours (7% of drivers).

	Drivers	Percentage
Less than 30 mins	9	6%
30 – 60 mins	20	13%
1 – 2 hours	21	14%
More than 2 hours	10	7%
Irregular	86	57%
No answer	6	4%
	152	100%

19. Part of waiting point association

Drivers were asked whether they are organized at their daily waiting point, for instance, in an association. Most of them (83%) are organized in such an association, versus 14% not. The data collected on average fees for the association membership could not be used due to a lack of specification on the fee period.

	Drivers	Percentage
Yes	125	82%
No	22	14%
No answer	5	3%
	152	100%

20. Part of another organisation

Organisations mentioned:

- Umbani
- Umoja wa madereva bajaji kilungule B/Driver's association of Kilungule B
- Umoja wa chama Cha Waendesha bajaji Mavurunza/ Mavurunza Bajaj driver association
- Goba center bajaji drivers/
- UMWB
- Kumbani
- Umoja wa Bajaji Changanyikeni-Ubungo/ Drivers' association of Changanyikeni-Ubungo
- Bambem (drivers' association)

21. Use of mobility apps

Drivers were asked whether they use a smartphone application, such as Uber or Bolt. The large majority of them (91%) do not use such an app. Among nine drivers using an app, six used Bold, one Uber and one Wiki.

	Drivers	Percentage
Yes	9	6%
No	138	91%
No answer	5	3%
	152	100%

Among the few using an app, no clear tendency could be identified regarding the number of hours logged in the app or the average number of trips done using the app.

Hours	Drivers	Percentage
3	1	13%
4	1	13%
6	1	13%
8	2	25%
10	1	13%
12	2	25%
	8	100%

Trips	Drivers	Percentage
4	1	13%
6-9	1	13%
10	2	25%
15	1	13%
20	1	13%
25	2	25%
	8	100%

22. Interest in e-bajaj

When asked whether they would be interested in switching to an electric bajaj, 82% of drivers stated to be interested, versus 5% not interested and 12% indicating that it would depend. Limited information was provided about electric three-wheelers to avoid bias in the answers; additional details about e-bajajs and the SOLUTIONSPlus project were shared after the answers.

	Drivers	Percentage
Yes	125	82%
No	8	5%
It depends	18	12%
No answer	1	1%
	152	100%

Drivers replying "it depends" mentioned the following parameters.:

Linked with benefits:
- It depends on the benefits I get.
- It depends on the conditions (said twice).
- It will depend on the associated benefits.
- It will depend on the electric bajaj's benefits.

Linked with electricity and fuel costs
- I found it good because fuel costs are high.
- It depends on the running cost of the vehicle.
- It depends on the running cost, e.g. electricity costs.
- It depends on how much electricity it consumes

Linked with the vehicle's quality

- It depends on the quality of the vehicle.
- It depends on the quality and durability of the vehicle.
- It depends on the make of bajaj that will be involved, it will be better if they get TVS bajaj.

Linked with the range capacity

- I don't know how far the vehicle can travel.
- The kind of vehicle should guarantee the vehicle's trips.

Linked with more information about e-bajajs and about the project

- I can decide whether to agree or not when I will know about the procedure.
- It depends if I am going to like it or not.

We then had a closer look at the 82 % that were interested. Specifically, we use logistic regression to understand whether underlying individual or bajaj-related characteristics increase the likelihood of the stated intention to switch to an electric bajaj. Following univariate analysis, we identified six statistically significant variables (at a 95 % significance level). Below we describe these variables and how they contribute to the stated intention to switch to an electric bajaj:

i. Those that purchased a bajaj via a 'hire to owner' scheme are more likely to be interested in electric bajajs.
ii. The more drivers pay for repairs, the more likely they are to switch to an electric bajaj.
iii. Similarly, the more daily trips they complete per day, the more likely they are interested in switching to an electric bajaj.
iv. Owners of older vehicles are more likely to be interested compared to those that recently purchased a bajaj.
v. The availability of a guarded parking space has a strong positive impact on the intention to switch to an electric bajaj, while those that park outside their house are likely not interested.
vi. Finally, being a member of a driver association has a positive impact on the intention to switch to an electric bajaj.

II. GPS tracking of ICE three-wheelers

A. Background and methodology

Purpose and definitions

The GPS tracking survey aims to provide insight into daily distances, movement, and parking patterns to better assess compatibility and needs for transitioning to electric bajajs. Collecting and analyzing GPS data from bajajs makes it possible to gain these insights, capture and evaluate local needs, and identify appropriate solutions. This could include investigating suitable charging solutions (e.g., overnight or on-demand charging). In addition, an overview of frequently used parking areas can help assess, for instance, suitable locations for developing overnight charging parking areas.
In this report, the term "unit" refers to a bajaj equipped with GPS trackers as part of the data collection. Each of these units is associated with a waiting point. A waiting point is a location where units can wait to pick up passengers. In addition, these waiting points may be associated with the drivers' union to which a unit belongs.

Data

This analysis includes two primary data sources. The first source is the GPS tracking data collected as part of the SOL+ project between mid-March and mid-April 2022 in Dar es Salaam. The data was collected using "Developix Technologies" GPS trackers and processed by the "Wialon" platform. The period from 03/19/2022 to 04/23/2022 is observed in this analysis. While the descriptive statistical analysis uses the summary statistics of the platform provider, the spatial analysis uses the raw dataset in ".wln" format. The raw data containing GPS messages transmitted by 20 units during the data collection period were analyzed with the R programming language. Furthermore, additional information regarding each unit's waiting point, including location, name, and description of the waiting point and potential destinations, supplements the GPS data.

The waiting points included in the GPS tracking campaign comprise Mbezi Mwisho (WP1), Kimara Mwisho (WP2), Kimara Korogwe (WP3), and the intersection of University Road/Sam Nujoma (also known as Njia panda ya Chuo-Changanyikeni (WP4). Each unit is part of a particular waiting point association and therefore based at a specific waiting point located at strategic locations. Figure 1 shows the described waiting points.

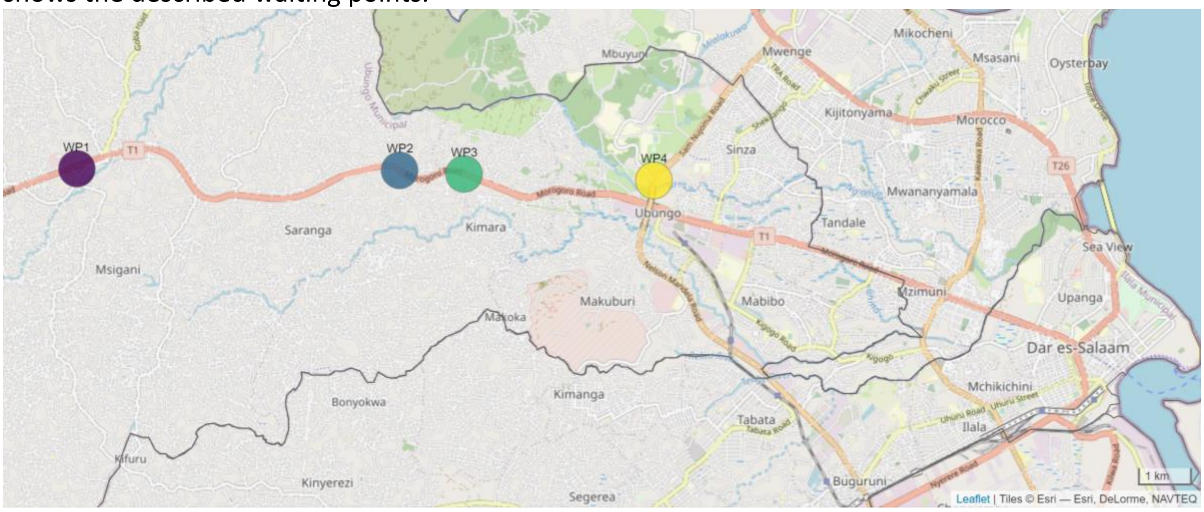


Figure 1 Waiting points included in the GPS survey

Procedure

Data cleaning and preparation
The following paragraphs briefly outline the raw dataset's data preparation and cleaning process.

Raw datasets:

- .wln data export from Wialon
- Information on waiting point locations and potential destinations per driver

Processing of "normal" data:

1. Classification of GPS data regarding the different waiting points
2. Cleaning process
    - Removal of alarm messages and irrelevant columns
    - Removal of invalid data, i.e., Observations with missing or zero values for latitude and longitude
    - Removal of observations with identical Timestamp, Name/UID, longitude, and latitude (Duplicates)
3. Transformation of the cleaned data frame to a spatial data frame

Processing of "spatial" data frame:

1. Grouping data by unit and date
2. Calculation of new variables (for each observation)
    - Time difference from the GPS point to the next GPS point
    - Distance from the GPS point to the next GPS point
    - Speed [m/s and km/h]
    - Distance from the GPS point to the assigned waiting point
3. Cleaning process:
    - Removal of spatial outliers (See Figure 2: Points in the orange box)

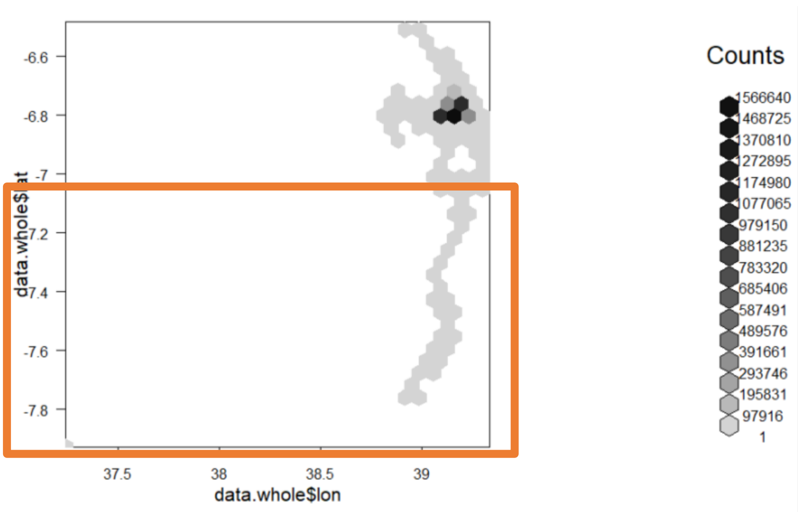


Figure 2 Removed observations outside of Dar es Salaam

Exploratory spatial analysis

The following paragraphs briefly outline the steps followed for analyzing the nighttime parking patterns. The analysis examines locations where units are parked during the night, including drivers parking at home and various protected or unprotected locations. For this purpose, time windows during which a significant percentage of vehicles stand still between midnight and 3 am were identified. This is followed by a visual representation of the locations and the spatial clustering of the GPS points based on the geometrical attributes. According to Knox's (1989) definition, cited by Aldstadt (2010), a spatial cluster is "a geographically bounded group of occurrences of sufficient size and concentration to be unlikely to have occurred by chance." There are several methods to identify such spatial clusters; in our case we used a method from the field of spatial data mining. Considering the geometric properties of the data points, we aim to find the clusters' exact position and shape information (Liu et al. 2012). Other attributes were ignored. Therefore, the spatial clusters presented in this report refer only to the geometric properties, i.e., the geometric coordinates where the vehicles were located during the identified time windows.

The main objective was determining the spatial distribution of nighttime parking and whether patterns are apparent. Hierarchical clustering was used to identify all data points within 500 m next to each other. The analysis was first performed for the units of each waiting point individually, followed by a collective analysis and clustering of all units. The following steps were performed:

1. Identification of nighttime windows with the smallest amount of unparked units
   1.1 First, a visual exploration was carried out, considering the longitude and latitude patterns during the observation period.
   1.2 For validation the percentage of vehicles with a speed of less than 10 m/s or 0 m/s was calculated.
   1.3 Based on these results, time windows were selected for each waiting point. The following table shows the selected time windows and the proportion of observations with a velocity of less than 10 m/s or 0 m/s.

Table 1 Time windows of nighttime parking analysis per waiting point

	WP1	WP2	WP3	WP4
Time period	1 to 2 am	midnight to 1 am	midnight to 1 am	midnight to 3 am
Speed = 0	97%	92%	96%	97%
Speed < 10 m/s	99%	99%	99%	98%

2. Exploration of the observations for the units of each waiting point. The observations of each waiting point were analyzed individually.
3. Spatial Clustering: GSP points that are closer than 500 m to each other are grouped together.
4. Analysis of units grouped by waiting point.
5. Synthesis of the analysis and spatial clustering to identify patterns for the whole dataset.

B. Descriptive statistics

General overview

After cleaning the data, the data analysis includes approximately 4.85 million observations. The number of observations per bajaj varies significantly. While the transmitted data for most GPS trackers amounts to more than 200,000 observations, data from four bajajs show fewer than 50,000 observations for the entire period. The following figure provides an overview of the number of collected observations for each unit during the data collection period.

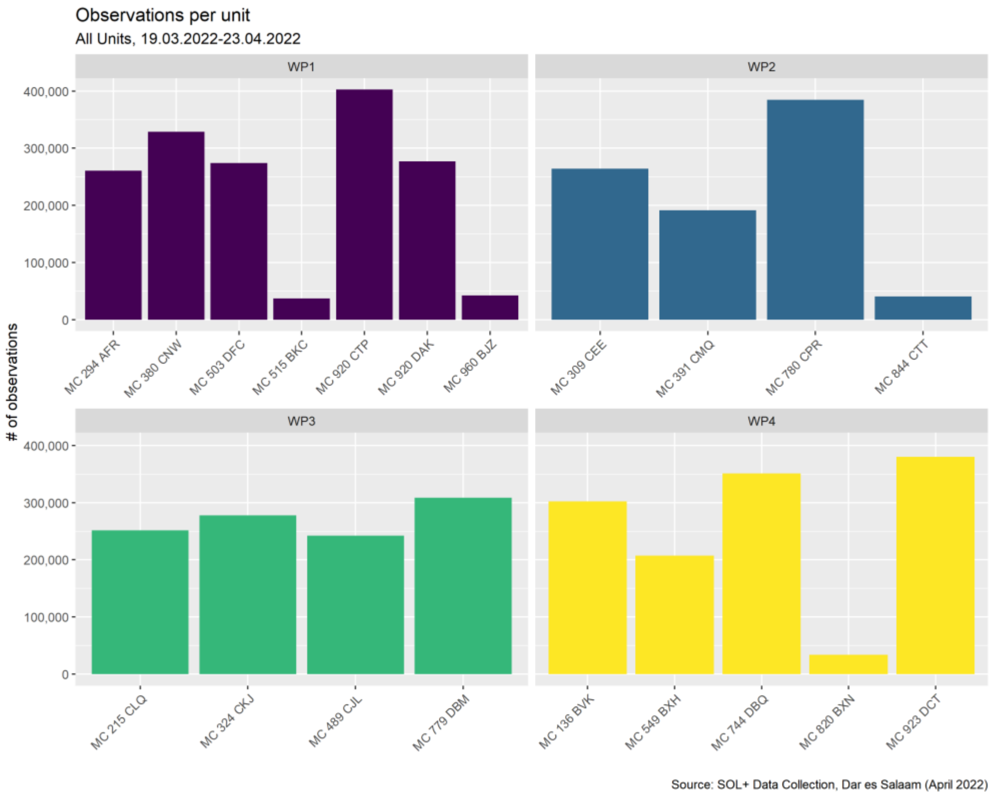


Figure 3 Number of observations per unit

To assess the consistency of the data collection, we look at the distribution of observations collected per hour and per day. Ideally, we would have the same number of observations for each unit every day (e.g., transmitting a GPS track every 10 seconds around the clock). This is not the case on all days and times, which suggests inconsistencies in the collected data. We identified a couple of reasons that contribute to the inconsistencies. During the preparation of the tracking campaign, we noticed that some devices have irregular tracking intervals. Although this was communicated to the data provider, this bias could not be solved entirely. We also monitored the tracking activities during the entire period and noticed that some devices indeed appeared offline. However, the data provider explained that the tracking devices were being charged once the bajaj engine was running. Once the engine was turned off (especially overnight), there was, therefore, the possibility that the devices disconnected. While this would not impact the analysis and results, we also must mention that we have been informed that other devices have been offline due to technical/connection issues.

It can be observed that the units MC 515 BKC (WP1), MC 960 BJZ (WP1), MC 820 BXN (WP2), and MC 844 CTT (WP3) contain fewer observations than the majority of units. This could mean that the data is incomplete. To avoid incomplete data from skweeing the analysis days with a daily distance of less than 10 km 69ddition69 are excluded from the analysis. In 69ddition, for comparison purposes, Chapter 2 discusses both the descriptive statistics for all units (n=20), and those for units with more than 50,000 observations, excluding units with missing data (n=16), separately.

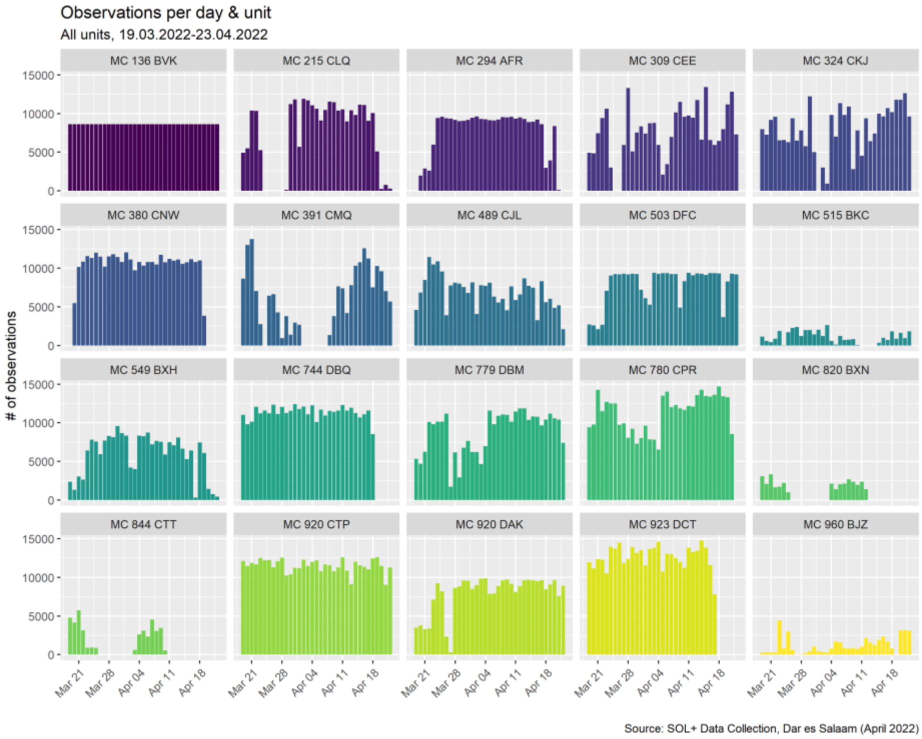


Figure 4 Number of observations per day for each unit

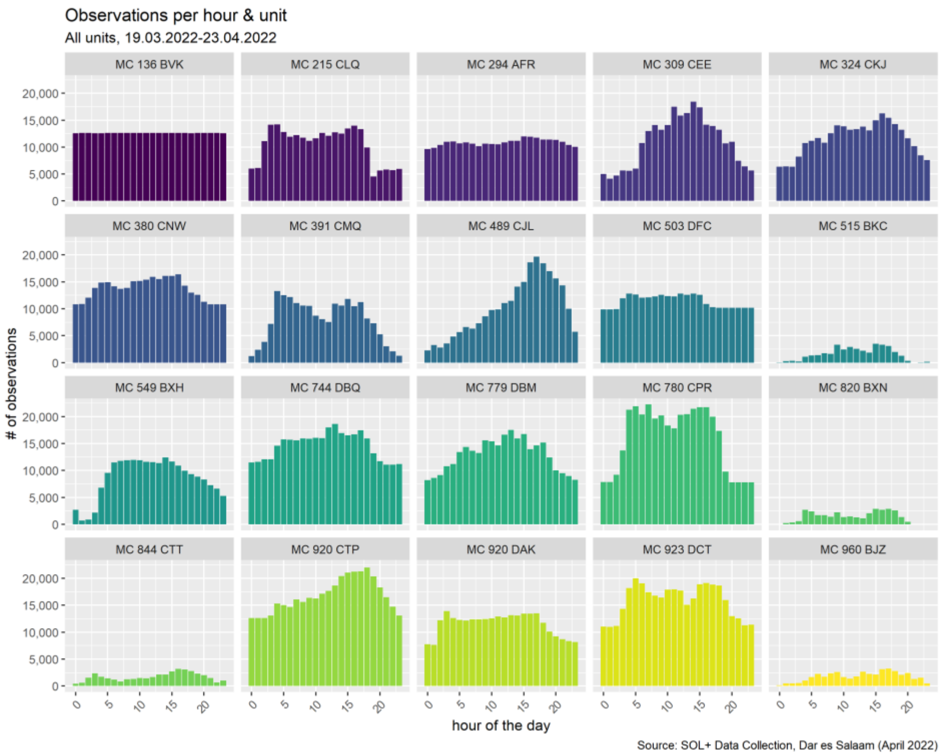


Figure 5 Number of observations per hour for each unit

Mileage patterns

We analyze the milage patterns per unit during the data collection period to obtain information about daily distances. In the following, we first present the analysis results obtained by considering the entire dataset. However, as previously described, there is the possibility of invalidity for four surveyed units. For this reason, the data are then considered separately, and an insight into the results of the data from the units with and without the potentially invalid observations is provided.

Milage pattern of all bajajs (n=20)

According to the GPS tracking results, the average daily mileage of bajaj is about 120 km. This distance is higher than expected, especially when compared to findings in the literature (Goletz et al. 2021) and from the driver survey. Possible explanations are the different locations within the city that have been analyzed as well as the imperfect relationship between perceived (by the drivers) and actual (measured) distance. In addition, note that for validation purposes we also calculated milage patterns based on the raw dataset (see following sub-section). The breakdown of average daily mileages by weekdays, Saturdays, and Sundays suggests some differences in usage patterns regarding the different days of the week. While the average value remains relatively robust for all categories (between about 111 km and 125 km), notable differences are observed when taking a closer look at the reasonable extremes of the data – i.e., the 1.5 interquartile range (IQR) values that are denoted by the whiskers in our boxplots.

Simply put, this statistic indicates the highest values that fall within 1.5 times below and above the middle 50 % of data. For the daily calculation, we obtain an upper 1.5 IQR value of about 154, which increases to about 166 for weekdays, 182 for Saturdays, and 212 for Sundays, respectively. In other words, while the daily mileage of all tracked vehicles are relatively close to each other on a daily and weekday basis (note, also, the size of the boxes and that there are just a couple of outliers), for the Saturdays and Sundays calculation, we observe many vehicles that tend to drive more considerable distances. This could indicate less idling time (e.g., due to less traffic or less waiting time for passengers), private hires for out-of-town trips, or other personal trips of drivers without passengers. However, some of the variations can certainly also be attributed to the shorter period and the small(er) number of observations in the respective sub-samples. Consider that we draw on 620 observations (=mileages per day per unit) from 36 days for the daily calculation, while there are only 86 observations on five days for the Sunday calculation.

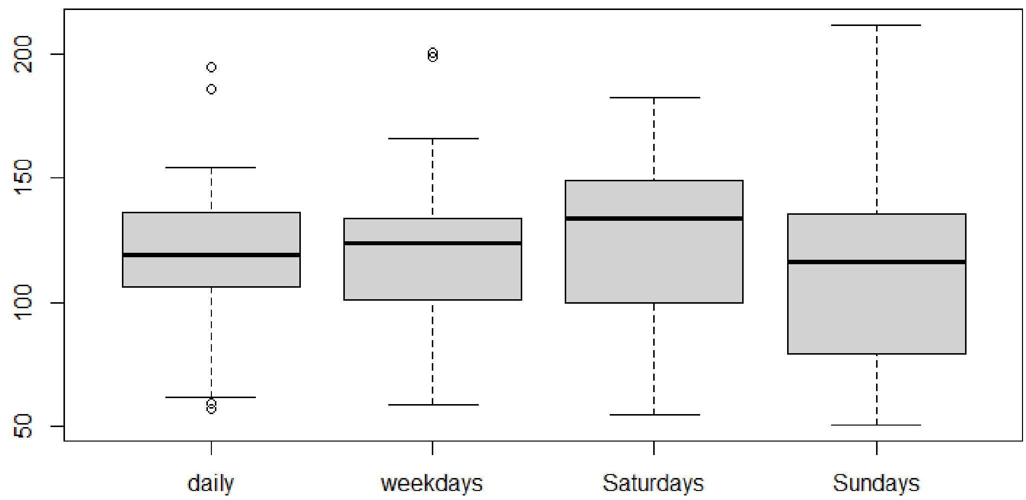


Figure 6 Boxplot of average mileage in km (n=20)

Table 2 Descriptive statistics average mileage in km (n=20)

	Distance in km					
	Min.	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**
Daily	57.38	107.91	119.41	120.11	135.85	194.83
Weekday	58.92	101.92	123.97	121.53	133.56	200.35
Saturdays	54.83	105.00	133.97	125.15	147.31	182.40
Sundays	51.00	82.66	116.38	111.53	133.00	211.50

Milage pattern of bajajs with more than 50,000 observations (n=16)

Compared to the previous analysis, we can see here that the mean daily distance, excluding the incomplete data, increases from 120 to 129 km. In addition, the mean daily distance is likewise relatively robust, ranging from 124 to 130. Although the comparison of the two datasets generally does not reveal significant discrepancies, it should be noted that we cannot rule out the occurrence of systematic errors in GPS monitoring due to factors beyond our control (e.g., tracker calibration).

Figure 7 Boxplot of average mileage in km (n=16)

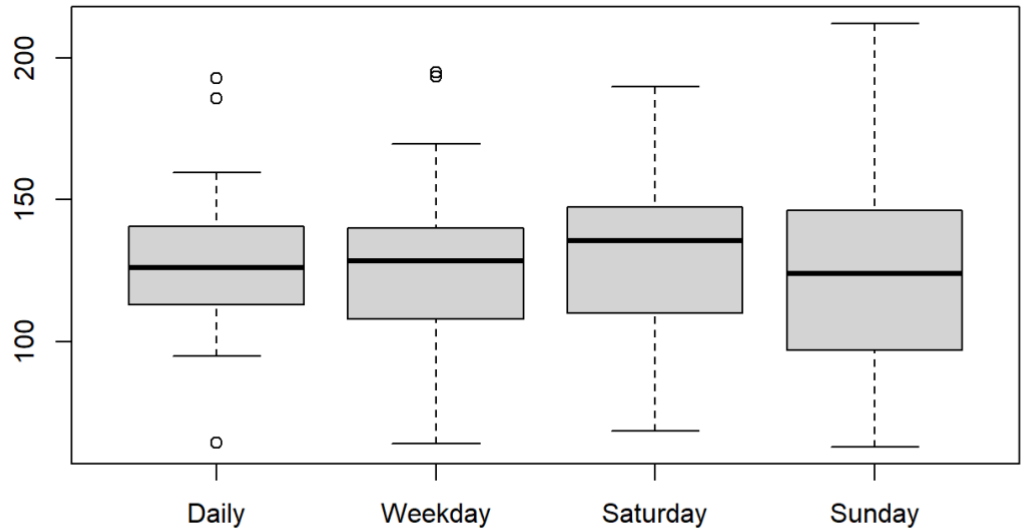


Table 3 Descriptive statistics average mileage in km (n=16)

	Distance in km					
	Min.	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**
Daily	64.3	114.6	126.0	129.3	138.2	192.8
Weekday	63.86	108.77	128.36	130.38	137.14	194.73
Saturdays	68.51	111.34	135.53	129.08	146.01	189.88
Sundays	62.9	102.1	123.8	124.4	143.8	212.0

C. Exploratory spatial analysis of night parking locations

The following analysis results present the nighttime parking behavior of all bajajs participating in the GPS survey. The analysis first focuses on exploring time windows in which the movement patterns of bajaj show little to no movement during the night. After the time windows are identified, the analysis includes identifying high frequency-parking areas. One goal of this analysis is to investigate potential interrelationships between nighttime parking locations and determine if there are locations at which different units park collectively. Identifying night parking patterns can provide insights into the parking behavior of bajaj drivers in Dar Es Salaam and support the development of charging strategies or the location planning of potential shared nighttime charging stations. The analysis results include the night parking locations of all bajajs; these can include public and private parking facilities and parking locations in front of homes.

The following figure shows the distribution of night parking locations during the data collection. The color scale corresponds to the waiting point each bajaj is assigned to. For example, points in purple represent vehicles belonging to waiting point 1, while points in yellow belong to waiting point 4.

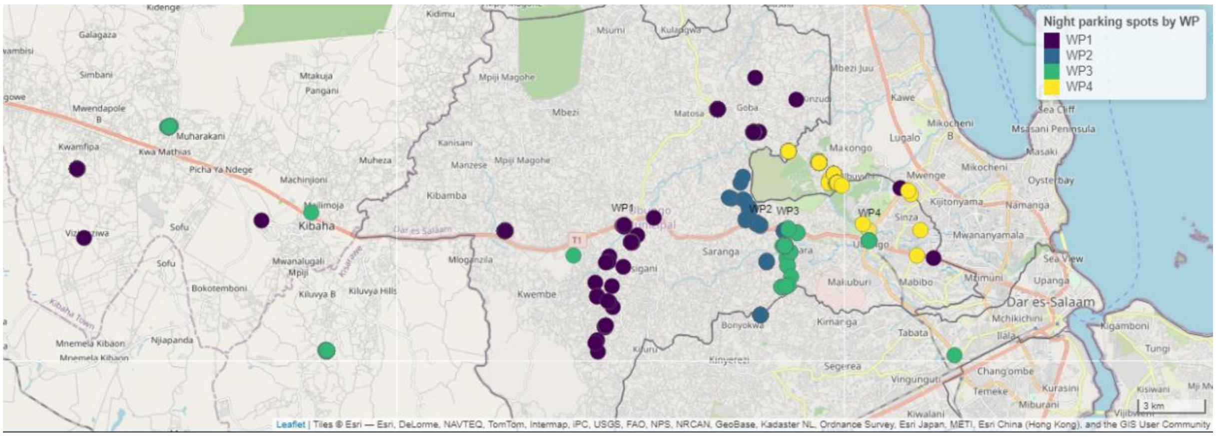


Figure 8 Distribution of night parking locations per waiting point.

In the following paragraphs, we explore the observations of the individual waiting points separately. The goal is to determine the location of nighttime parking hotspots. After analyzing the data of each individual waiting point, all observations are analyzed together.

Mbezi Mwisho north & south (WP1)

For the waiting point Mbezi Mwisho the analysis considers a time window between 1 and 2 am. In total, the data of 201 overnight parking locations are available, which are initially divided into 20 spatial clusters. A spatial cluster is a group of points less than 500 m apart. From these 20 clusters, five main clusters are finally identified. Out of the 201 observations, 170 are within these five clusters. Clusters 1 and 2 are located on the potential WP1 corridor, with Cluster 1 being located next to the Mbezi Mwisho waiting point. Cluster 5 is located outside of Dar es Salaam. Thirty-nine of all night parking spots used by the units of WP1 are in Cluster 1, followed by Clusters 3 and 4. It can be observed that the parking clusters are mainly used by a single bajaj, which is parked there regularly. Cluster 3 had a maximum of two bajaj parked on six nights. Cluster 1 was used by two bajajs in four nights of data collection. It is important to note that few intersections and thus shared parking locations were found. The spatial clusters described, therefore rather represent the most frequently used nighttime parking spots of individual units.

The following figure shows the five main parking locations of the units from WP 1. The table shows how often which unit parked in the respective cluster. In addition, it provides information about the ratio of observations in this cluster to the total number of observations.

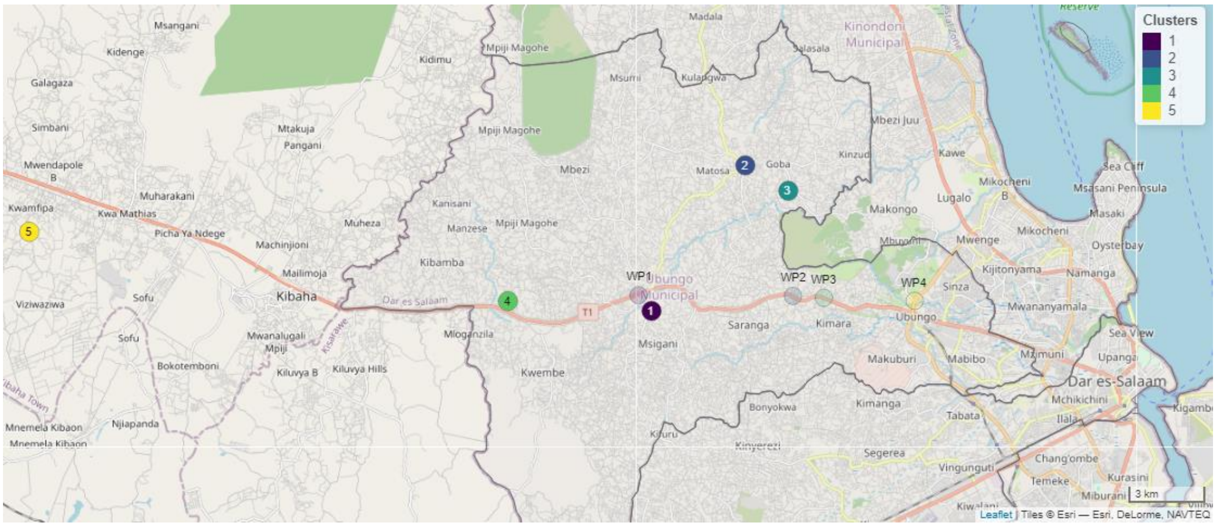


Figure 9 Locations of night parking clusters (WP1).

Table 4 Nights spent at each spatial cluster (Units of WP1).

	Nights spent in each cluster per unit									
Cluster	**MC 294 AFR**	**MC 380 CNW**	**MC 503 DFC**	**MC 515 BKC**	**MC 920 CTP**	**MC 920 DAK**	**MC 960 BJZ**	**Max. # of vehicles per night**	**Total**	**Ratio (in %)**
1	4	0	35	0	0	0	0	**2**	**39**	**19**
2	0	30	0	0	0	0	0	**1**	**30**	**15**
3	0	0	0	7	0	0	27	**2**	**34**	**17**
4	0	0	0	0	35	0	0	**1**	**35**	**17**
5	0	0	0	0	0	32	0	**1**	**32**	**16**
Total # of observations per unit	30	30	35	8	35	33	30			

Kimara Mwisho (WP2)

For WP2, the analysis focuses on the distribution of night parking between midnight and 1 am. The decision for this time window is based on the result that 92% of all observations of WP2 have a speed of zero and 99% a speed of less than ten m/s. In total, 83 observations are available for this waiting point. First, 8 spatial clusters were identified, from which the three main clusters were selected. The main clusters contain 64 of the 82 observations. Cluster 3 is located directly at WP3, and cluster 2 is located on a potential corridor to Matosa. As with WP1, it can be observed that the parking areas are used mainly by one vehicle. While clusters 1 and 3 were used by only one bajaj, cluster 2 was used by a maximum of two bajajs. It is worth noting that while there is no complete data for unit MC 844 CTT (resulting in a total of eight available observations for this bajaj), the unit parked three of the eight nights in cluster 2.

Table 5 Nights spent at each spatial cluster (Units of WP2)

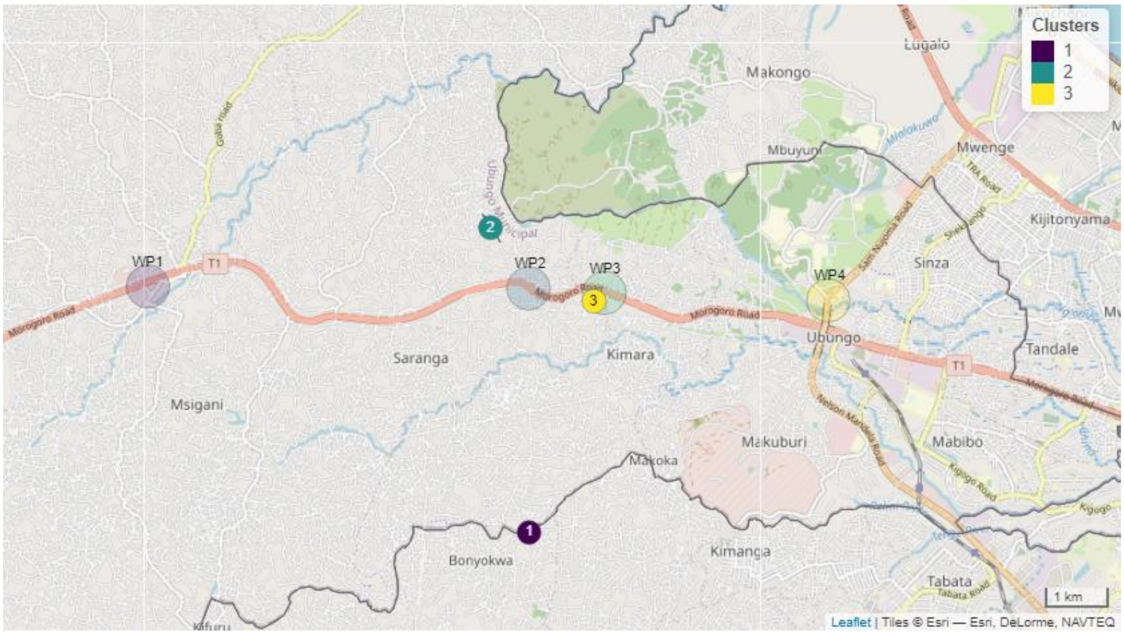


Figure 10 Locations of night parking clusters (WP2)

Nights spent at each cluster per unit

Cluster	MC 309 CEE	MC 391 CMQ	MC 780 CPR	MC 844 CTT	Max. # of vehicles per night	Total	Ratio (in %)
1	17	0	0	0	**1**	**17**	**20**
2	0	10	0	3	**2**	**13**	**16**
3	0	0	34	0	**1**	**34**	**41**
Total # of observations per unit	24	17	34	8			

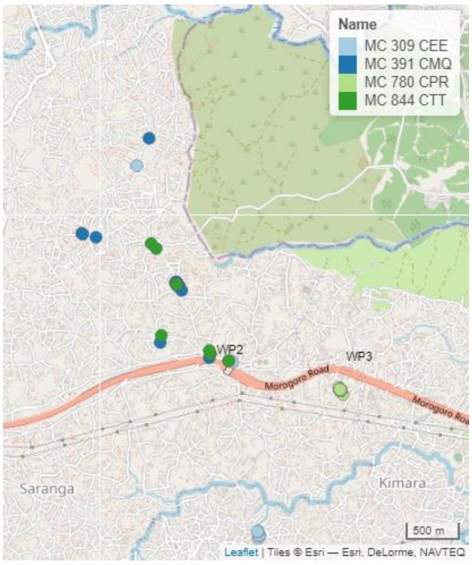


Figure 11 Locations of night parking spots around WP2 & WP3 (only observations of WP2 bajaj).

Kimara Korogwe (WP3)

Among the parking locations of the units belonging to the third waiting point, 13 spatial clusters were initially identified. In total, 104 observations are available for this waiting point, of which 77 lie within the three main clusters. Two of the parking areas – clusters 2 and 3 – are located outside Dar es Salaam and a used by a single bajaj each. Clusters 1, located near WP3, comprises 40 observations and hosts a maximum of two bajaj per night.

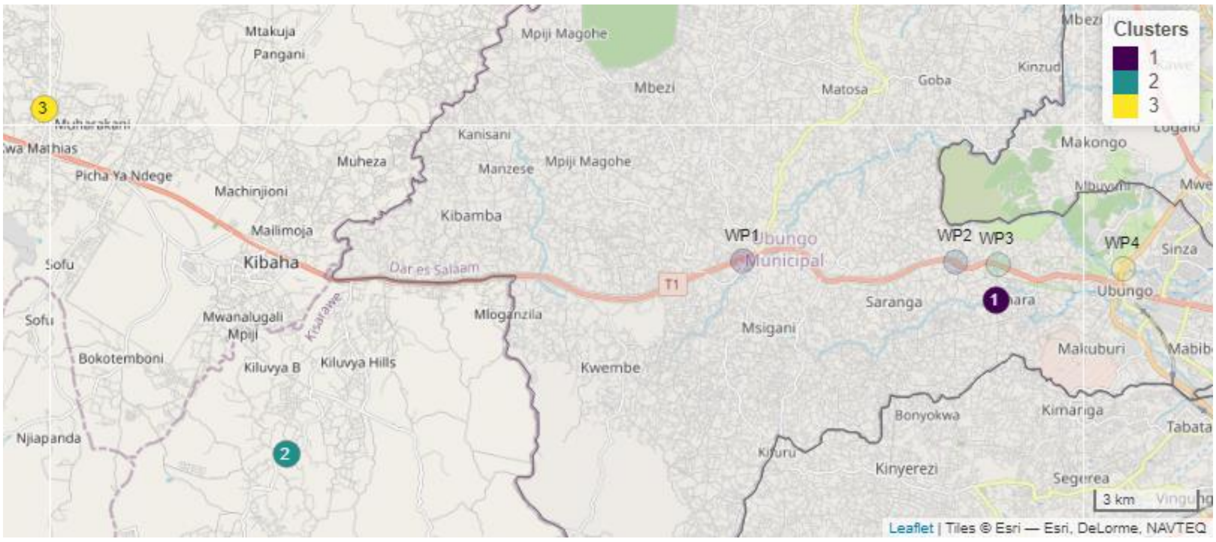


Figure 12 Locations of night parking clusters (WP3).

Table 6 Nights spent at each spatial cluster (Units of WP3)

	Nights spent at each cluster per unit						
Cluster	**MC 215 CLQ**	**MC 324 CKJ**	**MC 489 CJL**	**MC 779 DBM**	**Max. # of vehicles per night**	**Total**	**Ratio (in %)**
1	5	0	0	35	**2**	**40**	**36**
2	17	0	0	0	**1**	**17**	**15**
3	0	0	20	0	**1**	**20**	**18**
Total # of observations per unit	27	19	23	35			

While the bajaj with the ID “MC 780 CPR” does not reside in one of the main nighttime parking areas, the analysis shows that the vehicle parks in various locations throughout the survey period. Figure 13 provides a glimpse of the nighttime parking patterns for this unit. Out of 19 nights, the unit spent five nights near Cluster 1 or WP3 and six nights near WP4.

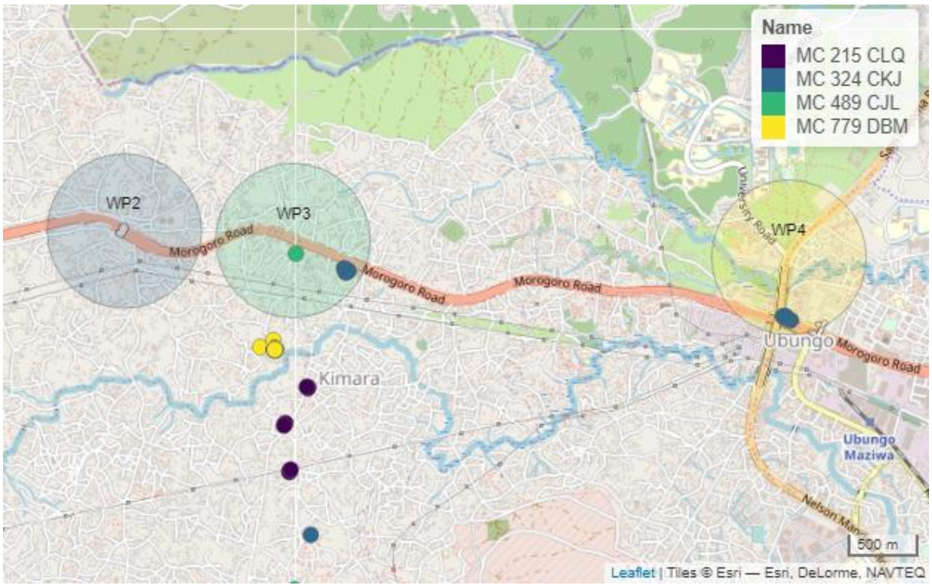


Figure 13 Parking behavior around WP2, WP3 & WP4 (only bajaj's of WP3)

Njia panda ya Chuo (WP4)

The analysis of night parking patterns of bajaj's based at WP4 looks at the time window between midnight and 3 am. The reason for choosing this time window is that 97% of the observations have a speed of 0 km/h at this time during the whole survey period. In addition, observations for the unit "MC 820 BXN" are available in this time window, which is not the case for smaller time windows (i.e., from midnight to 1 am). Initially, nine spatial clusters were identified, from which the four main clusters were selected. The main four clusters contain 106 of 113 observations.

As in the analysis of the previous waiting points, it can be observed that four units show a regular parking pattern. For two clusters, there are days when two vehicles simultaneously park within these clusters. It is noticeable that the identified parking locations are at the end of the potential corridor to Changanyikeni.

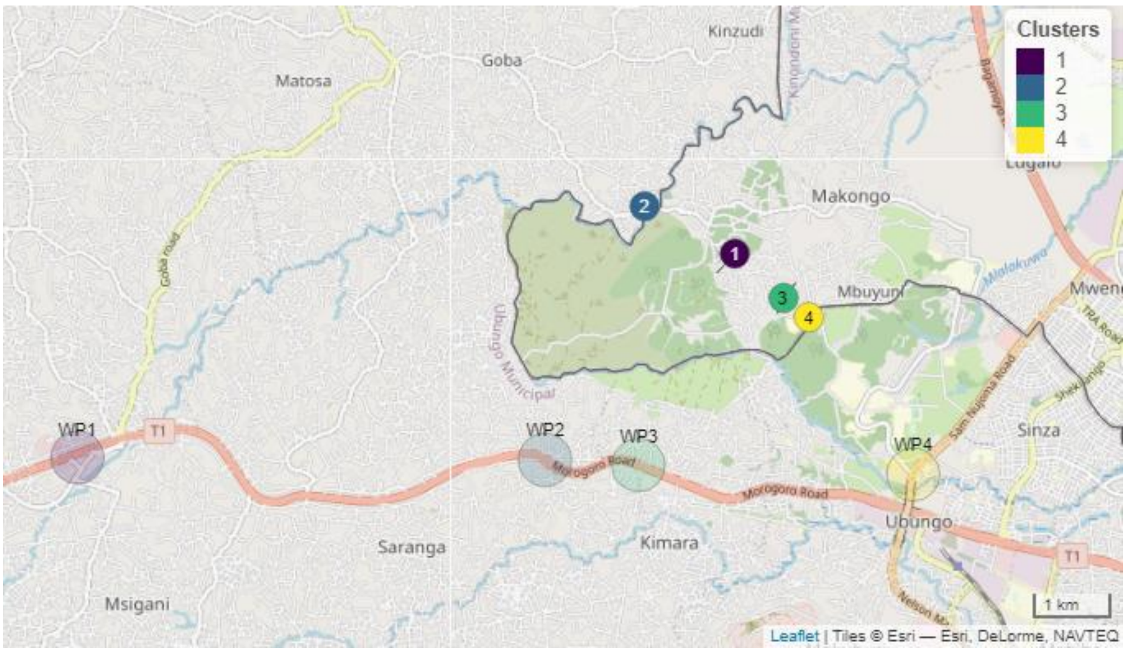


Figure 14 Locations of night parking clusters (WP4)

Table 7 Nights spent at each spatial cluster (Units of WP4)

	Nights spent at each cluster per unit							
Cluster	**MC 136 BVK**	**MC 549 BXH**	**MC 744 DBQ**	**MC 820 BXN**	**MC 923 DCT**	**Max. # of vehicles per night**	**Total**	**Ratio (in %)**
1	35	0	0	1	0	**2**	**36**	**32**
2	0	13	0	0	0	**1**	**13**	**12**
3	0	1	29	0	0	**2**	**30**	**27**
4	0	0	0	0	27	**1**	**27**	**24**
Total # of observations per unit	35	14	31	3	30			

Analysis of all waiting points

The joint analysis of parking locations for all WPs highlights similarities and differences in nighttime parking patterns among the WPs. The following figure summarizes the previous results by showing the earlier described clusters of the individual WPs displayed on one map.

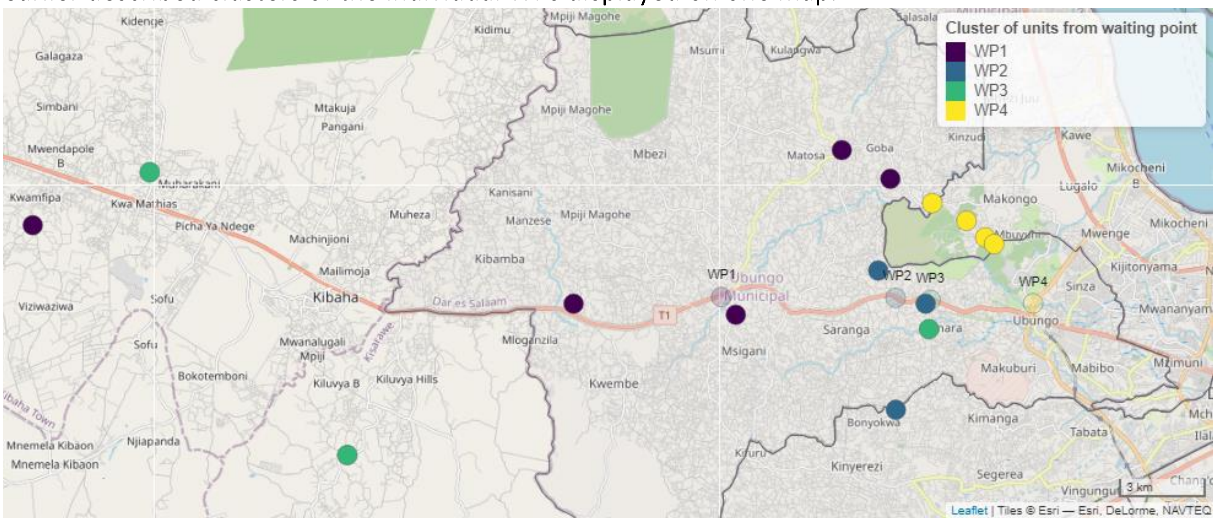


Figure 15 Combined map including clusters of all WP's

Subsequently, the analysis procedure applied to the individual WPs is performed on the entire dataset. First, clusters of points closer than 500 m are identified. Then, the spatial clusters with the most significant number of observations (above ten) are selected, and the number of units parked at each location is examined. A total of 15 main clusters were identified, which correspond to the clusters identified during the analysis of the individual waiting points. While three of the clusters are located outside the Dar es Salaam city boundary, several clusters are located close to the surveyed waiting points. Three are near Kimara Mwisho (WP2) and Kimara Korogwe (WP3), and one is on the south side of Mbezi Mwisho (WP1).

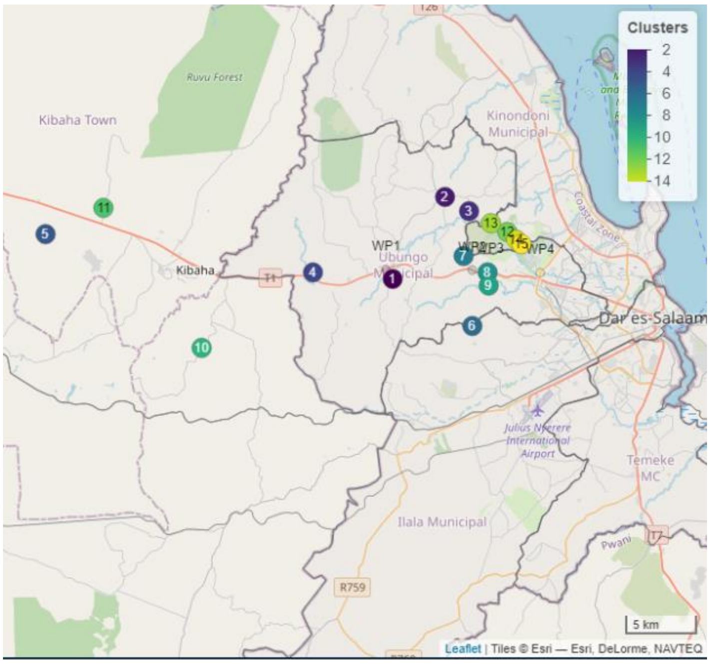


Figure 16 Locations of night parking clusters (entire dataset)

This iteration aims to investigate potential interrelationships between nighttime parking locations and determine if there are locations at which units from different waiting points park collectively. However, this hypothesis could not be verified. As shown in the table below, the distribution of overnight parking by different units from each waiting point is distributed among the clusters, and no overlapping pattern can be identified. A reason for this may be the distance chosen between the points or the small sample size, among other factors. Nevertheless, the results allow us to conclude the tendency of a large proportion of bajajs to park at a regular location. The proximity of some parking clusters to the waiting point is also worth emphasizing. The analysis shows that units based at one waiting point tend to use nearby nighttime parking locations, such as clusters 12, 13, and 14 (Figure 18). In addition, there are cases where units from different waiting points park close to each other, such as in clusters 7, 8, and 9 (Figure 17).

Table 8 Nights spent at each spatial cluster (entire dataset)

Cluster	WP1	WP2	WP3	WP4	Total
1	39	0	0	0	**39**
2	30	0	0	0	**30**
3	34	0	0	0	**34**
4	35	0	0	0	**35**
5	32	0	0	0	**32**
6	0	17	0	0	**17**
7	0	13	0	0	**13**
8	0	34	1	0	**35**
9	0	0	40	0	**40**
10	0	0	17	0	**17**
11	0	0	20	0	**20**
12	0	0	0	36	**36**
13	0	0	0	13	**13**
14	0	0	0	20	**30**
15	0	0	0	27	**27**

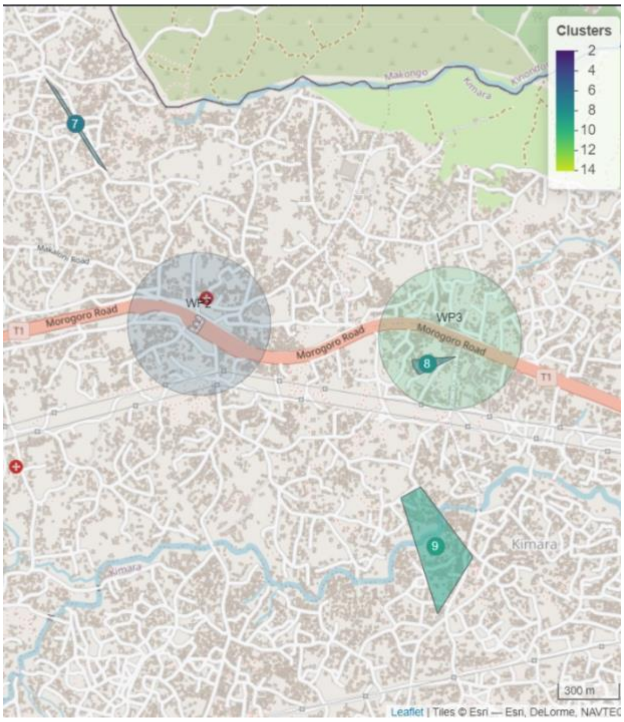


Figure 17 Clusters around WP2 & WP3 (entire dataset)

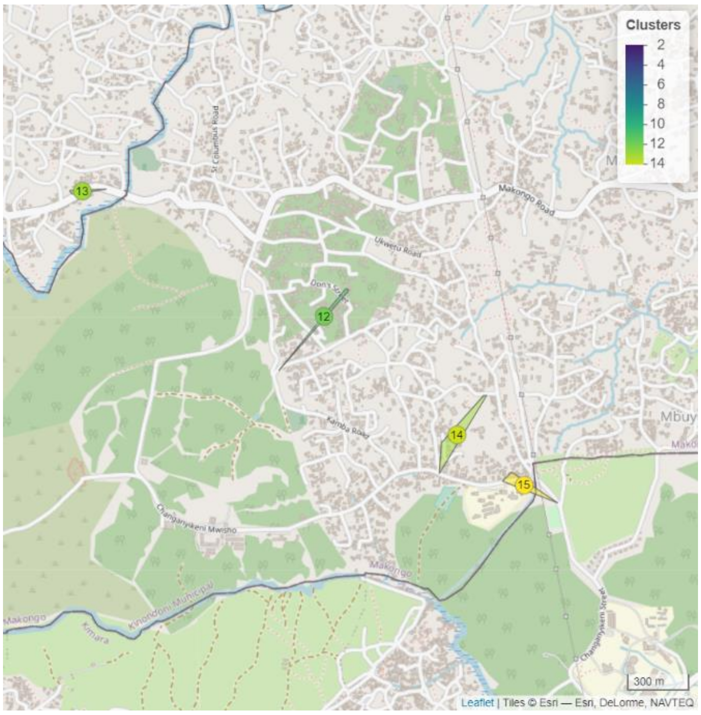
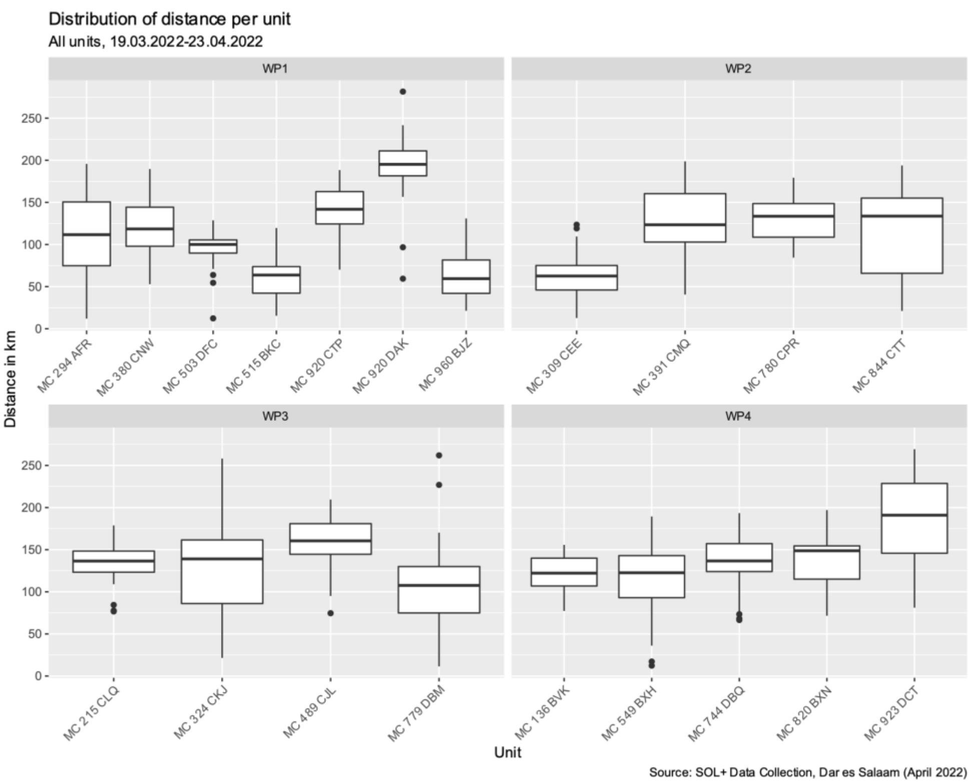


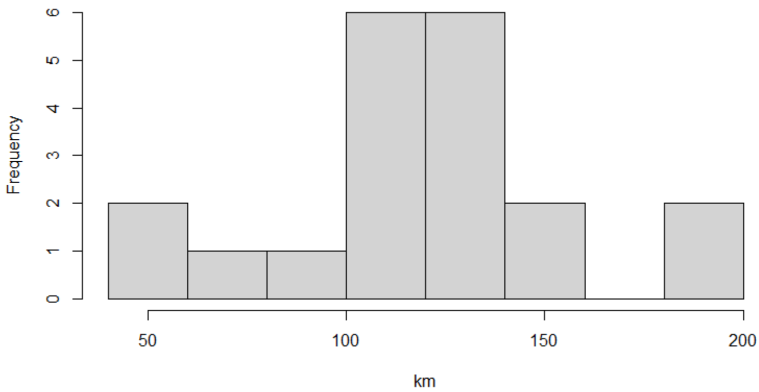
Figure 18 Cluster in the area Changanyikeni (entire dataset)

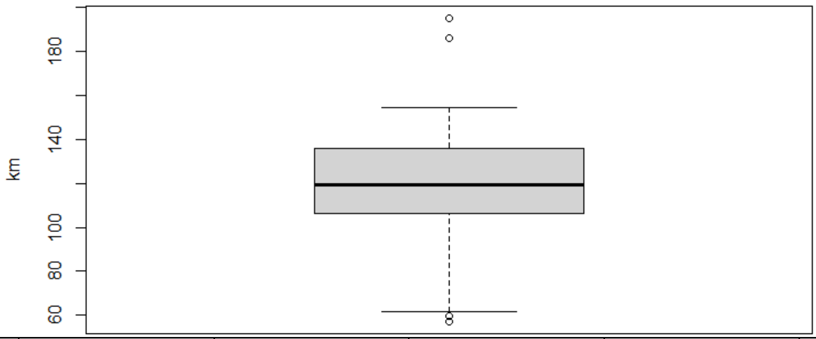
D. Additional figures mileage patterns of bajajs (n=20)

i. Average daily milage during the entire analysis period per unit



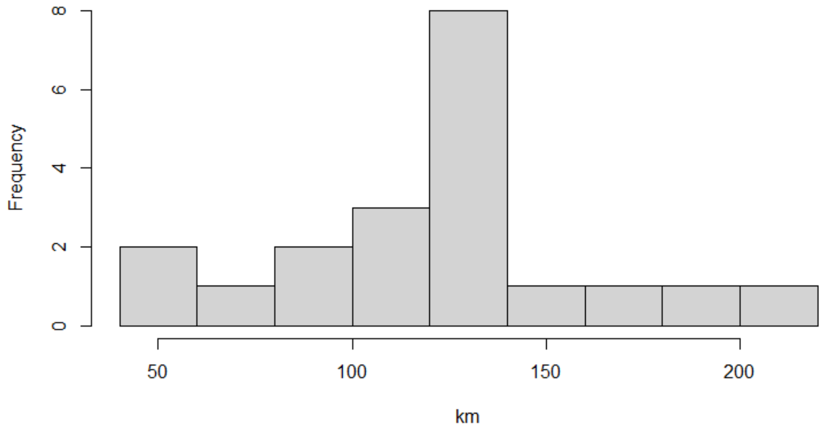
ii. Average daily mileage during entire analysis period (36 days)

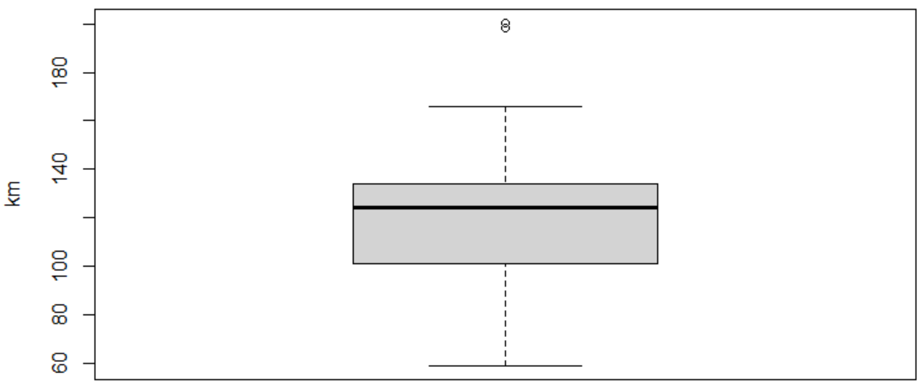




Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
57.38	107.91	119.41	120.11	135.85	194.83

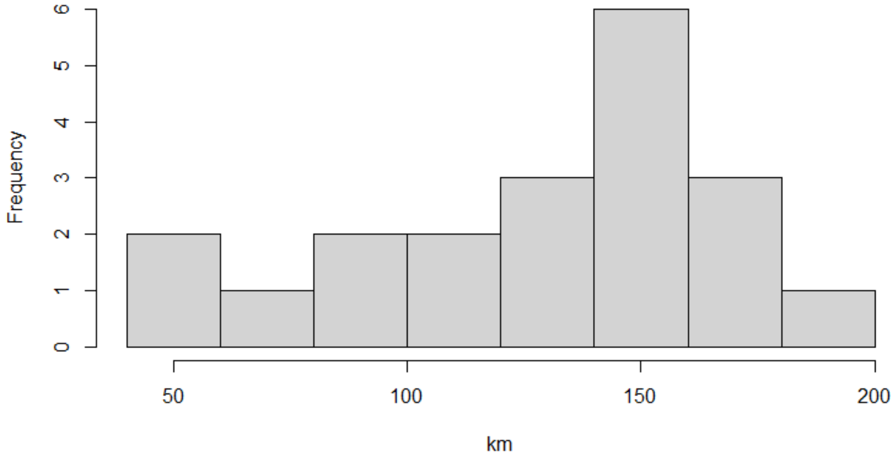
iii. Average daily mileage on weekdays (25 days)

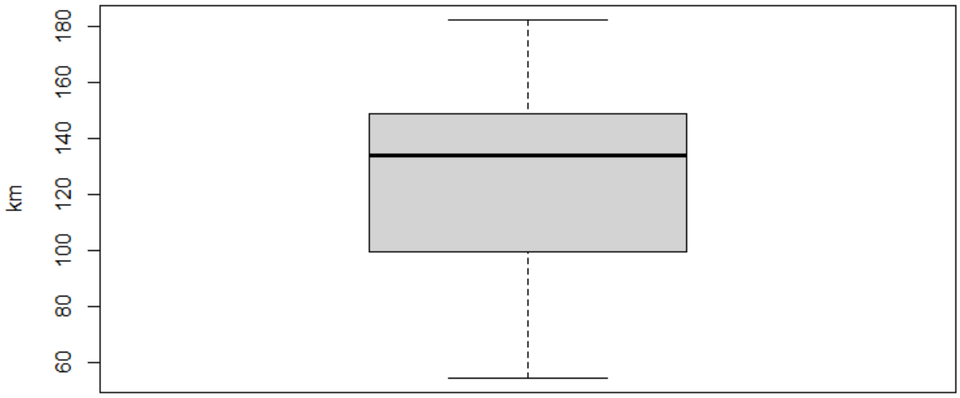




Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
58.92	101.92	123.97	121.53	133.56	200.35

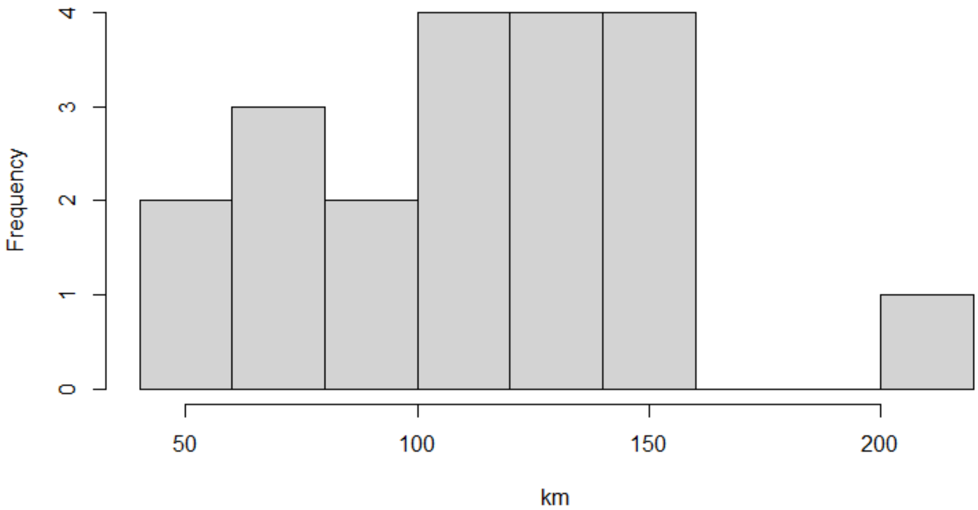
iv. Average daily mileage on Saturdays (6 days)

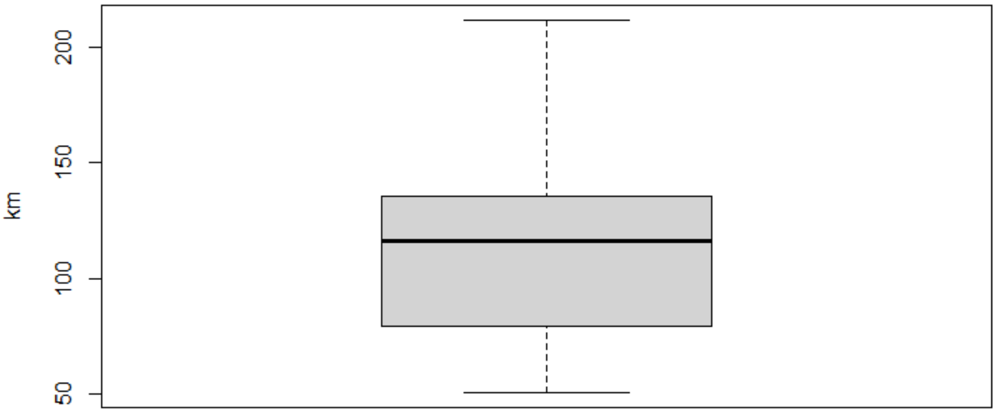




Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
54.83	105.00	133.97	125.15	147.31	182.40

v. Average daily mileage on Sundays (5 days)





Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
51.00	82.66	116.38	111.53	133.00	211.50

Annex II. Topography analysis

A. Evaluation of the elevation profiles

Road gradients have a significant influence on the vehicle energy consumption of ICE as well as electric vehicles (Liu et al., 2017). Flatter routes offer a more favourable context to deploy electric vehicles as they may reduce the need for a larger battery size, powerful motor, and the frequency of charging. In addition, manufacturers of electric vehicles indicate maximum gradeability (see Part 2.3). A vehicles gradeability is defined as the highest grade a vehicle can ascend maintaining a particular speed and is measured in 1) angle of inclination to the horizontal (degree), 2) the percentage of rise over run, and 3) ratio of one part run to a particular number of parts (e.g., 1 in 20 meters) (Yamsani, 2014).
For the evaluation, the elevation gain, the elevation loss, the maximum positive and negative slope and the average slopes of each route are considered. Since the slope capability of an EV can be an important factor for routes with steep hills or other challenging terrain, the slope capability values determined in the market analysis were used to support evaluating the slopes of the routes.

Table 8: Examples of electric three-wheelers gradeability

Vehicle	Gradeability (degree)	Gradeability (%)
Mahindra Treo	12.7	22.54%
Kinetic Safar Smart	10.2	17.99%
Piaggio Ape E-City	10.8	19.00%
Hykon India Ltd, Hetto	10.2	18.00%
Volta EV – Model 80X and Retro	9.0	15.84%
Kerala Neem G	7.0	12.28%
Average	**10.0**	**17.61%**

For the final assessment of the routes' slopes, it was assumed that slopes could range from 0 to 30%, with 30% being the maximum slope and thus the worst rated. The routes were compared for elevation loss and gain, assigning the worst rating to the route with the most significant change and the highest rating to the route with the least change. It was assumed that a difference of 0 m would be best. The results are described in Table 9.

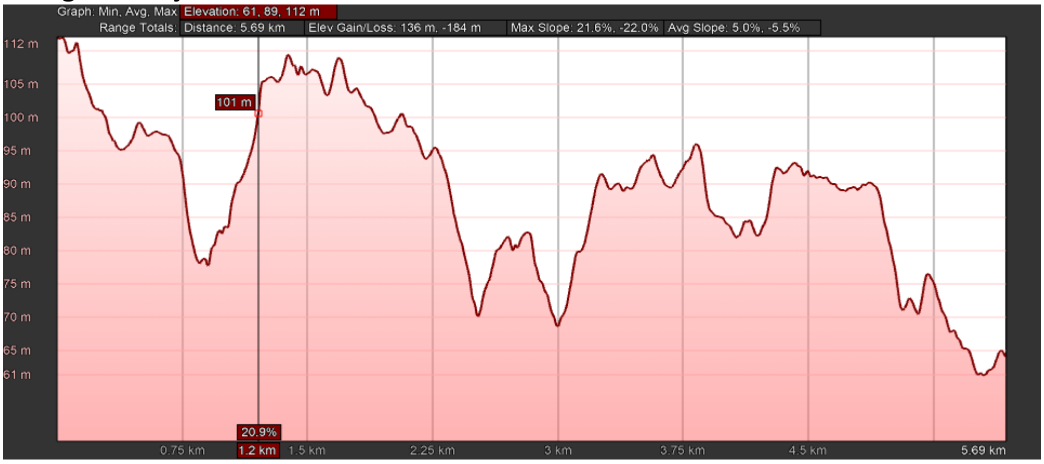
Table 9: Elevation profiles of the six corridors and evaluation

	Total lenght	Max. Slope (+)	Max. Slope (-)	Avg. Slope (+)	Avg. Slope (-)	Min Elev.	Avg Elev.	Max Elev.	Elev. Gain (+)	Elev. Loss (-)	Max. Slope (+)	Max. Slope (-)	Avg. Slope (+)	Avg. Slope (-)	Elev. gain	Elev. loss	Result
Route	**km**	**%**				**m**					**Evaluation**						
Korogwe - Maji Chumvi	5.7	21.6	22.0	5.0	5.5	61	89	112	136	184	3	3	8	8	4	2	**4.7**
Mbezi Mwisho - Kifuru	7.0	12.9	11.8	3.7	3.5	126	144	168	139	141	6	6	9	9	4	4	**6.3**
Mbezi Mwisho - Goba	8.8	15.8	15.2	4.5	4.7	116	140	166	216	227	5	5	9	8	0	0	**4.5**
Kimara North - Kwa Komba	3.5	17.7	21.1	4.3	5.6	89	113	131	79	97	4	3	9	8	6	6	**6.0**
Kimara South - Bonyokwa	4.1	13.5	18.2	4.5	5.5	87	103	134	93	127	6	4	9	8	6	4	**6.2**
Njia Panda ya Chuo - Changanyikeni	3.9	10.8	10.4	3.1	2.4	56	94	109	84	36	6	7	9	9	6	8	**7.5**

For the pilot project's success, it is crucial to ensure sufficient gradeability when selecting a vehicle, especially for routes with steep maximum slopes, such as Korogwe-Maji Chumvi and Kimara North-Kwa Komba. Vehicles with insufficient gradeability may struggle to climb these slopes and may not be suitable for use on these routes. As such, it will be necessary to carefully consider and assess potential vehicle providers and gradeability before taking a final decision.

B. Overview of the elevation profiles of the six routes

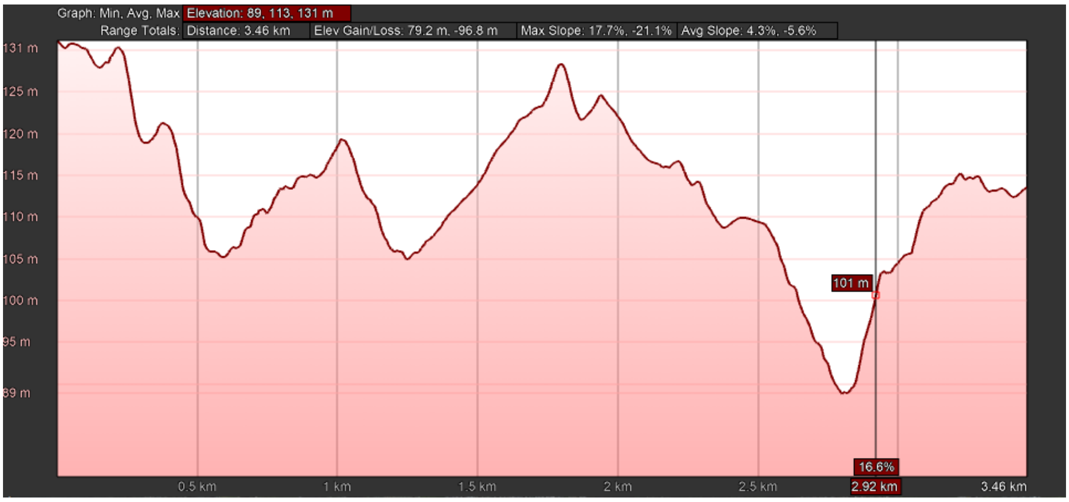
i. Korogwe - Maji Chumvi



ii. Mbezi Mwisho – Kifuru

iii. Mbezi Mwisho – Goba

iv. Kimara North - Kwa Komba



v. **Kimara South – Bonyokwa**

vi. **Njia Panda ya Chuo – Changanyikeni**

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