D1.6 IMPACT ASSESSMENT RESULTS

VOLUME 6: DAR ES SALAAM, TANZANIA

This project has received funding from the European Union Horizon 2020 research and innovation Programme under grant agreement no. 875041

PROJECT PARTNERS

ABOUT

This brochure has been prepared for the project SOLUTIONSplus. The project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement no. 875041

TITLE

SOLUTIONSplus Impact Assessment Results

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All the pictures are provided by the SOL+ partners

June, 2024

APRIL 2024

DOCUMENT IDENTIFICATION

STATUS	Ongoing	DUE DATE	30 April 2024
VERSION	v1.0	SUBMISSION DATE	30 April 2024

DELIVERABLE NUMBER	D1.6 – Volume 6
DELIVERABLE NAME	Impact assessment results: Dar es Salaam, Tanzania
WORK PACKAGE NUMBER	WP1
DELIVERY DUE DATE	30 April 2024
ACTUAL DATE OF SUBMISSION	30 April 2024
DISSEMINATION LEVEL	PU
LEAD BENEFICIARY	DLR
BENEFICIARIES	WI, UEMI, UN-Habitat
RESPONSIBLE SCIENTIST / ADMINISTRATOR	Marc Hasselwander (DLR), Mirko Goletz (DLR), Emilie Martin (UEMI)
ESTIMATED EFFORT (PERSON-MONTH)	6PM
INTERNAL REVIEWER	Subash Dhar

This document is issued within the frame and for the purpose of the SOLUTIONSplus project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 875041. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the European Commission.

(*) Dissemination level: PU: Public, fully open, e.g. web; CO: Confidential, restricted under conditions set out in Model Grant Agreement; CI: Classified, Int = Internal Working Document, information as referred to in Commission Decision 2001/844/EC.

EXECUTIVE SUMMARY

As part of the SOLUTIONSPLUS project, the feasibility and implementation of electric three-wheelers to support the Bus Rapid Transit (BRT) public transport system in the city of Dar es Salaam was performed. In a contextualised implementation approach, electric three-wheelers that are owned and operated by private persons but perform feeder mode tasks into public transport were developed. In addition, the project supported the introduction of pedal-assist electric bicycles used for urban deliveries, capacity-building activities, policy advice and awareness raising activities. The project spanned 54 months, commencing in 2020 and concluding in June 2024. As part of the project, the project team conducted an Impact Assessment (IA) to evaluate the success of the project. This executive summary presents the major findings of the IA, including results obtained up to April 2024. It forms part of Deliverable 1.6 of the SOLUTIONSPLUS project.

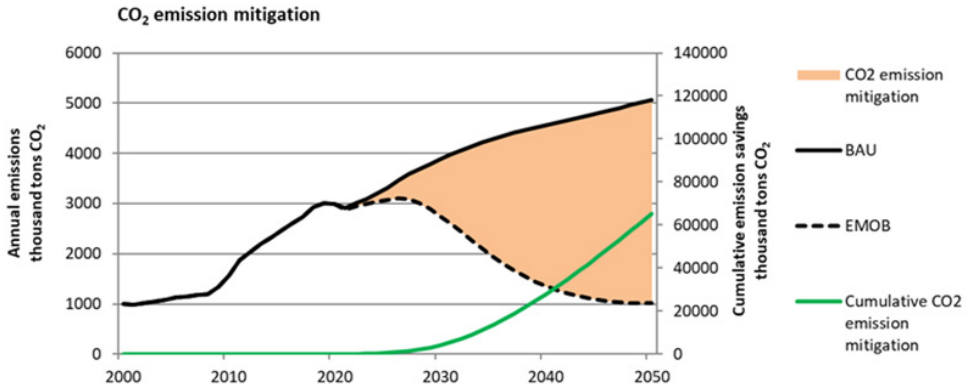
The IA is based on the assessment of Key Performance Indicators (KPIs), which were defined in Work Package 1 of the SOLUTIONSPLUS project. The KPIs were developed based on inputs from experts. A generic set of KPIs was defined by the project team, however the KPIs were adapted for each pilot city to account for specific contexts. The following table lists the KPIs that were discussed throughout the IA for Dar es Salaam:

Financial indicators	A1	Financial Viability
	A2	Ease of raising external funding
Institutional/political indicators	B1	Coherence with national plans and development goals
	B2	Alignment with supra-national/national/city legislation & regulations
	B3	Ease of implementation (in terms of administrative barriers)
Climate-related indicators	C1	Impact on GHG emissions
Environmental Indicators	D1	Impact on air pollutants
	D2	Impact on noise
	D3	Impact on environmental resources
Social indicators	E1.1	Access to jobs, opportunities, services (personal travel)
	E4.1	Road accidents with fatalities/serious injuries
	E4.2	Road accidents with minor injuries/material damage
	E4.3	Road accidents involving vulnerable road users
	E4.4	Additional indicators entering the descriptive evaluation
	E5	Impact on charging safety

	E6	Impact on security
	E8	Quality of e-mobility services
Wider economic indicators	F1	Impact on national/local budget
	F2	Impact on external trade
	F3	Impact on employment

The results of the impact assessment can be summarised as follows:

Electric three-wheelers



In relation to the **financial indicators**, the project demonstrated a positive internal rate of return, indicating that the operation of electric three-wheelers in Dar es Salaam is likely to be profitable. **Institutional and political indicators** were discussed during the validation process. The results indicated that electric three-wheelers are aligned with city goals, but that there are still governance-related barriers that may delay their introduction. **Climate-related indicators** were evaluated using the UNEP eMobility Calculator and primary data on noise, indicating that electric three-wheelers would significantly contribute to reducing climate and local particle and noise emissions and would facilitate resource conservation. In general, electric three wheelers in Tanzania show emissions that are 76% lower than their internal combustion engine counterparts. To show the overall impact on the emissions of the three-wheeler market in Dar es Salaam, we compare three scenarios: benchmark, moderate, and optimistic. The results from the comparison of benchmark and optimistic are shown in the figure below (for details see section 3): we conclude that if by 2030, 70% of the three-wheelers that are sold are electric ones, CO2 emissions of the fleet could drop by 29% from the benchmark scenario.

Social indicators were assessed using diverse methodologies, including accessibility analysis, but also expert inputs. The project's impact on the accessibility of public transport (SDG 11.2) was assessed using the widely acknowledged concept of Sustainable Development Goals (SDGs). The results indicated that the project would help to increase the accessibility of public transport for the overall population. However, a slight negative effect on road safety was identified, which mainly stems from the fact that electric three-wheelers are less noisy than their ICE counterparts. Nevertheless, the project is expected to result in a general improvement in the quality

of the mobility service. **The wider economic indicators** suggest that the project could have a significant positive impact on the economy, particularly if local manufacturing and maintenance are considered. However, it should be noted that the full economic effects will only be realised once the project is implemented on a larger scale.

Overall, the project showed that the implementation of electric three-wheelers presents a promising solution to tackle sustainability and transport related challenges in a growing mega city like Dar es Salaam.

Pedal-assist electric bicycles

The environmental impact assessment shows that the shift from ICE boda bodas to electric bicycles demonstrates significant potential for reducing CO2 emissions. Substituting an ICE motorcycle with an electric bicycle, under the current characteristics of electricity generation, would result in an annual reduction of 2,723 kg of CO2e, equivalent to a substantial 95% decrease in CO2 emissions. These benefits will increase with the launch of the Julius Nyerere Hydropower dam.

CONTENTS

1 BACKGROUND AND CONTEXT

1.1. POPULATION, ECONOMIC INDICATORS AND EMISSIONS

Dar es Salaam is the by far largest city in Tanzania and its economic hub. It is a growing mega-city with a population of around 7,7 million (World Population Review, 2023) that has steadily increased in the last decades. Using satellite imagery from the World Settlement Footprint (DLR, 2012), the images below show the extension and density of the urban area in Dar es Salaam between 1988 and 2012. Hand-in-hand with the ongoing urban extension goes a growing demand in mobility and transport, and especially public transport, which is addressed in the study that is presented here.

In 2022 Tanzania's GDP per capita (current international US$) amounted to $3099 (Worldbank, 2023). CO2 per capita in Tanzania was estimated at 0.221 metric tons in 2014 with the transport sector contributing 57% of the total CO2 emissions from fuel combustion (IEA Statistics, 2014). With renewable electricity output currently at 37% of total electricity output (IEA, 2021), the country's aim is to increase its share of renewable energy production through increased use of hydropower, solar and other renewable energy sources.

- Population: 7,7 million (2023)
- GDP per capita: $3.099 (2023)
- CO2 emissions (per capita): 0.221 metric tons in 2014

1.2. URBAN TRANSPORT

As a result of the steady urban extension and economic growth, transport demand in Dar es Salaam has increased in the last years, leading to increased travel demand in the city. To address this, the city of Dar es Salaam has introduced a Bus Rapid Transit System established by the Dar Rapid Transit Agency (DART) in 2016. To date, Dar es Salaam's BRT system comprises two lines (Phase 1) of a total length of 21.1 km, in operation since 2016 (DART, 2022) The extension of DART is currently ongoing, with a planned deployment into a total of six phases. At the completion of the entire BRT, the network is planned to consist of a total of 154.4 km of segregated corridors, 18 terminals, and 288 stations, integrated to feeder services and the integration of infrastructure for non-motorized transport modes near stations (ibid).

While the BRT system is established by a government authority, a large share of public transport ridership is still being handled by paratransit or semi-regulated transport operated by individuals: a fleet of mini- and midi-size buses called 'dala-dala' run throughout the city's streets, that a growing number of two- ('boda-boda') and three-wheeler taxis ('bajaji' - named after the most Indian company bajaj who import three wheelers to TZ/Dar es Salaam) complements. Two- and three-wheelers have become increasingly common since the mid of the 2000s and are being used by passengers for shorter trips as well as feeder trips towards the BRT and dala-dala stations.

Overall, most of the city dwellers travel by minibus or walk: 43% to 51.2% of residents use public transport by minibus (47.9%) or BRT (3.3%), 43% to 39% walk, 4.9% use motorcycles, 3.7% cars, 0.5% bicycles, 0.4% commuter rail, and 0.3% ferry (range as indicated by DART, 2022 and JICA, 2018). However, due to the lack of a recent census and a household travel survey, all numbers should only be considered as approximations. Since 2014, when the total number of 3-wheelers was estimated to be around 50.000

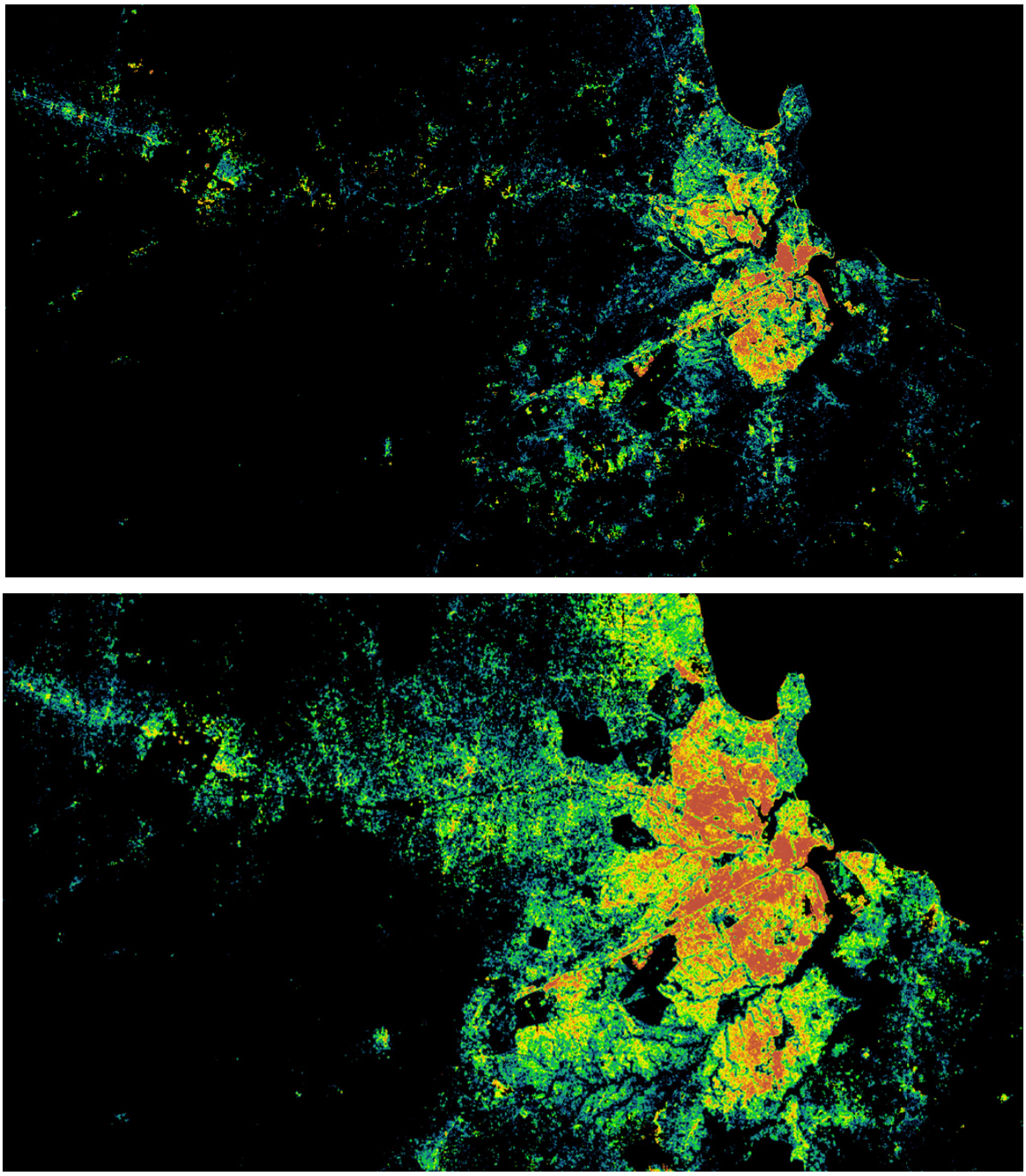


Figure 1: GPS tracks of 3-wheelers in Dar es Salaam, at Kimara BRT station
(Source: DLR/World Settlement Footprint, Images from 1988 [above], 2012 [below])

(Bishop & Amos, 2015), they grew above-average due to rising imports since then.

1.3. IDENTIFICATION OF MAIN PROBLEMS

The rapid population growth of Dar es Salaam in the past two to three decades has imposed many challenges on the development of the city. As the population continues to increase, people make more trips within a city over a long distance (Kanyama et al,2005). The supply of an adequate public transport system and infrastructure is one of these main challenges today.

- Increasing private car ownership due to increased wealth/income

- Increasing transport demand due to the population growth and increasing economic activities
- Longer distances travelled resulting from urban sprawl
- Increasing number of two- and three-wheelers since mid of the 2000s

All of the above points increase negative externalities from transport as well as increased congestion. All motorised modes rely on fossil fuels, thereby leading to increased CO2 and particle-emissions. Motorised two- and three-wheelers have considerably expanded in Tanzania from 52,015 in 2007 to 1.2 million now, which poses a challenge due to their reliance on fossil fuels. Additionally, noise and safety externalities result as well as increased travel times due to road congestion.

The development of an integrated public transport system has to be considered as the main priority in terms of urban mobility, as private individual transport will further increase the externalities and congestion. Besides the further development and construction of a high- capacity rapid transit system such as BRT, the feeder modes for fine distribution also need to be addressed. Especially three-wheelers have proven to be suitable for the context of Dar es Salaam, as their rapid increase shows.

Total emissions for Dar es Salaam from household energy, buildings and Industry, all road transportation and solid waste was estimated at 8,065,907million tones' of carbon dioxide equivalent (CO2e) with 1.3 tones' CO2e per capita in 2016. Contributions from the transport sector was reported at 32% being the second largest contributor of GHG (gases included CO2,CH4 and N20) after waste (Dar es Salaam GHG Emissions Inventory Report, 2016).

- As of 2015, the current public transport system in Dar es Salaam was composed of approximately 6,820 registered dala-dalas owned by 3,700 owners with 362 licensed routes for public transport (ESIA, 2015). The city is increasingly witnessing an increased number of motorcycles and tricycles as an important means of transport running parallel with the dala-dalas and also serving the outskirts of the city as a major means of transport servicing the last mile connectivity aspect. There were 4,432 registered boda-boda as of May 2014 and an increasing number of tricycles which provide the much-needed income opportunities. As of 2015, the market had created an estimate of about 50,000 direct jobs (Bishop, 2015). The city is also traversed by a few bicycles most of which are privately owned, the ferries that serve the population in the southern part of the city and the Dar es Salaam commuter train running through the city centre.
- The existing BRT system is still being developed, currently there are ongoing constructions of phase two and the consequent phases to follow (Phase 2 - 6). The the six BRT phases are planned to be operational by 2035, according to DART's Report on the "Promoting Soot Free Buses in Tanzania" Project (Dar Rapid Transit

Figure 2: GPS tracks of 3-wheelers in Dar es Salaam, at Kimara BRT station (Goletz & Ehebrecht, 2020)

Agency, 2022).

- The new BRT fleet from phase 2 alone is expected to conform to the Euro III emission standards achieving an offset of 104.243 metric tons of pollutants per day (BRT ESIA, 2015).

Average levels of PM2.5 and PM10 recorded in Dar es Salaam City study by Njee et al in 2016 were 48.8 µg/m3 and 152.9µg/m3 from traffic with major contributors being old diesel engines commuter buses, congestions and the general rapid increase in the number of vehicles.

Currently, there's a growing number of three-wheelers operating in Dar es Salaam as on-demand taxi services ('micro-informal' transport, see Goletz & Ehebrecht, 2020). They can be characterized as a semi-legal, yet unorganized mode of transport and are part of Dar es Salaam's informal transport sector that also includes the dala-dalas. Dala-dalas are more tightly regulated: all dala-dala in Dar es Salaam are marked by color strips indicating the routes where they are allowed to operate, for easier identifcation by the police and officials of the Land Regulatory Authority (LATRA) (communication shared by the Urban Living Lab Center, November 2023). High fines are imposed on dala-dalas if they are found to operate on non-authorised routes (ibid).

The situation of three-wheelers is different. Their legal regulation is not fully clear, as they do not need prior authorization and are not serving official routes; there are also said to be allowed to carry only a maximum of three passengers (information shared by LATRA officials, February 2022), although this cannot be traced back in legal texts.

Three-wheelers serve for a set of different trip types, with feeder services into the BRT and dala-dalas being very common (ibd.). It frequently happens that many three-wheelers mainly run between the BRT stations along Morogoro-Road into the settlements lying north and south of it. Figure 2 shows the trips that have been derived from GPS tracks, depicts such a situation. One three-wheeler was tracked throughout a whole day, thereby frequently making trips southbound from the Kimara BRT station and likely already serving as an informal BRT feeder. Goletz & Ehebrecht also measured the average trip distance of three-wheelers being 2.8 km, while Czeh (2019) states 2.98 km as the average trip distance. Czeh also identifies the number of daily trips averaging at 21.5km for three wheelers in 2018, with 64.1 km per day or 448.6 per week, respectively. In 2022, SOLUTIONSplus partners conducted a detailed study also using GPS tracking deployed in various areas connecting to BRT stations, which found an average daily mileage with ICE bajajs in the areas of 120 km going up to 136 km (upper value of the interquartile range) (SOLUTIONSplus, 2023).

1.4. DESCRIPTION OF THE DEMONSTRATION PROJECT

In Dar es Salaam, the project promotes the electrification of three-wheelers ("bajajs") already providing feeder services to the bus rapid transit system (BRT), tests new mobility options in the form of pedal-assist electric bicycles used for urban deliveries, raises awareness on electric mobility, and identifies policies to remove barriers to sustainable and electric urban mobility.

Initially, the deployment of electric three-wheelers was planned around 5 DART stations considering urban locations and in peri-urban areas where combustion-fuelled three-wheelers are currently very common as feeder-modes. As of April 2024, 31 new three-wheeled vehicles locally assembled have been deployed (30 new vehicles and 1 retrofitted bajaj), and 12 vehicles (4 retrofitted bajajs, 8 new vehicles) are still to be deployed by the end of the SOLUTIONSplus project at the end of June 2024. Areas for deployment near the BRT system include waiting points near the BRT

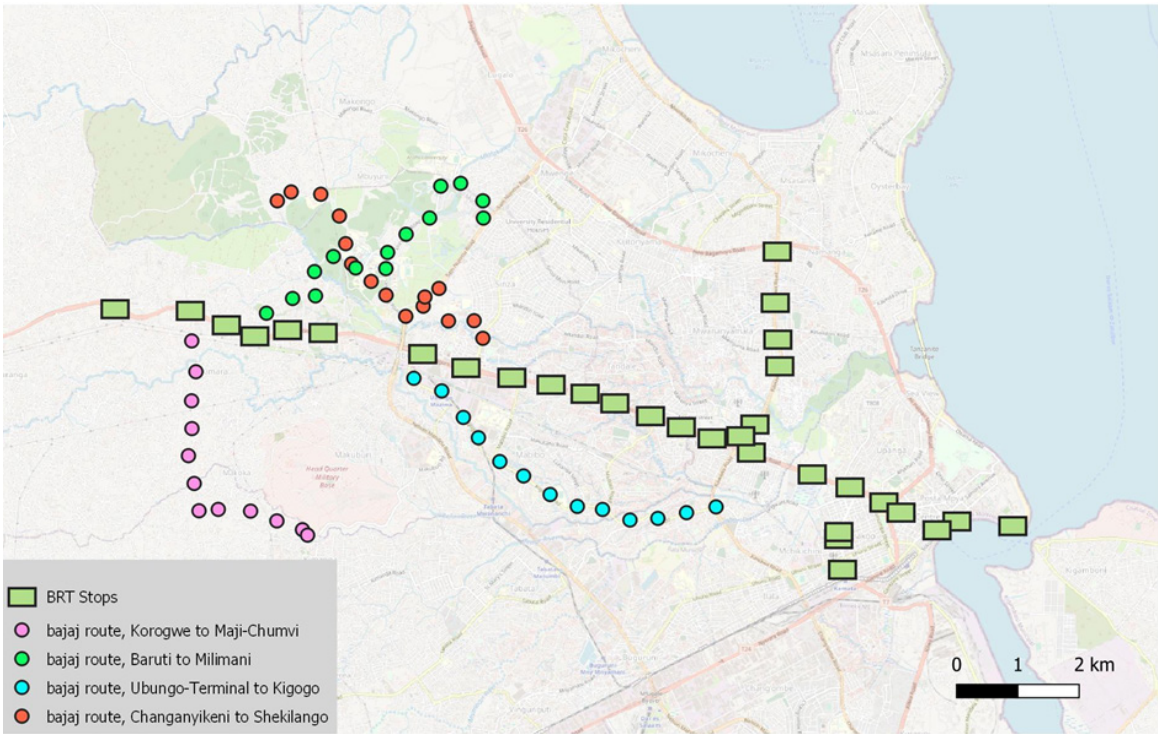


Figure 3: Map showing initial planning for the introduction of electric three-wheelers in Dar es Salaam

stations Ubungo Maji and Gereziani. While drivers currently mostly charge at home, chargers are planned to be operated in the coming weeks at four further locations connecting to the BRT system (Gereziani, Morocco, Ubungo, Mloganzila).

Overview of the models tested and supported

As of April 2024, 31 new three-wheeled vehicles locally assembled have been deployed (30 new vehicles and 1 retrofitted bajaj), and 12 vehicles (4 retrofitted bajajs, 8 new vehicles) are still to be deployed by the end of the SOLUTIONSplus project at the end of June 2024. These electric three-wheelers are either retrofitted (converted) fossil-fuel bajajs into electric bajajs, or fully new electric three-wheelers. Hence, a wide range of vehicle designs and technologies were tested. The project carefully studied the patterns of ICE bajajs to identify the adequate combination of technical specifications – in particular, the battery capacity – and the charging strategy (SOLUTIONSplus Feasibility assessment to electrify feeder three-wheeled vehicles in Dar es Salaam, 2023). Lastly, all electric three-wheelers all use lithium-ion batteries, comparatively more performing than lead-acid batteries and more adapted to the needs of the drivers of bajajs, and representing a shift away from other electric three-wheelers found using polluting and less efficient lead-acid batteries.

During Phase I focusing on promoting local Research & Development, two companies were financially supported by UN-Habitat. Auto Truck assembled two new electric bajajs and retrofitted one ICE bajaj at the Dar Institute of Technology (DIT). The collaboration with the DIT has provided strong local anchorage, enabling the assembly of vehicles and the training of engineering students. The vehicles are charged at DIT, located near the BRT stop 'DIT Main Gate'. The vehicles have been tested and are currently pending certification from TBS and registration with TRA which will allow for subsequent commercialisation. Designs for the fleet application management system were developed in collaboration with the Kenyan branch of the hardware supplier Teltonika, a company based in Lithuania. Another company, Sustainable Energy Services Company (SESCOM) retrofitted three ICE bajajs. After finalising a retrofitting

Figure 4: Phase I - Auto Truck/DIT Company Ltd (left) and SESCOM (right)

Figure 5: Phase II - Expanding the e-bajaj fleet: new e-three wheelers by TRI (top) and Ekoglobe (bottom)

manual and proceeding to the technical operational testing, the vehicles were tested and are pending certification by TBS. They will then be registered with TRA and LATRA Authorities and deployed along the Tangi Bovu – Goba route. This route connects to the Mbezi Mwisho BRT terminal, and connecting to other minibus bus stops, such as the Ulomi bus stop.

During Phase II looking to expand the e-fleet locally assembled (2023-2024), Ziotio Company (brand TRI) and Ekoglobe were selected to provide additional vehicle design and charging approach, with seed funding provided by UEMI. Via SOLUTIONSplus, Ziotio Company (brand TRI) deployed 20 electric bajajs using plug-in charging overnight and topped up during the day, and 5 further vehicles of the iterated bajaj model E2 early 2024, integrating feedback from the drivers on the battery and vehicle design

(see figure 5). EKOglobe assembled 12 electric three-wheelers for passenger services and trained 12 drivers. The vehicles are operated at a bajaj waiting point close to a Bus Rapid Transit (BRT) station, where drivers use them to provide passenger feeder services to a university and residential area. The technical specifications and the route selected for the pilot are based on the 2023 SOLUTIONSplus feasibility study to electrify existing three-wheelers near BRT stations. Drivers access the vehicles on a lease-to-own basis with daily mobile money payments and battery exchange fees.

1.5. INITIAL ASSESSMENT OF STAKEHOLDERS AND USER NEEDS

The User Needs Assessment was carried out in the months of November and December 2020 and in January 2021. The assessment was carried out in line with the concept that was provided by the SOLUTIONSPLUS project as described in Deliverable D 1.3, in order to harmonize the assessment approaches over the demo cities that are part of the project. As primary method interviews with key stakeholders were carried out and the results and findings of these are presented below. Due to a very low response rate at the time of writing this report (n=2), the results of the complementary online survey are not considered in this report.

Table 2. Applicable KPIs and corresponding report sections

Stakeholder Group	Stakeholder name	Stake-holder ab-brev.	Method (Inter-view, Survey, KPI)	Date
National & regional authorities	Dar es Salaam City Council	a1	Interview	10 Dec 2020
	TBS	a2	Interview	11 Nov 2020
	LATRA	a3	Interview	27 Nov 2020
Public transport companies	DART	b1	Interview, KPI	11 Dec 2020
NGOs and Eco-Organisa-tions	TATEDO	c1	Interview	12 Nov 2020
Academia	NIT	d1	Interview	24 Dec 2020
OEMs, Private companies, Start-Ups	ELICO	e1	Interview, KPI	26 Nov 2020
	RISE / Sollatek	e2	Interview	20 Nov 2020
	Jiwe Kubwa	e3	Interview	13 Nov 2020
Service Providers	TANESCO	f1	Interview, KPI	17 Nov 2020

1.6. RESULTS USER NEEDS– EXPERT INTERVIEWS

1.7. AIMS OF THE CITY AND EXPECTATIONS OF STAKEHOLDERS

1.8. EXPECTATIONS

On a demo level, stakeholders b1, c1, e3, b1, d1 expect that the demo project will create awareness, open opportunities, build capacities and will be a source for stakeholders networking. Furthermore, stakeholders b1, a3 expect the project to help integrate the various transport modes in the city with e-mobility feeder services and thereby promote sustainable transport. Stakeholder e1 expects the demo to increase the private sector involvement in e-mobility, thereby promoting it as a whole in the country. Stakeholders a3, e3 expect that at the demo level, the project will be a catalyst/stimulus to the business community to venture into e-mobility.

On a scaled-up level the project will reduce emissions, fight climate change, reduce importation of fossil fuels, venture/spill into other cities, reduce pollution, efficient use electricity/energy, and create employment (Stakeholders a1, c1, a3), create new business opportunities and allow for investments (a1, a3, c1, e3,) and also lead to improved health conditions (Stakeholders a3, d1). It will furthermore generate economic benefits – more jobs, reduce transport cost, generate profits for operators, and also increase reliability due to the use of electricity (Stakeholders a3, b1, d1, e3).

Stakeholders b1, f1 made suggestions how the above-mentioned expectations could be met, for instance by creating an enabling environment (rules and regulations, policies, guidelines, also mentioning the need for collaboration between private and public sectors on e-mobility infrastructure development and investment, while ensuring that all all key stakeholders and players from the transport sector are involved at the very beginning/start of the project. This will also create the need for training on necessary aspects of e-mobility for local stakeholders – vehicles, operations, maintenance. Stakeholder b1 particularly mentioned the need for a proper institutionalization to manage the e-mobility services.

Users

Regarding users of the proposed e-mobility solutions under the demonstration, stakeholders a2, c1, d1 expect that it will be used by people of all classes in the business industry community, public sector servants, commuters and the general public. Apart from passenger transport, delivery services will increasingly use bajaj services as online business is booming, where motorbikes are currently used but are regarded as an unsafe mode (d1). Special user groups might be school children who currently face the challenge of the timing of the school buses, with children leaving home very early and coming back very late; in a scaled-up scenario, the electric bajajis will offer an option to such parents (d1). Furthermore, public services may use e-bajaj that are owned by institutions as an official transport means to serve their employees, something which is already done by Stakeholder d1 and was suggested to be applied on a wider scale by a2, e1. Stakeholder e1 also stated the high price sensitivity of users in Dar es Salaam, meaning that the price will determine who will end up using e-bajaj.

In general, e-bajaj were considered as a means of passenger transport and for freight (delivery services and logistical services) with equal importance in the future, despite freight not being part of the SOLUTIONSPLUS demo project.

Where

For the demonstration as well as a scaled-up scenario, stakeholders opined that e-bajaj could be used in urban as well as in peri urban areas (outskirts of the city). Due to the ban of 2- and three-wheelers in the CBD of Dar es Salaam, stakeholder b1 however indicated that currently a service provision there would not be possible.

Stakeholder b1 also stated that areas in the city where the operation of busses is not possible due to narrow or other improper road conditions could be considered to be served by e-three-wheelers. In the future, e-bajajis may become popular in port authorities to facilitate movement of staff within the area, in industries to deliver goods (Stakeholder a2). Looking beyond the city scape, e-bajaj may be highly suitable to be used in rural areas, where there is electricity and/or renewable energy available (Stakeholders a2, b1, c1, f1).

Regulation

In Tanzania or Dar es Salaam, at the time of the interviews there was no regulation in place that addresses e-mobility directly, however there are current regulations that implicitly address questions related to e-mobility. Generally, policies and regulations exist that promote sustainable urban transport modes such as BRT (Stakeholders a3, b1, f1). Another example is the Tanzania Energy policy, that generally mentions that renewable energy should be diversified to reduce dependence on conversional energy sources, whilst investing in clean technologies for environmental protection (Stakeholder d1).

Positive examples however do already exist, and there are already private persons that have imported a limited number of e-mobility vehicles to Tanzania, showing that its theoretically possible (e2). But despite these positive examples, the current regulations have several drawbacks that may not encourage e-mobility in the country, such include absence of tax exemptions for the import duties or running of e-vehicles (Stakeholder e2).

Regarding the energy side, existing policies and regulations generally allow using “clean” energy sources such as electricity and natural gas in the transport sector/ system (Stakeholder d1, e3). Stakeholders in the field of transport are becoming more and more active towards the topic of clean energy sources in transport, with DART having signed an MOU with UNEP recently to help develop guidelines on different energy efficiency technologies including e-mobility, that is also supported by the Ministry of Finance (Stakeholder b1). Also, Tanzania’s Bureau of Standards (TBS) already has a standardized process to certify new vehicles, that could also be applied to electric vehicles leading to a control of quality of the vehicles themselves and their spare parts (Stakeholder a2).

Stakeholders agree that, despite the fact that policies generally allow for e-mobility to be brought in, there is the need for specific e-mobility regulations and rules that cover topic such as import and duties, standardization, incentives that would allow a commercial, large scale importation and usage throughout the country. Further topics mentioned that need regulation are tariffs, tax exemptions / overall tax regime, licensing and creating awareness. Stakeholder e2 mentioned that the ban of bajaj in the city center, that is being enforced today, should be revised for e-bajaj thereby creating a strong incentive for adoption (Stakeholder d1). Highly important, also is the issue of recycling of old vehicles which should be addressed as soon as possible, especially regarding batteries (Stakeholder c1, e1). Already happening is an import of 2-wheelers, mostly originating from China, that however is not sufficiently regulated to date (Stakeholder e1). Future policies should therefore touch topics related to training as well as charging infrastructure and energy grid development (Stakeholders a3, b1, f1). As an ongoing activity, Tanzania’s Land Transport Regulatory Authority (LATRA) is in the process of reviewing their regulations to accommodate other cleaner technologies in the transport sector (Stakeholder d1). Stakeholder e2 suggested a KPI for the project that measures the clarity for businesses how importing vehicles works,

how much it costs, what's happening if you import them.

1.9. CHALLENGES

One of the main challenges that needs to be overcome is the adoption barrier that typically comes with new technologies, such as e-mobility. Overall, it was stated by all stakeholders that there is currently limited knowledge on EVs and associated technologies. As such, there is almost no e-mobility existing to date in Tanzania, meaning a lack of experience and no positive examples showcasing that it works. For the case of our demo project, Stakeholders a2, c1, e1, e3 mentioned this adoption barrier that would lead to resistance to adopt e-mobility. Furthermore, challenging weather conditions (hot climate, wet rain season) in Dar es Salaam were mentioned (Stakeholder a1, d1), maybe requiring a special robust vehicle design. Stakeholder d1 also mentioned that e-bajaj should accommodate the fact that it is not uncommon to overload bajaj today, for instance by carrying up to four passengers in vehicles that have been designed for two passengers, thereby requiring a sturdy vehicle design and sufficient power of the electric drivetrain.

Another challenge mentioned is associated with the high initial investment cost to buy EVs, compared to conventional vehicles (Stakeholders a2, c1, e1, e2, e3, f1). Making this even more costly is the need to build up a public charging infrastructure (which is currently not existent, Stakeholder c1, d1, a3). Additionally, Stakeholder c1 mentioned that the high initial cost of investment into electric vehicles could be adequately addressed if financial institutions see a strong business case, nevertheless, this is not yet the case in Dar es Salaam and Tanzania. Another obstacle mentioned is the non-reliability of the energy grid (a1), due to frequent blackouts. However, the overall power of the current electricity grid was also described as being sufficient in most cases for home-charging single e-bajaj overnight (Stakeholder e2). There is therefore a strong need to build up a public charging infrastructure in Dar es Salaam.

Stakeholder a1 expressed the opinion that a possible dominance of the EV sector by a few companies could lead to limited competition in the future. Stakeholder b1 expressed that the multiplicity of institutions involved in the urban transport sector could hinder a proper project coordination. Stakeholder e2 mentioned that the planning of the project would be very challenging in relation to deciding which routes should be served, which ownership model for the vehicles would be adopted, how drivers should be selected and the overall business model development.

1.10. SOLUTIONS

To overcome the obstacles, a number of suggestions were given by the stakeholders. Stakeholders a1, d1, e2, e3 mentioned the need for political support for a successful project implementation, the need to engage the government for assured commitment towards the project and ensure well-established project management structure. Furthermore, the involvement of all stakeholders at an early stage of implementation was suggested (Stakeholders a2, d1), such early engagement could be fostered by creating a stakeholder platform for the exchange of information and knowledge sharing about challenges and solutions (Stakeholder b1).

Looking at the institutional landscape, the establishment of a department under an existing institution or even a separate institution that is responsible for urban mobility was suggested by Stakeholders b1, e1. Creating a framework of a free market environment where competition will thrive to improve services in the sector was suggested, likewise the institutionalization of laws, by laws and regulations to

support e-mobility (Stakeholder a1). This would hopefully lead to the presence of investors who will ensure availability of EV and spare parts (a1) and create an enabling environment for businessmen in terms of financial resources, allowing them to shift/ venture in the newly emerging business opportunities (Stakeholder c1). Having lower fares for e-bajaj over regular fueled bajaj was also suggested (Stakeholder e1).

Another topic mentioned was awareness raising at all levels of the community, from national leaders to community members and the advocacy of e-mobility (Stakeholders a1, a2, a3, b1, c1, f1). Campaigning at bus stations was suggested by stakeholder e1. Testing the e-bajaj during the demonstration phase for comfort, safety and performance to suit the needs of the users was suggested by Stakeholder d1.

The overall topic of training was frequently mentioned: Stakeholders b1, a3, f1, e1 suggested to provide the necessary training on e-mobility for key stakeholders, stakeholder c1 added the need to retrain current workers of the three-wheeler market.

Stakeholder a2 mentioned the need to have a survey on this project to end up with a mobility solution which accommodates owners and users' needs, leading to a robust product with the same or better requirements, capacity in terms of space and energy that can deal with the situation of the existing infrastructure (poor roads).

1.11. SUSTAINABILITY OF THE E-MOBILITY SOLUTIONS TO BE IMPLEMENTED

Achieve sustainable mobility

Amongst the stakeholders, there was a general consensus that the planned e-mobility solutions are useful to contribute to the goal of sustainable urban mobility in Dar es Salaam. As at the moment all bajaj running in Dar es Salaam are driven by combustion fuel; therefore, switching to electricity as a power source will help to significantly reduce CO2 emissions and air pollution.

Stakeholders also mentioned the aspect of safety, with 3-wheeled bajaj are considered to be safer then 2-wheelers (Stakeholders a1, d1), that are currently very frequent. Stakeholder e1 expressed concerns that e-vehicles due to being very silent may lead to more accidents. Furthermore, improved accessibility, also to social services, and a reduction of equity related issues in access to transport were named (Stakeholders a2, a3, d1, b1, f1). Bajaj were named as being particularly inclusive as they easily allow for the transport of people with special needs (e.g. disabilities, elderly, children) much better than with 2-wheelers or in crowded buses (Stakeholders d1, f1).

Contribute to plans and schemes

In Tanzania, government efforts have been geared towards promoting cleaner fuel for the transport sector such as CNG for hybrid-vehicles, electricity for trains and mass transport systems such as the BRT system in Dar es Salaam. Stakeholders were of the view that the planned e-mobility-solutions will contribute to these government initiatives and plans. (Stakeholders a2, b1, d1, e1) Specifically, the integration with other modes was mentioned by Stakeholder b1, as the demonstration activities will link feeder services with the BRT in Dar es Salaam.

1.12. IMPACT ON EXISTING BUSINESS MODELS

The current three-wheeler market in Dar es Salaam is dominated by private operators that are engaged by various forms in the market. Ownership is horizontally fragmented, with lots of different owners of bajaj being active in the market today,

ranging between owners who are also drivers and only own one vehicle up to owners who own dozens up to hundreds of vehicles and rent them out. Typically, drivers of vehicles are organized in associations that try to control access to the market on a geographical basis, for instance by claiming certain street junctions exclusively. The implementation of a feeder service may therefore directly challenge the business models of those operating in the area it is being implemented in, creating the need to consider how to deal with that.

To increase the acceptance of the demo project, bringing on board all stakeholders who are involved in the business is required (Stakeholders a2, a3, e1, b1, e3). Stakeholders brought up concerns that all people working in the current three-wheeler market, ranging from drivers, mechanics, spare part dealers, fuel sellers will be threatened. Stakeholders a3, b1, e3, f1 expect jobs lost in the "old" bajaj sector will be compensated by newly created jobs, for instance fuel attendants' posts will be replaced by jobs for people working at charging stations. Stakeholder d1 mentioned that e-bajaj may also affect investments into other means of transport, as more people will move to EVs leading to negative effects and business failure for instance in the dala-dala minibus sector.

To overcome this, Stakeholders b1, e3, f1 for instance proposed that the project can engage mechanics on the type of technologies they can work with, and provide training to them to deal with e-bajaj. Stakeholders a2, c1, f1 mentioned that the current distributors of conventionally fueled bajaj should be helped to become e-bajaj distributors to speed-up the transition. Stakeholder e3 suggested that existing groups of bajaj drivers could be surveyed before the implementation of the project.

Stakeholders e1, e2 proposed to test and monitor different business models during the demonstration phase. Three different operating models were proposed by Stakeholders e2: (1) proof-of-concept with DART where operators bid for concessions, (2) keeping the current ownership-driver-structure for a small group of drivers and (3) to offer a small group of drivers e-bajaj with a loan (good conditions), thereby mitigating cannibalization of their current business model. Stakeholder b1 suggested that e-bajaj should not face competition from conventionally fueled bajaj, similar to BRT which is not allowed to face competition from dala-dalas.

1.13. IMPLICATIONS FOR PLANNING AND URBAN DEVELOPMENT

The interview touched on implications of the demonstration and an upscaled project on planning and urban development.

Urban development

Stakeholders a3, f1 reflected on the fact of urban growth, where e-bajaj could make cities become more liveable, open transport opportunities and provide better access to public transport, however both stakeholders as well as stakeholder d1 were concerned that this could lead to urban sprawl. Stakeholder d1 reflected on the problems that came up when new means of transport, two- and three-wheelers for instance, came up in the past in the city without proper allocation of parking space. Stakeholder b1 mentioned that they are aware of such effects when planning the BRT and the entire transformation of the urban mobility sector towards e-mobility. For instance, the Dar es Salaam Transport Master Plan is designed with the concept of transit-oriented development, whilst the city's service plan is designed to accommodate trunk lines and feeder services, that could also comprise the location of charging points (Stakeholder b1). Increasing charging points, according to stakeholder a1, could trigger demand for electric vehicles, but will also change the cityscape (Stakeholder a1, e1). Stakeholder

e2 suggested that building charging infrastructure for e-bajaj at BRT stations could also allow upscaling these charging stations to accommodate for e-BRT in the future.

Transport system

Regarding implications for the city's transport system, stakeholders were of the view that the demonstration and a scaled-up scenario will require that the existing road transport infrastructure is designed to accommodate the different means of transport, including the e-bajaj. Expanding the road infrastructure to the outskirts to accommodate all modes of transport, including cars, bajaj, motorcycles and buses was mentioned by Stakeholders a1, a2, a3, b1, d1, f1. Stakeholder b1 mentioned that in phase 2 of the BRT development, plans already exist to include bajaj terminals.

Energy system

Energy systems are key for the development of electric mobility. In Tanzania, ongoing projects seek to expand the electric power generation and distribution capacities (Stakeholders a2, b1, f1), also for renewable energies (Stakeholder b1). In Dar es Salaam, there are no notable external implications as reliable power is now available in many areas of the city (Stakeholder a3). Stakeholder f1 expressed the view that the country's energy policies encourage use of electricity for economic purposes, which stakeholder d1 said could help increase government revenues. Stakeholders a1, a3, b1 indicated that the development of the e-mobility sector could engender the need to expand other energy sources such as CNG and foster the development of micro-grids. Stakeholder d1 furthermore mentioned opportunities for the private sector to supply energy for e-bajaj through solar and small hydro's in other parts of the country.

2 KEY PERFORMANCE INDICATORS (KPIS)

2.1. PRIORITIZATION OF KPIS ADDRESSING THE SPECIFIC CITY NEEDS

As explained in the methodology section of D1.6 – Vol.1 (Section 2.1.4), the priorities of the stakeholders are formally determined through the weights assigned to the selected attributes (KPIs). The attribute weighting activity in Dar es Salaam took place in conjunction with the stakeholder interviews organised in relation to the user needs analysis of Section 1.5. The procedure described in Section 2.1.4 (Vol.1) was followed for all 10 interviewed stakeholders, representing five stakeholder groups (refer to Section 1.5).

Figure 6 exhibits the mean values of the weights received for all L1, L2 and L3 attributes, as they have been calculated after applying the Delphi method. Both relative (in black) and cumulative (in brackets) weights are shown. Relative weights indicate stakeholder priorities within a family and sum to 1. Cumulative weights at each level are determined by applying the relative weights of that level to the cumulative weight of the parent attribute. To minimise potential mistakes, the sum of all cumulative weights at each level is set to 100. The cumulative weights of L1 are identical to the corresponding relative ones, only expressed at a different scale.

Looking on the L1 attributes, we can conclude the following: With a cumulative weight of 18.36, effects on society appear as the main priority of the stakeholders, apparently reflecting the necessity to invest in e-mobility even in the case the proposed project is

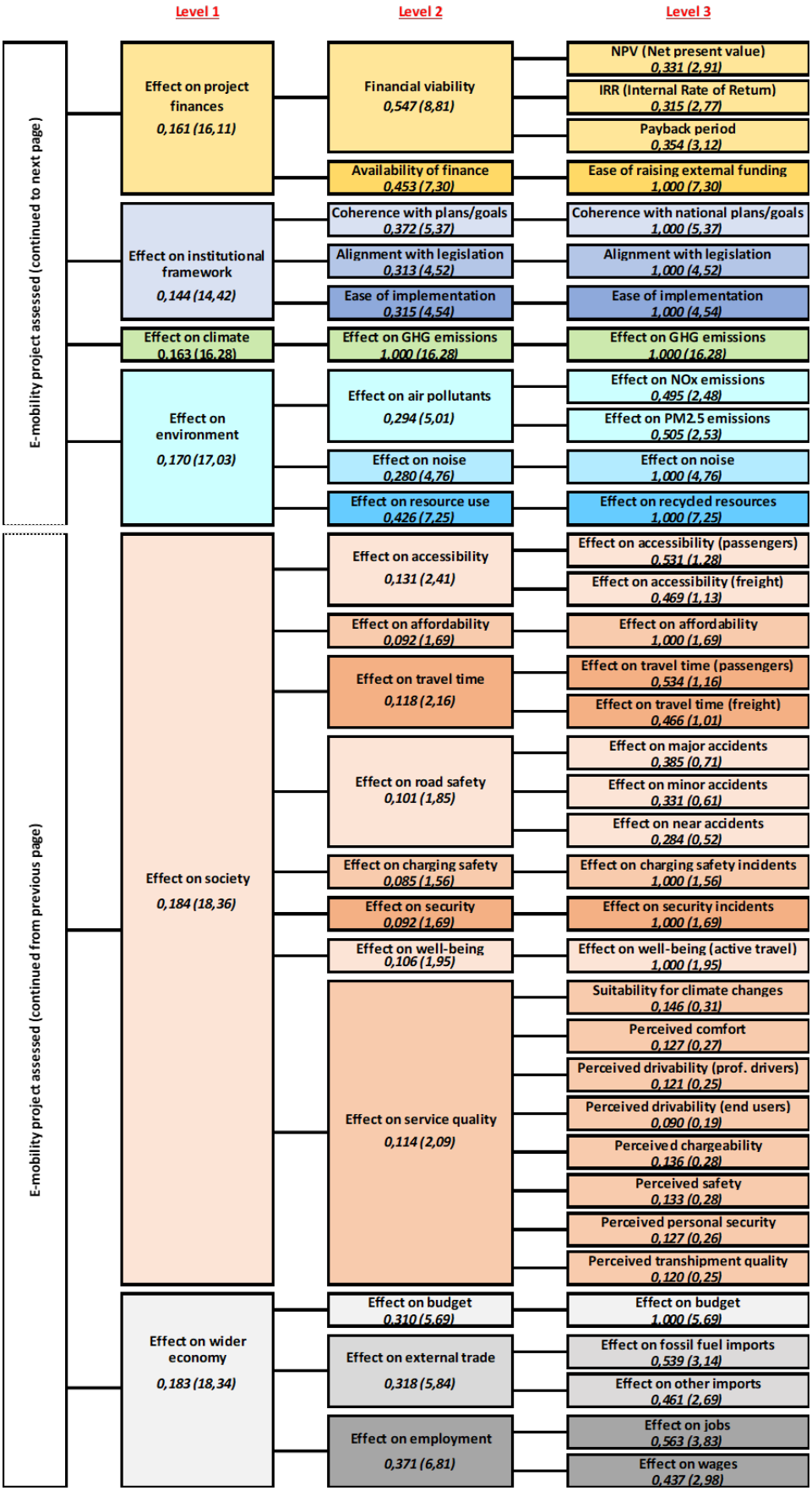


Figure 6. Attribute weights indicated by the Dar es Salaam stakeholders

not self-sustainable. In line with the findings of the user needs analysis (refer to Section 1.5), the effect on wider economy have the second highest priority with a weight of 18.34, probably signifying the high relevance that the transport sector plays for the economy of Tanzania and Dar es Salaam. Next is the effect on the environment (17.03), which can be interpreted as a sign for the need to undertake measures to lower the emissions and (negative) environmental impact of growing transport demand in Dar es Salaam, but also in the light of the fact that the SOLUTIONSPLUS demonstration project implements a sustainable mobility solution. The same arguments also hold for the effect on climate (16.28). Before last of influence was ranked the effect on project finances (16.11), and last turned the effect on the institutional framework, indicating that these factors where seen as not very important for such a project.

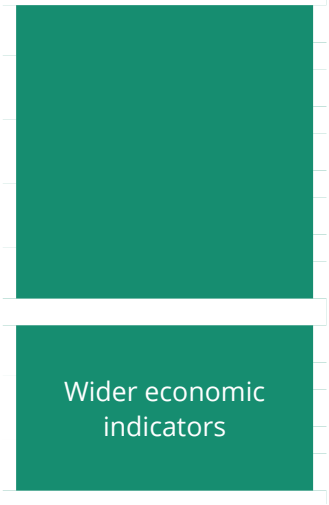
3 ASSESSMENT OF THE DEMONSTRATION PROJECT

This section describes the assessment of the demonstration project in Dar es Salaam based on the KPI framework developed by the consortium.

3.1. SELECTION OF KPIS FOR ASSESSING THE DEMONSTRATION PROJECT

Recognizing the diversity of demonstration components across the SOLUTIONSplus cities, it is important to note that not all KPI are relevant for all components. Based on internal evaluation as well as feedback from relevant stakeholders, the selection of relevant KPIs is listed below:

Financial indicators	A1	Financial Viability
	A2	Ease of raising external funding
Institutional/political indicators	B1	Coherence with national plans and development goals
	B2	Alignment with supra-national/national/city legislation & regulations
	B3	Ease of implementation (in terms of administrative barriers)
Climate-related indicators	C1	Impact on GHG emissions
Environmental Indicators	D1	Impact on air pollutants
	D2	Impact on noise
	D3	Impact on environmental resources
Social indicators	E1.1	Access to jobs, opportunities, services (personal travel)
	E4.1	Road accidents with fatalities/serious injuries
	E4.2	Road accidents with minor injuries/material damage



E4.3	Road accidents involving vulnerable road users
E4.4	Additional indicators entering the descriptive evaluation
E5	Impact on charging safety
E6	Impact on security
E8	Quality of e-mobility services
F1	Impact on national/local budget
F2	Impact on external trade
F3	Impact on employment

The KPIs that are not applicable mainly relate to freight transport and active travel such as

- E1.2 Access to pickup delivery locations
- E3.3 Change in travel times due to e-mobility services (freight)
- E7 Impact on well-being and active travelling

To assess the relevant KPIs, we performed several data collection campaigns such as

- GPS tracking
- Noise measurements
- Driver survey
- Passenger survey
- Project team's evaluations
- Stakeholder interviews

Finally, we also leverage programs and software packages such as the UNEP E-Mob calculator or DLR's PtAC to perform the analyses.

Not all KPIs were assessed on a quantitative scale, meaning that we had to rely on expert stakeholder knowledge to be able to derive results for them. See Section 4 for details on KPIs which we discussed with Stakeholders.

More details follow below in the sub-chapters of the respective KPIs.

3.2. ELECTRIC THREE-WHEELERS

Financial indicators

IRR (Internal Rate of Return)

For the financial assessment of the project, we rely IRR (Internal rate of return). This metric denotes the rate of return that sets the net present value of the future cash flows of a project equal to zero. An IRR higher than the opportunity cost of the project owner indicates a profitability that exceeds the expected one from other activities and suggests the undertaking of the project. The higher a project's IRR is, the more

eBajaj	**E3W operator no. 1**					
Category	**Parameter**	**Value**	**Units**	**Ref**	**Rev**	**Comments /**
General info	Number of bajaj	25		1		
	Discount Rate	10%				
Propulsion	Battery type	Li-ion				
	Battery size	7	KWh	1		
	Range per charge at start	100	km	1		
	Motor	4	Kw	1		
	Vehicle efficiency	11.5	km/Kwh			
		0.09	Kwh/km	1		
	Battery life	3000	Cycles	1		
	Battery Useful Capacity at start	85%	%			
	* Battery Useful Capacity at start	5.95	KWh			
	Battery Useful Capacity at end	70%				
	* Battery Useful Capacity at end	4.9	KWh			
	* Battery range at start	68.39	km/charge			
	* Battery range at end	56.32	km/charge			
	*Charging frequency per day	2.08	cycles/day			
	* Battery life	5.76	years			
Capital cost	**Total Capital cost**	**158.600**	**USD**			
	*** Capex per year per bajaj**	**2551**	**USD/year**			
	Purchase price per bajaj	6344	USD	1		150,000 Tsh/week over 104
	Expected useful life	3	years	1		
	Residual value	960	USD	1		
	*** Capex for charging**	**80**	**USD/year**			
	Capital cost of charger	200				1 Charger for 25 eBajaj
	*** Capex in replacement battery**	**45.000**	**USD**			
	Replacement battery	1.800	USD /battery pack	1		
	Depreciation schedule	0.10				
Operational profile	Route	Flexible				
	Length of trip	13	km	1		
	*Trips/day	10.0	trips/day	1		
	Total distance/day	130.0	km/day			
	Operating days/year	250	days/year	1		
	*Total vehicle kms in a year	812500	vkm			
Yearly operating cost	**Total operating cost**	**56.000**	**USD/year**			**For operating 10 bajaj**
	*** Fixed Operating Costs**	**5.050**	**USD/year**			
	- Insurance costs, office, etc. / bajaj	202	USD/year	1		
	- Moto taxi registration / bajaj		USD/year			Might be included already in the
	- Helmet Cost		USD/year			Might be included already in the
	-		USD/year			
	*** Personnel cost**	**38.403**	**USD/year**			
			USD/Month			
			USD/Month			
	Driver	1.536	USD/Year			https://worldsalaries.com/averag
			USD/Month			
	*** Charging Cost**	**9.896**	**USD/year**			
	- *Energy Consumption per day	11.31	Kwh/vehicle			
	- Electricity Tariff	0.14	USD/Kwh			
	*** Maintenance cost**	**2.650**	**USD/year**			
	- Maintenance cost	56.00	USD/year	1		
	- co-op fee per day	0.20	USD/day			
Yearly revenues	***Total revenues**	**118.750**	**USD/year**	1		
	Daily Revenues per bajaj		USD			
Income tax	Income tax rate	30%				
VAT		18%				
Battery swapping						
						Reference
				1		Finance data_Operators_Dar

Figure 7. Input values for assessing the e-bajaj

desirable its undertaking becomes.

To calculate the IRR for the e-bajaj, we used data from the manufacturer of one of the four companies financially and technically supported in Dar es Salaam (confidentiality granted, as per the company's request). The calculation is based on replacing 25 vehicles. Other assumptions made are shown in Figure 7.

The results show a very good value for the IRR (22.49%), which indicates that the project is profitable. The translation into a 5-star rating is shown below.

STAR	IRR RANGE	RATIONALE	RE-SULTS
1★	IRR ≤ 0%	Absolute loss	
2★	0% < IRR ≤ 7.5%	IRR below risk free rate set by Central Bank	
3★	7.5% < IRR ≤ 16%	IRR below lending rate to set by Banks	
4★	16% < IRR ≤ 20%	IRR expected higher for EVs[2] due to higher capital costs, risks with technology (battery swapping) and small volumes	
5★	**IRR > 20%**	**Profitable**	**22.49%**

Climate-related indicators

Impact on GHG emissions

The UNEP E-Mob calculator is used to analyse the impact of transitioning to e-bajajs on GHG emissions and air pollution. The GHG emissions are calculated well-to-wheels (including CO2 emissions in electricity production). We thereby calculate and compare

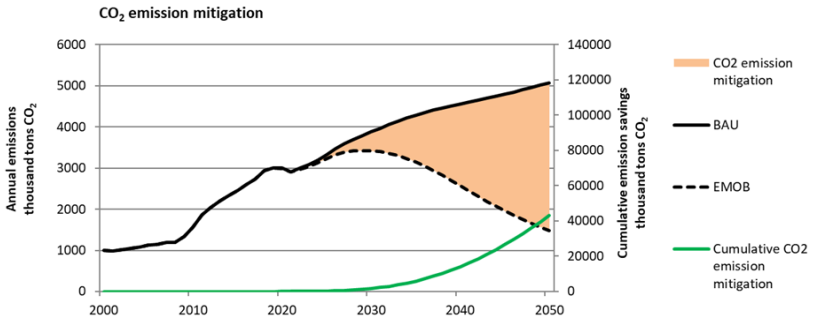


Figure 8. CO2 emission mitigation for the conservative e-bajaj scenario

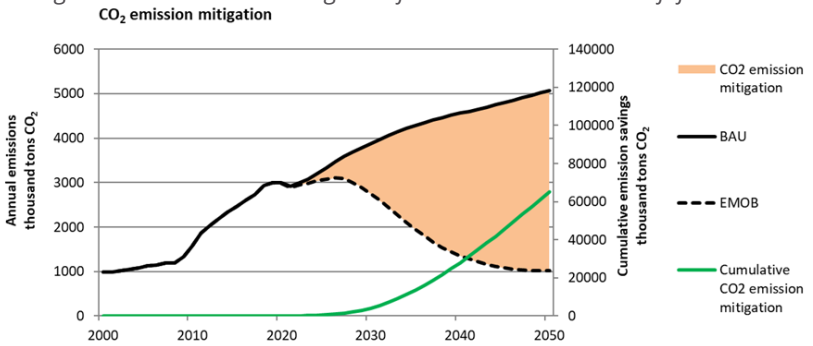


Figure 9. CO2 emission mitigation for the optimistic e-bajaj scenario

three scenarios:

- the benchmark scenario, without any e-bajajs,
- a conservative e-mobility scenario, where the sales of e-bajajs are increasing to 100% unil 2050, and.
- an optimistic e-mobility scenario, where the sales of e-bajajs are increasing to 100% until 2040.

In the conservative scenario, around 14% of the fleet will be battery electric by 2030, while in the optimistic scenario, 51% of the vehicle stock will be battery electric by 2030. These figures rise to 51% (83%) by 2040 (2050) in the conservative scenario and to 82% (93%) by 2040 (2050) in the optimistic scenario. In the benchmark scenario where we have no e-Bajaj's the CO2 emissions increase from 2991 thousand tons CO2 in 2020 to 3879 thousand tons CO2 in 2030 and further to 5067 thousand tons CO2 in 2050.

The results for the conservative scenario indicate that the max. cumulative CO2 emission mitigation potential sums up to 43,121 thousand tons between 2020 and 2050, reaching an annual value of 1567 thousand tons in 2050.

The results for the optimistic scenario indicate that the max. cumulative CO2 emission mitigation potential sums up to 65,311 thousand tons between 2020 and 2050, reaching an annual value of just 1,018 thousand tons in 2050.

For the period until 2030, the CO2 emissions the conservative e-bajaj scenario decline to 3,414 thousand tons CO2 or **11.9% lower than benchmark scenario, for the optimistic scenario this value rises to 29%.**

3.2.1. Environmental indicators

Impact on air pollutants

Similar to CO2 emissions, we also leverage the UNEP E-Mob calculator to calculate the

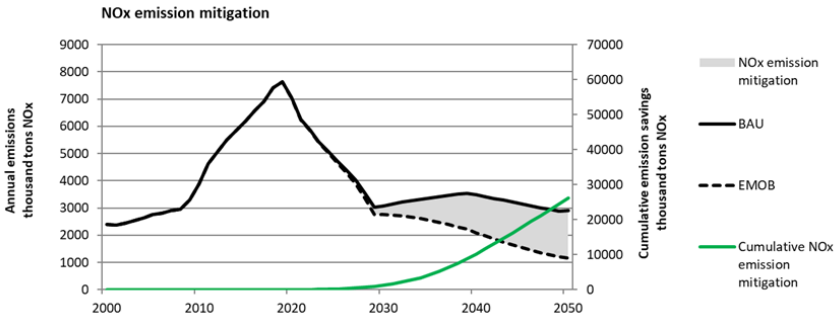


Figure 10. NOx emission mitigation for e-bajaj scenario

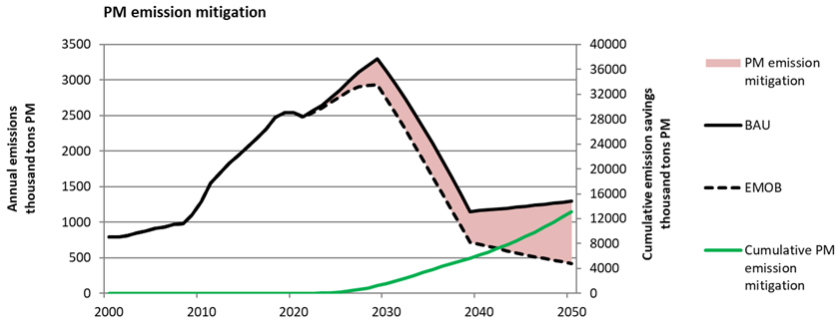


Figure 11. NOx emission mitigation for e-bajaj scenario

project's impacts on air pollutants including NOx and PM.

For the period until 2030, the **NOx** saving potential equals approx. 329 thousand tons or **10.66%**, while for **PM**, the saving potential equals approx. 388 thousand tons or **12.44%**

Impact on noise

Noise exposure does not only depend on its magnitude, but also of its intensity, frequency, duration, variability and time of occurrence. It is therefore advised to measure the subjective perception of the respondent in question using categorical scales. Nevertheless, this perception should additionally be related/validated with acoustic measures.

To address the former, we conducted a survey with bajaj drivers in August 2023. Using a 5-point Likert scale to measure noise levels, ranging from significantly noisier to significantly quieter compared to conventional bajaj vehicles, the e-bajajs received a respectable score of **4 out of 5 points.** This suggests that e-bajajs are perceived as notably quieter than their ICE counterparts.

This was further validated through noise measurements on the respective vehicles performed in December 2023 using smartphone and portable microphones. Both measurements took place on the same route to ensure comparability (Figure 12).

The results showed that the noise exposure on the e-bajaj was significantly lower, about 3.8 dB(A), compared to the ICE counterpart (Figure 13).

Impact on environmental resources

The impact on environmental resources is assessed with regards to its alignment with the Circular Economy (CE), which is defined as "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations". The CE is based on three shared principles, which can be summarized as follows: (i) design out waste and pollution, (ii) keep products and materials in use, and (iii) regenerate natural systems.

Against this background, the KPI has been assessed by the project team based on the assessment scheme in Table 2.

3.2.2. Social indicators

Impact on accessibility

The indicator assesses the impact of e-bajajs on accessibility. The SDG 11.2 indicator will be used for this purpose. It is defined as the proportion of the population that has convenient access to public transport. The KPI value will be estimated as the difference in the SDG 11.2 indicator values with and without the introduction of e-bajajs. For this purpose, we utilize the PTaC tool developed by DLR Institute of Transport Research and leverage the following data sources:

- Population distribution in the city (Source: DLR World Settlement Footprint)
- Street network for walking (OSM-OpenStreetMap)
- Public transit stops (locations, ideally including different entrances)

Figure 12. E-bajaj (left) and conventional bajaj

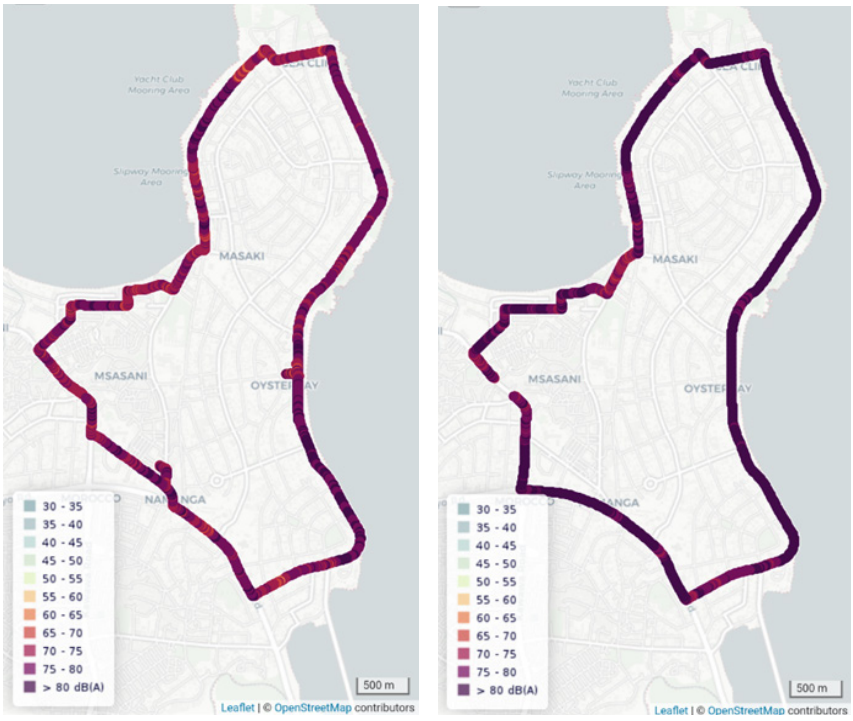


Figure 13. Comparison on noise measurements done on the same route

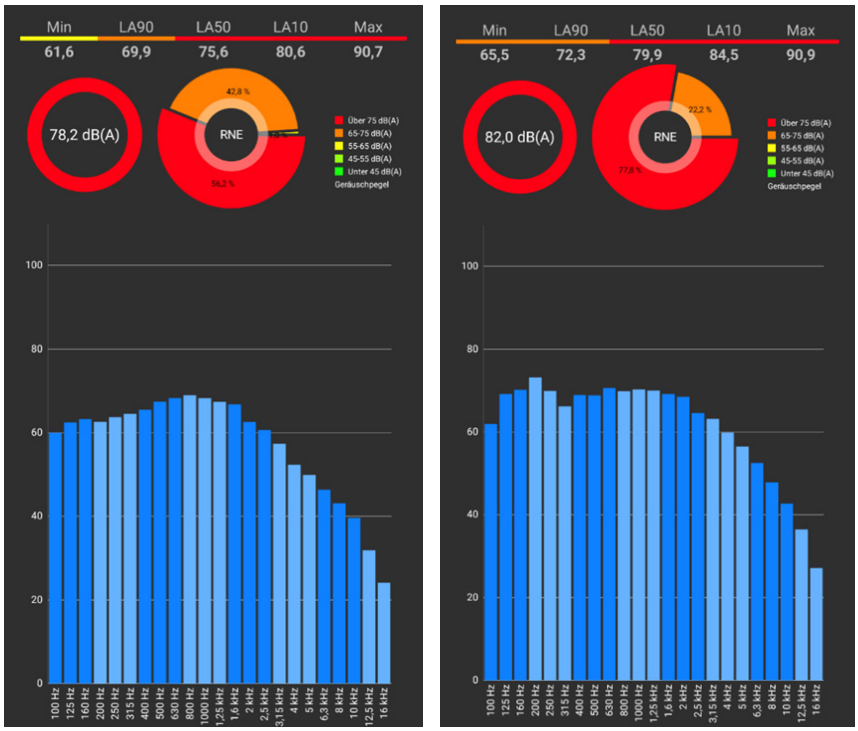


Figure 14. Results of the noise measurements

Table 2 Assessment Scheme for Impact on Environmental Resources

Question	Does the project enhance/promote circular economy in the project city? Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	Evaluation by project experts followed by validation by local stakeholders
Notes	The evaluation combines your assessment on three separate dimensions: A. Useful application of materials through: • **recycling** – i.e., processing materials to obtain the same (high grade) or lower (low grade) quality, and/or • **recovering** – i.e., incineration of material with energy recovery B. Smarter vehicle use and manufacturing through: • **rethinking** – i.e., making vehicle use more intensive (e.g., by sharing arrangements), and/or • **reducing** – i.e., increasing efficiency in vehicle manufacturing or use by consuming fewer natural resources and materials C. Expanded lifespan of vehicles and their parts through: • **reusing** – i.e., using of a discarded vehicle that is still in good condition and fulfils its original function by another operator/user, and/or • **repairing** – i.e., maintaining/repairing defective parts so that the vehicle can be used with its original function, and/or • **remanufacturing** – i.e., using parts of discarded products in a new vehicle with the same or different function
Evaluation	1. The answer to all three dimensions (A and B and C) is negative 2. The only positive answer concerns dimension A **3. The only positive answer concerns dimension B** 4. The only positive answer concerns dimension C or the answer to C is negative but both A and B receive positive answers 5. The answer to C and one or both of A and B is positive

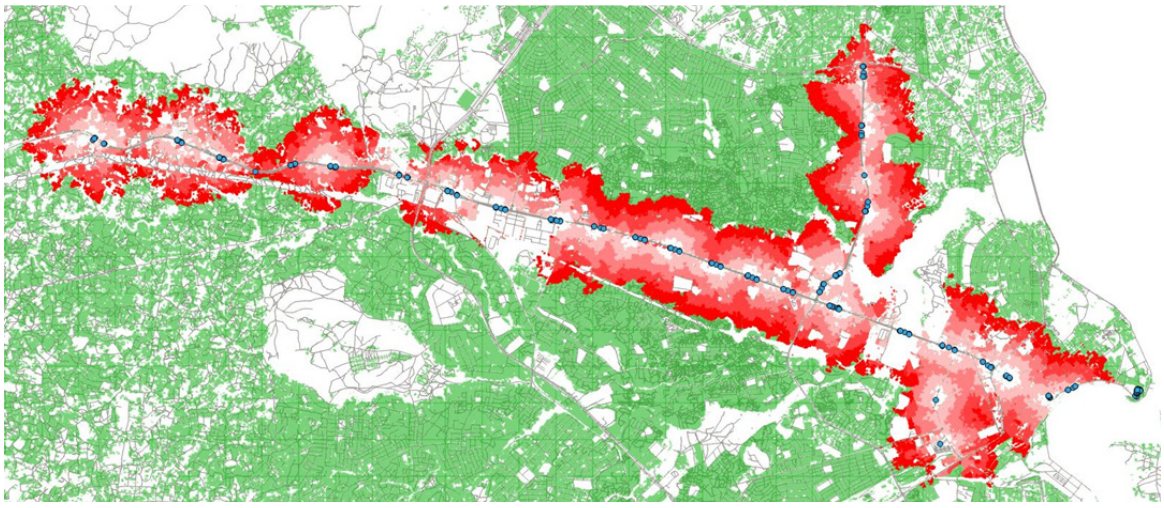


Figure 15. Visualization of accessibilities at BRT stations and bajaj corridors

First, we calculated the base case according to which 15% of the population in Dar es Salaam have access to public transport (i.e., the BRT system). The share increases by 4.5% to 19.5% if e-bajajs are formally integrated as feeder services at the BRT stops (Figure 15).

Impact on road safety

The impact on road safety has been assessed by the project team based on the assessment scheme below with regards to (i) road accidents with fatalities/serious injuries, (ii) road accidents with minor injuries/material damage, (iii) road accidents involving vulnerable road users (VRUs), (iv) traffic related near accidents/dangerous situations, and (v) traffic related near accidents/dangerous situations involving VRUs.

The overall score can be calculated as the average score for the five sub-indicators. Hence, the results for the KPI on road safety is: **3/7**.

This score is due to the expected slight negative effect of the less noisy vehicles that increase the likelihood of accidents. As evidenced in the literature, electric vehicles are more difficult for pedestrians to hear and, therefore, compromise traffic safety (Cocron and Krems, 2013).

Table 2 Assessment scheme forimpact on road safety

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of number of road accidents with fatalities/serious injuries in the area (compared to the situation before the implementation)** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of road accidents with fatalities/serious injuries) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of road accidents with fatalities/serious injuries) **3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of road accidents with fatalities/serious injuries)** 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of road accidents with fatalities/serious injuries) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of road accidents with fatalities/serious injuries) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of road accidents with fatalities/serious injuries)

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of road accidents with minor injuries/ material damage in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of road accidents with minor injuries/material damage) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of road accidents with minor injuries/material damage) **3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of road accidents with minor injuries/ material damage)** 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of road accidents with minor injuries/material damage) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of road accidents with minor injuries/material damage) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of road accidents with minor injuries/material damage)
Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of road accidents involving VRUs in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure

Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of road accidents involving VRUs) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of road accidents involving VRUs) **3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of road accidents involving VRUs)** 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of road accidents involving VRUs) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of road accidents involving VRUs) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of road accidents involving VRUs)
Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of near accidents and dangerous situations in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of near accidents and dangerous situations) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of near accidents and dangerous situations) **3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of near accidents and dangerous situations)** 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of near accidents and dangerous situations) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of near accidents and dangerous situations) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of near accidents and dangerous situations)
Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of near accidents and dangerous situations involving VRUs in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:

Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of near accidents and dangerous situations involving VRUs) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of near accidents and dangerous situations involving VRUs) **3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of near accidents and dangerous situations involving VRUs)** 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of near accidents and dangerous situations involving VRUs) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of near accidents and dangerous situations involving VRUs) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of near accidents and dangerous situations involving VRUs)

Impact on security

This KPI refers to measures taken by a transport system to keep its passengers, employees and freight safe, to protect the operator's infrastructure and equipment, and to make sure that other violations do not occur. In order to identify and address potential security risks, this KPI applies the risk assessment methodology to four dimensions, herewith referred to as Security Performance Standard (PS):

- PS1: Infrastructure and operation
- PS2: Vehicles
- PS3: Transport of goods
- PS4: Transport of persons

In the case of Dar es Salaam, we only assess the PS1, PS2, and PS4, since the transport of goods is not applicable to our project components. To assess the risk impact, we rely on 5-point Likert scale from 0 (no adverse impact expected) to 4 (high adverse impact expected). Similarly, the risk probability is measured from 0 (likelihood of occurrence is very low) to 4 (likelihood of occurrence is very high). The results from the project team's assessment is shown below.

The results for the assessment of the three PS accumulates to **13 out of 48** possible points.

Therefore, the project's security risk can be deemed moderate. The only factor that negatively influences the security aspects of e-bajajs is the requirement for additional infrastructure and equipment, such as charging facilities, which may be susceptible to misuse, vandalism, and theft.

Security Performance Standard	Guiding aspect	Risk Impact (consequenc-es	Risk Probability (likelihood)	Security Performance Score
Instructions		Choose from: No impact [0] to Very high impact [4]	Choose from: Very low proba-bility [0] to Very high probability [4]	Risk Impact X Risk Probability
PS1: Infrastructure and operation	Infrastructure and operation security score	3	2	6
PS2: Vehicles	Vehicles security score	0	0	0
PS3: Transport of goods	Transport of goods security score	-	-	-
PS4: Transport of persons	Transport of people security score	4	1	4
Overall Security Performance				**∑10**

Quality of e-mobility services

A survey was conducted in August 2023 among 13 drivers using electric three-wheelers developed by one of the companies supported by SOLUTIONSplus. The survey included both closed questions about their opinions on various quality aspects of the new vehicles, and open-ended questions for a finer-grained understanding of the drivers' perceptions on the quality of the electric three-wheelers operations. The survey was conducted with drivers operating in various geographical areas in Dar es Salaam. Some drivers were plying routes revolving around a specific waiting point, others were operating independently of a waiting point. When operating from a waiting point, the survey was conducted only with the driver at a distance from other drivers, to avoid external interactions or influence, which could create bias. The survey was conducted in Kiswahili; answers were translated by surveyors into English.

Note	In this part of the questionnaire, we would like to have your opinion on how the new e-bajaj solution (indicated below as 'NEW') compares to the one that you used before for the same transport (i.e., conventional bajaj, indicated below as 'OLD') in relation to the eight different quality features shown below.

Procedure	Direct rating by end users through survey/questionnaire, with the exception of Feature #3 and #6, which will be assessed on the basis of feedback received from professional drivers
Feature #1 Suitability for adverse weather conditions	1. The OLD solution is much better than the NEW one 2. The OLD solution is better than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is better than the OLD one [mean: 3.9]** 5. The NEW solution is much better than the OLD one
Feature #2 Comfort in travel	1. The OLD solution is much more comfortable than the NEW one 2. The OLD solution is more comfortable than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is more comfortable than the OLD one 5. **The NEW solution is much more comfortable than the OLD one [mean: 4.6]**
Feature #3 Ease of driving (by professional drivers)	1. The OLD solution is much easier to drive than the NEW one 2. The OLD solution is easier to drive than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is easier to drive than the OLD one [mean: 4.2]** 5. The NEW solution is much easier to drive than the OLD one
Feature #4 Ease of driving (by other users)	1. The OLD solution is much easier to drive than the NEW one 2. The OLD solution is easier to drive than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is easier to drive than the OLD one [mean: 4.1]** 5. The NEW solution is much easier to drive than the OLD one
Feature #5 Ease of charging/ refueling	1. The OLD solution is much easier to charge/refuel than the NEW one 2. The OLD solution is easier to charge/refuel than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is easier to charge/refuel than the OLD one [mean: 3.7]** 5. The NEW solution is much easier to charge/refuel than the OLD one
Feature #6 Safety	1. The OLD solution is much safer than the NEW one 2. The OLD solution is safer than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is safer than the OLD one [mean: 4.2]** 5. The NEW solution is much safer than the OLD one

Feature #7 Personal security (in terms of unlawful behaviors)	1. The OLD solution is much more secure than the NEW one 2. The OLD solution is more secure than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is more secure than the OLD one [mean: 4.3]** 5. The NEW solution is much more secure than the OLD one
Feature #8 Continuity of journey chains, including transshipment to other modes	1. The OLD solution is much better than the NEW one 2. The OLD solution is better than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. **The NEW solution is better than the OLD one [mean: 4.1]** 5. The NEW solution is much better than the OLD one

Analysis of the open-ended questions

Overall, 15.4% of drivers reported to be very satisfied with the electric three-wheelers, 69.2% were satisfied, and 15.4% were neutral. The overall performance was considered good by most drivers, especially for short-distance trips, in urban areas, and for trips without heavy loads.

A particular area providing strong satisfaction was the re duction of operational costs. All 12 drivers highlighted this aspect when asked what their primary purpose for using an e-bajajs was, mentioning "reduced running and maintenance costs", "avoid fuel expenses", "get more profit" or "increase income". In addition, two drivers mentioned their interest in using new technology, one identified an opportunity to increase the number of trips. None cited environment-related motivations for opting to drive an e-bajaj. Overall, all drivers stated that being an e-bajaj driver is financially viable, or "very viable" for them.

Yet, a couple of challenges and areas for improvement on the vehicle prototype were identified by the drivers. The first one was the capacity or « autonomy » of the battery which was considered to be too low or depleting fast ("not holding charge", "drained"). This was repeatedly mentioned by more than half of the drivers (66%). Due to this constraint, driving in hilly areas of the city or carrying passengers with luggage was considered difficult by some drivers. As a result, drivers recommended that the company proceed to modifications with the battery, often suggesting the addition of one to two additional batteries, or shifting to a bigger battery allowing "travel more than 100 km" on a single charge.

Other recommendations were made to improve the prototype, including greater robustness of the vehicle's body, tyres, shock absorbers, and switches. In addition, the drivers stressed various issues related to spare parts, such as the lack of some EV-specific spare parts, the difficulty in accessing others (e.g. brakes), or the lack of information on their prices. Finally, the lack of staff trained to service or repair the vehicles was seen as a challenge by the drivers, as "mechanics are forced to improvise to service e-bajajis". One driver mentioned the need for training in basic maintenance.

The e-bajajs were reported to have both positive and negative impacts on the drivers' services. Some drivers reported a positive development thanks to positive customer feedback being "fond of e-bajajs" or enjoying the "quiet ride", which, for some drivers,

has resulted in an increased number of customers eager to try a new vehicle or prioritising quietness. Overall, all drivers reported that the lack of noise is what makes passengers notice the difference from a fossil-fuel-powered vehicle. At the other end of the spectrum, other drivers emphasised that the limited battery capacity limits their ability to serve customers, resulting in them avoiding or refusing long travel distances, making long trips only in the morning, or not being able to meet customers' trip requests during recharging times, especially after midday. Not being able to offer trips during recharging times was seen as a barrier, but also as an opportunity to rest for one driver, as it "(meant) more consideration for my health". Working hours serving customers were reduced for all drivers due to the immobilisation time required for charging or trips to a charging place to swap the batteries, which was however often seen as compensated by additional customers.

Some drivers mentioned both positive and negative aspects unfolding simultaneously: "it (the e-bajaj) has increased my nearer customers but (I) stopped trips that are farther away", or "there are many of them (returning customers) because the e-bajaji produces no noise but sometimes I cannot serve them because the battery is drained".

Overall, despite the challenges mentioned, when asked if they want to continue driving e-bajajs in the future, drivers unanimously answered positively. Similarly, when asked whether they would opt for an e-bajaj or a conventional bajaj if they would have the choice, they all stated to opt for an e-bajaj. Low operational costs translating into savings and higher profits, positive customer feedback, driveability, low frequency of maintenance, and absence of noise, were indicated as underlying reasons for continuing to drive an e-bajaj.

Finally, drivers identified a number of potential barriers to widespread adoption, including a lack of advertising or marketing of the vehicles, the battery issues mentioned above, a lack of charging stations, and a lack of trained mechanics.

Evaluation:

- This survey was conducted with drivers using the initial vehicle model developed by the company. Results should be considered valid only for a specific point in time (August 2023) and for the first prototype.
- The drivers' feedback was integrated by the company to develop the subsequent iteration of the model. Recommendations to increase the battery were followed, alongside other modifications such as the shift from two battery packs to one battery pack, or changes in the vehicle design and robustness.

3.2.3. Wider economic indicators

To comply with the guidelines of the SOLUTIONSPLUS Impact Assessment, we address the set of wider economic indicators. The S+ Impact Assessment defined the following five indicators for the assessment:

- *Percentage change in relevant national/local budget (Unit: %)*
- *Percentage change in fossil fuel imports (Unit: %)*
- *Change in imports of vehicles/parts (Unit: Count)*
- *Number of additional jobs (Unit: Count)*
- *Number of skilled positions required*

For the assessment, it is important to know the total number of three-wheelers that are currently registered in Dar es Salaam. It was not possible to obtain these numbers

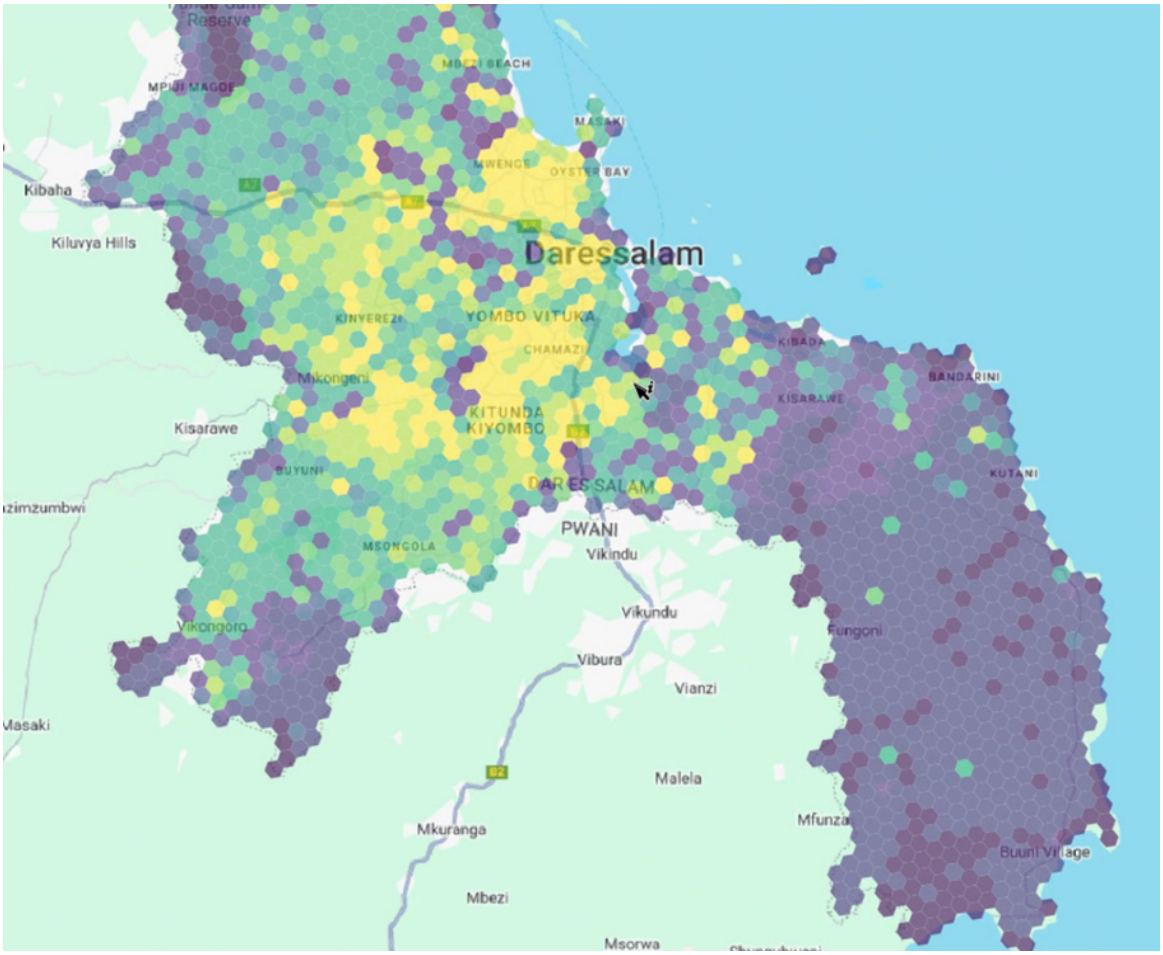


Figure 16. Total number of three-wheelers in Dar es Salaam, based on Estimation as in Goletz et. al (2024)

from official sources. CWe therefore modelled the numbers of vehicles based on aerial images and a spatial regression analysis (Goletz et al., forthcoming). The results of this approach estimated the total number of three-wheelers registered in Dar es Salaam for 2021 at 78.000. The results also allowed for a spatial distribution as shown in the following Figure 16, where a clear concentration of vehicles in the central areas of the city is visible, which is plausible.

Impact on national/local budget

During the demonstration project, less than 100 electric vehicles were introduced in Dar es Salaam as part of the SOLUTIONSPLUS project. Hence, the impact on the overall economic development is neglectable.

The following impacts on the indicators as above can be derived:

Percentage change in relevant national/local budget (Unit: %)

No quantifiable impact on overall budget.

Impact on external trade

Percentage change in fossil fuel imports (Unit: %)

No quantifiable impact, also because the electric vehicles do not consume fossil fuels.

Change in imports of vehicles/parts (Unit: 45)

In total, 45 vehicles were imported (40 by TRí, 5 by Ekoglobe)

Figure 17. Assembled e-three-wheelers from EkoGlobe

Impact on employment

Number of additional jobs (Unit: Count)

TRí: The company TRí imported 40 vehicles in total. As the company is also involved in the business by other clients, the total number of jobs created can hardly be estimated. We assume that 4-5 people would be needed to handle the import, assemble the vehicles and maintenance over the period of 12 months.

EkoGlobe: The company EkoGLobe imported 5 electric 3wheelers in total, creating work for 3 people for approx. 6 months.

Number of skilled positions required

Apart from the drivers of the vehicles, additional technical staff is needed. However, the number of skilled positions cannot be assessed by looking at the staff of the companies involved (TRí and Ekoglobe). This is due to the fact that these companies are actively involved in the business development and staff for running the fleet and business expansion are interlinked.

3.3. PEDAL-ASSIST ELECTRIC BICYCLES

The impact assessment on the pedal-assist electric bicycle component delves into the feasibility and potential impact of transitioning from ICE boda bodas to electric bicycles in Dar es Salaam. Among the KPIs developped for the SOLUTIONSplus project in Dar es Salaam, this assessment applies the financial KPIs A and KPIs C on the impact on GHG emissions.

3.3.1. Financial indicators

The comparative financial analysis of electric bicycles and conventional ICE boda bodas, incorporates data from the SOLUTIONSplus electric bicycle pilot study, the

driver survey and secondary sources. The analysis assesses the financial viability of pedal-assist electric bicycles compared to boda-bodas in three different scenarios:

- Baseline: Boda Boda Business as Usual
- Scenario BAU: Electric Bicycles Business as Usual (BAU)
- Increase Scenarios: Increase of Electric Bicycles Activities

  Scenario A: Range and Trip Increase (Overnight charging)

  Scenario B: Order Bundling and Optimization (Overnight charging)

  Scenario C: Overnight Charging & Battery Swapping

The net present value (NPV), the internal rate of return (IRR), and the payback period are the three key figures used to assess the financial viability of the baseline and three scenarios. All values are considered before taxes.

The NPV calculates the difference between the present value of the cash inflows (annual revenue) and the present value of the cash outflows (initial investment, annual operational costs) over the expected lifetime of the vehicle. Total annual operational costs are the sum of various categories such as driving licence certification/ renewal, night parking, electricity/ fuel costs, maintenance and other costs. Furthermore, personnel costs are included in operating costs - based on a monthly allowance for expenses during operations (e.g. food based on numbers obtained from FASTA drivers) and the minimum wage for jobs in the transport sector in Tanzania (ATE 2022). These values are used as proxies and may not accurately reflect the actual earnings of a delivery driver.

The IRR is the discount rate at which the NPV of all cash flows from the investment equals zero, it can be seen as the return generated by the purchase of the boda boda or electric bicycle and operation according to a typical operational profile analysed as part of this pre-feasibility study in Dar es Salaam (data obtained through desk research, driver survey and pilot study).

The payback period, on the other hand, indicates how long it takes for the initial investment to be recouped by the cash inflows from operating the vehicle.

Baseline: Boda Boda Business as Usual

The baseline scenario focuses on traditional ICE boda-bodas. These vehicles have an average purchase price of $1,121 and a residual value of 50% according to A2EI (2021). The annual operating costs amount to $3,877. For each of the presented cases, $1,869 of annual operating costs are attributed to personnel costs, meaning the salary of the driver. The annual revenue amounts to around $4,506. On average, a boda boda fare is $1.58 per trip, covers 11.88 kilometres per trip and makes around 9.7 delivery trips per day.

This results in a total daily distance travelled of around 115 km, with the boda bodas in use on around 294 days a year. The pre-tax NPV for the base case amounts to $1,251, the IRR lies at 47.96% and the pre-tax payback period at 1.79 years.

Scenario BAU: Electric Bicycles Business as Usual

Scenario BAU shifts the focus to the electric bicycles, in particular their financial feasibility without the support of the SOLUTIONSplus project. Here, the economic viability of the electric bicycles used in the pilot project is analysed using a range of parameters, including a Li-ion battery with a capacity of 0.46 kWh and a service life of 800 cycles. The electric bicycles have a range of around 40 kilometres per charge. The

cost includes $420 for the bicycle body and $200 for the battery pack.

In this scenario, based on an interim evaluation of operation in the pilot project, the riders cover an average distance of 9.57 kilometres with an average of 2.3 trips per day, which corresponds to a total daily distance of 22.01 kilometres on 298 days per year. Given this operational profile and an average delivery price per trip of $1.29 the total annual revenue amounts to $884. Over the expected useful lifetime of the bicycle over four years this leads to a negative pre-tax NPV of -$5,534, strongly indicating that investing in electric bicycles under the given scenario is not profitable.

Increase Scenarios: Increase of Electric Bicycles activities

The Increase Scenarios build on the BAU scenario and analyse an increase in the operating capacity of the electric bicycles.

Scenario A anticipates an increase in both the number of daily trips and the distance travelled per day. This scenario is based on the assumption that demand will enable an increase in the FASTA customer base. This could be achieved, among other things, through partnerships with facilities and institutions in the city centre, as tested in the pilot project with the Aga Khan Hospital. FASTA drivers reported that on very good days, when demand is strong, deliveries per rider can be as high as six trips per day, which is why this number of daily trips is assumed in this scenario. At the same time, it is assumed that the utilization of the full battery capacity is realised and an increase from 22 to 40 km is achieved, which would lead to a doubling of the daily mileage of the electric bicycles and a significant increase in the number of deliveries. The increase in operating costs in this scenario only considers the change in energy costs due to the increase in charging frequency. In **Scenario A** there is a significant improvement in the key financial numbers compared to **Scenario BAU**. The pre-tax NPV improves significantly to -$164, the IRR to -1.13% and the payback period, i.e. the time required to recoup the original investment, is now estimated at 5.13 years. While still unfavourable, these figures represent a significant improvement on previous estimates as they indicate a much lower net loss over the life of the project, reflecting a slight improvement in the overall profitability of the investment, albeit still with a negative return.

Under the assumption that FASTA is able to grow its customer base to match the capacity of a conventional boda boda driver (9.7 trips or customers per day) under the same scenario, the financial results could be much more favourable. This revised scenario – **Scenario B** – assumes an increase in trips, albeit over shorter distances (9.7 trips/day on an average distance of 4km). Under these modified conditions, it is conceivable to achieve a NPV of $5,227, an IRR of 252.87% and a payback period reduced to 0.52 years suggesting faster cost recovery and potential profits. However, it needs to be noted that this is a hypothetical scenario that does not consider market saturation and competition and a likely lower average revenue per trip for shorter trips. In addition, it may require operational adjustments, such as increased coordination and bundling of orders. Moreover, a possible faster wear and tear is not reflected in the operating costs.

Scenario C introduces the concept of battery swapping. This scenario aims to increase the operating capacity of electric bicycles to the level of ICE boda bodas, especially about the number of daily deliveries. Although it is assumed that the introduction of an additional battery doubles the maintenance costs and increases the capital costs by one additional battery, i.e. by $200, the operating efficiency of the e-bicycles is significantly increased. This scenario is particularly noteworthy for its financial impact, as it shows a significant increase in the IRR to 181.9% with the additional battery, as opposed to the IRR of -1.1% in Scenario A without the additional battery. The pre-tax

NPV for Scenario C lies at $4,691 and the payback period at 0.53 years.

Table 3 presents the results of the scenarios and baseline described above. To summarise, it can be said that under the given assumptions and constraints, the scenarios for the electric bicycle business with a high increase in trip frequency (Scenario B) and battery swapping (Scenario C) perform significantly better than the baseline scenario using boda bodas and the less ambitious electric bicycle scenarios (BAU and A). Scenarios B and C have particularly promising financial values that indicate good investment opportunities with quick returns, while Scenario BAU is unprofitable and Scenario A is close to profitability.

Table 3 Comparative financial impact assessment

Case	Description	Pre-tax NPV (USD)	Pre-tax IRR (%)	Pre-tax pay-back (years)
Baseline	Boda boda, 9.7 trips/ day	1,251	47.96	1.79
Scenario BAU	Electric bicycle business as usual, low number of trips, and 22km/day	-5,534	-	-
Scenario A	Electric bicycle range and trip increase, increase to 6 trips & 40 km per day	-164	-1.13	5.13
Scenario B	Electric bicycle range and high trip increase, increase to 9.7. trips/ day and 40 km/day	5,227	252.87	0.52
Scenario C	Electric bicycle battery swapping	4,691	181.94	0.53

3.3.2. Environmental indicators

Impact on GHG emissions

The environmental impact assessment shows, that the shift from ICE boda bodas to electric bicycles demonstrates significant potential for reducing CO2 emissions. As indicated in Table 4, an ICE motorcycle emits 2,875 kg of CO2e, while an electric bicycle only emits 152 kg of CO2e per year. Therefore, substituting an ICE motorcycle with an electric bicycle, under current characteristics of electricity generation, would result in an annual reduction of 2,723 kg of CO2e, equivalent to a substantial 95% decrease in CO2 emissions.

The CO2e annual emission were calculated as shown in the table above with the following assumptions:

- The electric bicycles are charged from the grid with carbon intensity of electricity of 367 g of CO2e, per kWh.
- Bicycles and motorcycles travel same distances which is about 115 km for 6 days a week for a year which is roughly 35,978 km annually.

Table 4 Comparison between ICE motorcycle and electric bicycle energy consumption

Description	Unit	Motorcycle	E-bicycle
Petrol consumption	l/100 km	3.7	
Electricity consumption	kWh/100 km		1.15
CO2 emissions	kg of CO2e/litre	2.1602	
CO2 emissions	kg of CO2e/kWh		0.367
Annual distance	km	35,978	35,978
Annual consumptions electricity	kWh		413
Annual consumptions petrol	liters	1,331	
CO2 annual emissions	kg of CO2e	2,875	152

- The motorcycle has 150cc which emits about 2.16 kg of CO2e per liter.
- The electric bicycles have similar specification like the EURIST bicycle currently operated by FASTA which has a 460Wh lithium-ion battery with a range of 30-40km on a single charge.

Presently, Tanzania's electricity installed capacity of 1,602 MW predominantly relies on natural gas (48%), followed by hydro (31%), petrol (18%), solar (1%), and biofuels (1%) (ITA 2021). With the upcoming launch of the Julius Nyerere Hydropower Project (JNHPP), boasting an installed capacity of 2,115 MW and soon connected to the national grid, this hydroelectric dam along the Rufiji River in eastern Tanzania, will double the national grid capacity and elevate hydro as the primary source of electricity, constituting 60% of the national grid. Opting for electric bicycles instead of ICE motorcycles for urban deliveries will therefore contribute to higher CO2 savings.

4 VALIDATION OF KPIS

This section of the report presents the validation of Key Performance Indicators (KPIs) with local stakeholders regarding the pilot e-bajajs in Dar es Salaam (impact assessment). These KPIs encompass institutional/political indicators, financial indicators, social indicators, and wider economic indicators.

4.1. BACKGROUND OF RESPONDENTS

The total number of institutions interviewed in Dar es Salaam regarding validation of the specific key performance indicators (KPIs) were seven across the three categories of institutions as shown in Table 5.

Table 5. Three categories of institutions

SN	Categories of Institutions	Institutions/Local Stakeholders
1	Government Agencies/ City Authorities	Land Transport Regulatory Authority Consumer Consultative Council (LATRA)
		Dar es Salaam City Council
		National Environment Management Council (NEMC)
		Tanzania Bureau of Standards (TBS)
2	Financiers/Donors	National Micro Finance PLC
		World Bank
3	Bajajs Association/Operators	Bajajs Waiting Point Association (Operators)
Total Number of Institutions		**7**

Source: Authors' Construct, May 2023

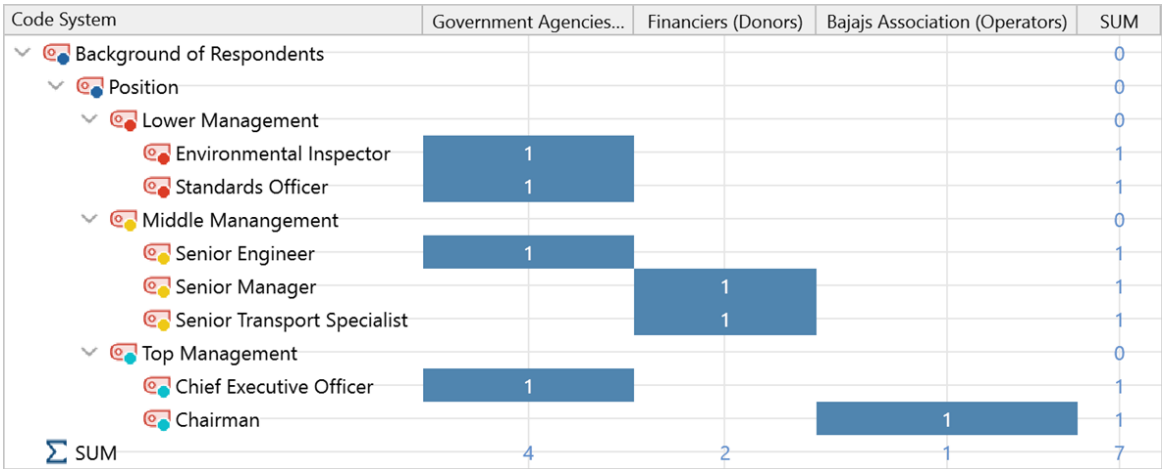


Figure 18. Levels of Management Position of Interviewees

In line with the background of the interviewees, the main category/code position inductively unravelled seven sub-categories/codes including Environmental Inspector, Standards Officer, Senior Engineer, Chief Executive Officer as shown in Figure 18.

4.2. VALIDATION OF FINANCIAL INDICATORS

4.2.1. Easiness to raise external funds for the e-bajajs pilot project

The respondents of the interviews discussed the ease of raising external funds for the e-bajaj pilot project in Dar es Salaam. One respondent from the National Environment

Management Council suggested accessing funds from the climate fund at the Council and through partnerships committed to climate change mitigation as an option. Another respondent noted that e-bajaj could be financially sound for the Land Transport Regulatory Authority due to revenues from license fees, and for the private sector (owners) due to reduced operational cost compared to conventional fuel-powered bajajs as oil and gas are expensive. The Dar es Salaam City Council identified their Climate Change Action Plan 2020-2050 as a tool to strategise and assist in raising the needed funds and offered to provide land for charging stations where possible. The World Bank representative stated that accessing funds for the project would be easy if a good business case was built and aligned with decarbonization and climate change agenda. The National Micro Finance PLC Bank already has a 'Mastaboda' product designed for bajaj loans, making it easy for operators to access financing.

4.3. VALIDATION OF INSTITUTIONAL/POLITICAL INDICATORS

4.3.1. Alignment of uptake of the e-bajajs pilot project with plans and policies

The e-bajaj pilot project aligns with national policies such as the National Environment Management Policy of 2021 and the Air Quality Regulation of 2007, which address climate change and air quality. At the city level, there is a move towards using natural compressed gas and encouraging cost-efficient and environmentally friendly transportation. However, there is currently no policy specifically for electric vehicles or e-bajajs. The Dar es Salaam City Council is working with Tri Company to identify areas for charging stations and potentially allow e-bajajs to enter the central business district rather than the conventional fuel-powered bajajs. The Climate Change Action Plan of 2020-2050 is a document guiding the city's priorities in energy, water, and other sectors.

4.3.2. Level of compliance of the e-bajajs pilot project with regulations and laws

The level of compliance of the e-bajajs pilot project to applicable regulations and laws is evaluated using a scoring system depicting full compliance, presence of uncertainty or non-compliance. Full compliance refers to the situation where the project element is fully compliant with the regulation, while non-compliance refers to the situation where it does not comply with the applicable regulation. In between the two extreme ends is the presence of uncertainty where the situation cannot be fully ascertained as either of the two. The compliance level of the e-bajajs pilot project varies depending on the use of e-bajaj. The e-bajajs for passengers are fully compliant, while the e-bajajs for cargo have a presence of uncertainty due to the absence of a law requiring registration and plate numbers for commercial use. The compliance of the e-bajajs is evaluated based on their compliance with the National Environment Management Policy of 2021, inspection by government institutions like Tanzania Bureau of Standards and traffic police, and clearance from the Tanzania Revenue Authority.

> *... e-bajaj for cargo is not fully compliant but the one that carries passengers is fully compliant. You know this e-cargo bajajs need to have plate numbers and if it is for commercial it needs to have white plate numbers. But currently, with the absence of the law, those cargo tricycles are not registered, they are just going to the market carrying goods without being registered*
>
> *(Government Agencies/ City Authorities, February 2023)*

4.3.3. Barriers to the implementation of the e-bajajs pilot project from an institutional perspective

The implementation of the e-bajaj project faces several institutional and political barriers. These barriers include the need for collaboration among different stakeholders which is considered crucial for the smooth functioning of the project. For instance, the lack of involvement of the National Environment Management Council (NEMC) in the project limits the financial budgetary allocation for the expected role of monitoring of the project implementation to be carried out by the NEMC. Political influence can lead to conflicting issues and delays in project implementation. This is the case where the judgements of political actors are overshadowed by individual political ambitions to the detriment of the success of the project. Inadequacy of charging stations is a major challenge which is evident from the interviews revealing that the long-term plans of the Tanzania Electric Supply Company Limited (TANESCO) or Tanzania National Roads Agency (TANROADS) do not have provisions for installing charging stations near roads. There is also the lack of incentives to motivate the import of e-bajajs as opposed to conventional fuel-powered bajajs. Reduction of import taxes on e-bajajs would be a good way to drive the shift towards e-bajajs and support the climate agenda of the country. Finally, the new technology of e-bajajs requires raising awareness on how to effectively adapt it for daily use and the operational requirements. It is important for people to know the availability and benefits of e-bajajs as well as the companies running them.

> *It is lack of incentives from the government. If these e-bajajs are not emitting while the others which are using fuel are emitting, they need to have incentives for those who are buying and importing e-bajajs from China to be exempted from the taxes*
>
> *(Government Agencies/ City Authorities, February 2023)*

4.3.4. Perceived data for national and city level planning from the e-bajajs pilot project

The participants in the interview identified several types of data that would be relevant for national and city level planning if made available through the e-bajajs project. These include air quality monitoring data, lifespan and management of e-bajaj batteries, recycling and repair information, data on the number and ownership of e-bajajs, identification of private companies importing e-bajajs, registration status of e-bajajs for passenger and cargo transport, and information on identified partners and stakeholders. Additionally, the participant suggested obtaining data on the city's long and short-term master plan.

4.4. VALIDATION OF SOCIAL INDICATORS

4.4.1. Impact of uptake of the e-bajajs pilot project on road safety

The impact of the e-bajajs pilot project on road safety would depend on factors such as driver training, maintenance and repair plans, and awareness campaigns. The e-bajajs could have a positive impact on the environment by reducing emissions and limiting the number of fuel-powered bajajs entering the city. However, the absence of sound from the e-bajajs could pose a challenge for road safety. Only drivers with special needs are allowed to enter the city center with the bajajs to avoid competition with non-special needs drivers. Thus, a shift to the use of e-bajajs by the drivers with special needs would help cut down emissions in the city centre. The short range of the e-bajajs could also cause road traffic breakdowns where the e-bajajs get stuck in the

roadway because of exhausted battery capacities before reaching a charging station.

4.4.2. Impact of uptake of e-bajajs pilot project on charging safety

We applied empirical instruments in line with the methodology of the project, however the results did not yield any plausible results. Based on impressions while carrying out the project and background talks with stakeholders, we however suggest that fire hazard and general aspects of safety should be considered with high priority for e-mobility and charging projects in Dar es Salaam. We suggest that subsequent projects should address aspects related to power grid stability, access to charging opportunities and safety conditions at households. These aspects will become increasingly important as electric vehicle fleets continue to grow in Dar es Salaam due to overall heavier load being imposed on the grid.

4.4.3. Impact of uptake of e-bajajs pilot project on public transport security (PS)

Infrastructure and Operation (PS1)

It is believed that the risk impact on infrastructure and operation for public transport security (PS1) will be very minor due to cautious driving resulting from the soundless e-bajajs. However, it is believed that the adoption of e-bajajs could have a high adverse impact on operations of the DART BRT due to increased mobility and flexibility offered by the e-bajajs. The likelihood of risk occurrence is considered very low due to good roads, thus, low probability of accidents. Powerful or long-range batteries are however needed since the route lengths could be quite long.

Vehicles (PS2)

The use of e-bajajs is expected to have a high impact on other carrying units, as they are more preferred due to economic reasons aside being environmentally friendly. The uptake of e-bajajs is also expected to have a significant impact on public transport security, as they offer a faster and more efficient mode of transportation. The likelihood of risk associated with vehicles is considered low, but the impact on other vehicles such as daladalas and cars is expected to be medium.

Transport of Persons (PS4)

The interviews revealed that the transport of persons (PS4) will have a high adverse impact on public transport options like the DART BRT. This is particularly the case because e-bajajs would be able to provide faster travel times for commuters. This will result in an increase in alternative options like e-bajajs and Uber. The impact on passengers will vary throughout the day, with high demand in the morning and evening and low demand in the afternoon.

4.4.4. Validation of wider economic indicators

The e-bajajs pilot project is expected to have a significant impact on wider economic indicators. The budget allocated for fuel will be reduced, resulting in a substantial change in the relevant public budget. The percentage change in fossil fuel imports will also decrease as the e-bajajs become more popular. However, the cost of e-bajajs is currently high compared to those using fuel, but if the government adopts e-mobility policies, the cost may be lowered, making them more competitive in the market. The stability offered by e-mobility will limit changes in bus fares and limit fossil fuel imports. This will have a positive impact on people, making them more interested in e-mobility and reducing their reliance on fossil fuels.

5 DISCUSSION

In Dar es Salaam, the project's main goal was to research and improve ways to increase the sustainability of the city's transport system. The city's transport system faces a growing demand, mainly driven by urban growth and increasing economic wealth, which in turn is driving up vehicle motorization rates. The city of Dar es Salaam has responded to these challenges by implementing a Bus Rapid Transit System (BRT), which will cover wide areas of the city when it is finished.

However, one of the yet untackled areas is the question of sustainable feeder services for the BRT. This project therefore aimed to develop an approach to introduce such sustainable feeder services for the BRT. The goal was to introduce three-wheelers and the needed infrastructure to run them (mainly charging & maintenance facilities) over the duration of the project. We also aimed to test the integration into business modes that are common and feasible for the city to see whether this project would also be viable after the project ends. The three-wheelers will be integrated with the BRT and will subsequently replace the growing fleet of internal combustion engine (ICE) three-wheelers.

As of April 2024, the project successfully introduced 31 new three-wheeled vehicles locally assembled (30 new vehicles and 1 retrofitted bajaj) into the city of Dar es Salaam; and and 12 vehicles (4 retrofitted bajajs, 8 new vehicles) are still to be deployed by the end of the SOLUTIONSplus project at the end of June 2024. These vehicles were delivered by four different companies, as described above. We conducted an extensive impact assessment (IA) to test the success of this measure, and the results are promising. For instance, we demonstrated that electric three-wheelers have a positive IRR, meaning they can be operated as a profitable business and would also be able to exist without our support. Furthermore, we demonstrated a highly positive impact on climate-relevant emissions, particle emissions and noise. Using a quantitative method, we also showed a positive social impact as denoted by assessing the Sustainable Development Goal Indicator 11.2. The impact on the wider economy is also positive, however due to the small overall scale of the pilot project only a scaled-up project would have a measurable impact on the wider economy.

For the future, three main research topics should be addressed:

- Further integration of BRT and electric three-wheelers must be studied. This should include looking at aspects such as integrated trip planning, ticketing and scheduling as well as physical integration. In all these field, the project did not advance as fast as expected, but we expect significant positive impacts if this field can be advanced.
- Co-existence with ride-sourcing, that is currently driven by companies such as Bolt and Uber, should be studied. In addition, the city should investigate the regulatory and goal-setting implications of this transition.
- Financial models and business models must be further examined. For instance, microfinance schemes should be explored to support the purchase of electric vehicles over ICE vehicles. The city should determine which business and ownership models (lease, lease-to-own, rent) such schemes should support.

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