HIGH VOLUME TRANSPORT
APPLIED RESEARCH

airqo
Breathe Clean.

Makerere University

MARGARET HAYMAN TRUST

AUTOSAFETY-UG

Autosafety Uganda: Tackling Road Transport Emissions and Crashes from the Source

Rubaga Chapter

December 2024

DT Global

UK International Development
Partnership | Progress | Prosperity

This research was funded by UKAID through the UK Foreign, Commonwealth & Development Office under the High Volume Transport Applied Research Programme, managed by DT Global.

Reference No.	HVT/ LB003 60L
Lead Organisation/ Consultant	Wanyama Autosafety Initiatives
Partner Organisation(s)/ Consultant(s)	AirQo – Makerere University
Title	Autosafety Uganda: Tackling Road Transport Emissions and Crashes from the Source - Rubaga Chapter
Type of document	Project Report
Theme	Low carbon transport
Sub-theme	Safety Risks and Road Transport-Induced Pollution Vis-à-vis Health and Ecological Impacts
Author(s)	Michael Wanyama et al., 2024
Lead contact	Michael Wanyama
Geographical Location(s)	Uganda - East Africa
Abstract	
Keywords	Transport, climate change, clean mobility, road safety, emissions, policy, e-mobility, public health, Africa
Funding	The research and reports about deliverables of Autosafety-Uganda, Rubaga Chapter Project is funded FCDO under the High Volume Transport Applied Research Programme, that supports innovations promoting clean, safe and sustainable mobility for all.
Acknowledgements	The UK Development Aid through DT Global for the funding and the technical support that enabled the success of this project; and in-kind support from local partners including AirQo and the Ministry of Works and Transport. Much appreciation goes to Margaret Hayman Charitable trust for the funding support that enabled us kickstart the project.

Contents

Acronyms

AQ	Air Quality
COP28	28th Conference of the Parties to the UNFCCC
DC	Direct Current
DTC	Diagnostic Trouble Code
ECU	Engine Control Units
FCDO	Foreign, Commonwealth & Development Office
GPS	Global Positioning systems
HVT	High Volume Transport
OBD-II	On-Board Diagnostics Version Two
PEMS	Portable Emissions Measurement Systems
RPM	Revolutions Per Minute
TCC	Traffic Control Centre
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation
EV	Electric Vehicle
ICE	Internal Combustion Engine
MoWT	Ministry of Works and Transport
UPF	Uganda Police Force
LiFeP04	Lithium-Ion Phosphate
NAGOA	National Auto Garage Owners Association
UNEP	United Nations Environment Program
ICCT	International Council on Clean Transportation
WAI	Wanyama Autosafety Initiatives

Executive Summary

The project in Rubaga Division, Kampala, funded under the T-TRIID initiative as part of the High Volume Transport (HVT) Applied Research Programme, focused on raising awareness about the health and environmental impacts of road safety and transport-induced pollution.

It targeted communities with a high concentration of automobile repair garages, aiming to reduce road crashes and pollution by promoting change and best practices among motorists and workers in the auto industry, linking local actions, such as poor vehicle maintenance, to broader global issues like public health and climate change, emphasizing skill-building and the adoption of safer, environmentally conscious practices through the following activities.

- **Community and Participant Mobilisation:** Through these efforts, mechanics and technicians were recruited and sensitized on the importance of sustainability at work, such as proper vehicular maintenance, to mitigate pollution and road accidents. A diverse group, including garage owners, transport associations and spare parts dealers were mobilized to raise awareness among them. The project onboarded community leaders and transport business associations, fostering engagement at decision-making levels to drive policy change and encourage better vehicular practices. These leaders and associations were instrumental in pushing for innovations and research outcomes that focus on safety and pollution reduction.
- **Focus Group Discussions:** Engaging 218 mechanics aged 18 to 35, the project explored knowledge gaps in vehicular safety and emission control. Key challenges identified included limited access to proper tools and knowledge about modern vehicle technologies. Participants highlighted the role of car owners, mechanics, and the government in contributing to poor vehicle maintenance and pollution. These findings informed the design of four training workshops to equip local mechanics with essential skills.
- **Training Workshops:** Based on a needs assessment from focus group discussions, a total of 503 participants attended four training workshops designed to improve skills in vehicular emission control and safety. Participants learned about air quality issues, sustainable maintenance practices, and the importance of compliance with environmental regulations. Local leaders, government representatives and experts from Makerere University provided additional technical support, linking vehicle pollution to public health concerns.
- **Emissions Data Collection and Analysis:** The project collected tailpipe emissions data from 50 vehicles to assess the impact of maintenance practices on pollution. Results showed that poor-quality service, removal of emission control systems, and frequent travel on unpaved roads significantly increased emissions. The data will be used to lobby for better regulation and practices in vehicle maintenance.
- Electric Mobility Uptake through Retrofitting: This element explored retrofitting a conventional internal combustion engine (ICE) vehicle with an electric motor as a pilot to promote electric mobility in the informal sector. This effort seeks to extend the life of older, once high-polluting vehicles, and improve air quality by reducing fossil fuel dependence.
- Wanyama Autosafety Initiatives, in partnership with Makerere University, is positioned to support transport policy reforms in Uganda. The report includes a policy brief to support advocacy to stakeholders on reducing transport pollution and road accidents, with continued engagement beyond the life of this project.

In conclusion, this project successfully engaged the local community, trained over 500 mechanics, and collected valuable emissions data. Feedback indicates the need for continued training, policy reform, and joint efforts from key stakeholders to improve road safety and reduce pollution. There will be continued monitoring and follow up on the implementation of recommendations, and further investments in renewable energy projects to support electric mobility in Uganda.

1. Project Outline

1.1 Introduction

- Wanyama Autosafety Initiatives, based in Uganda, was awarded a research grant from the Transport-Technology Research and Innovation for International Development (T-TRIID) initiative, part of the High Volume Transport (HVT) Applied Research Programme. This programme, funded by UK Aid and managed by DT Global, aims to support innovative projects in low- and middle-income countries (LMICs) across Africa and South Asia to tackle transport challenges, particularly in relation to climate change, safety, sustainability, and urbanization pressures.
- Wanyama Autosafety Initiatives operates by engaging with both grassroots stakeholders and key industry leaders in Uganda's automobile sector. The NGO focuses on improving road safety, enhancing public health, and addressing climate change through innovation in transport. It serves as a bridge between the informal sector—such as semi-skilled mechanics working on outdated vehicles—and the formal regulatory bodies. The organisation facilitates skills development and policy advocacy for better regulations in Uganda's road transport sector.
- One of its primary goals is to create a data-driven transport system, feeding data into existing traffic control centres (TCC) to ensure quicker responses to road incidents. It seeks to mitigate the importation of substandard vehicles, improve the skills of technicians and tailor infrastructure programmes to address local needs. By doing so, it aims to improve safety, reduce pollution and promote climate resilience in Uganda's transport sector.

Wanyama Autosafety Initiatives collaborates globally with similar organisations to benchmark best practices and enhance the scope of its research, contributing to sustainable transport solutions in Uganda and across Africa. Its comprehensive approach integrates different sectors for maximum impact on road safety and transport innovation.

1.2 Background

- Uganda's capital, Kampala, is among Africa's most polluted cities. While several aggravating factors contribute to poor air quality (AQ) and under regulated road transport especially in the informal transport sector.
- According to the World Health Organization (WHO), air pollution is one of the world's biggest environmental hazards, responsible for at least 7 million premature deaths annually. Uganda alone loses over 31,000 people annually, most of them children. Air pollution kills more people than HIV/Aids, malaria, and tuberculosis combined, yet these issues continue to receive vastly more attention and resources.

In Uganda, nearly 5,000 people are killed in road crashes involving cars, buses, motorcycles, bicycles, trucks, or pedestrians annually. Road crash injuries are estimated to be the eighth leading cause of death globally for all age groups and the leading cause of death for children and young people aged 5 – 29 years. More people now die in road crashes than HIV/AIDS. According to recent statistics from Uganda police, the number of reported fatalities from road traffic crashes rose to 4,179 in 2023, marking an increase from 3,901 in 2022. In contrast, deaths from HIV/AIDS in Uganda have significantly declined due to improved access to treatment and prevention measures. UNAIDS reports a decrease in HIV/AIDS-related deaths, which are now lower than the figures associated with road traffic crashes. Based on data from iRAP, it has been estimated that Road traffic crashes impose a significant economic burden on Uganda, currently estimated to cost between 2% and 5% of the country's Gross Domestic Product (GDP) annually and this translates to substantial financial losses each year.

The 2023 Global status report on road safety by WHO shows that road traffic fatalities disproportionately affect low- and middle-income countries, where 90% of global road deaths occur. Therefore, these fatalities are a public health concern that must be addressed. Rising income levels and economic development in many developing countries have contributed to rapid motorisation, but road safety management and regulations have not kept pace. Action must be taken to address this ever-growing public health problem worldwide, with a particular focus on developing countries.

According to a Uganda Police Force (UPF) Annual Report, a 52% increase has been observed in road traffic crashes, which rose from 12,249 in 2020 to 23,608 in 2023. During that period, 15,106 crashes were fatal, and 20,452 were minor. Most road crashes in Uganda have been attributed to human error, such as speeding, driving under the influence of alcohol or other drugs, or distracted driving. Uganda has implemented some control measures to reduce road crashes, such as enforcing traffic laws in the Traffic and Road Safety Act 1998 (amended) through police roadside checks and speed management operations. Even though several reports indicate road crashes caused by vehicles in poor mechanical states, little effort has been made to solve the problem.

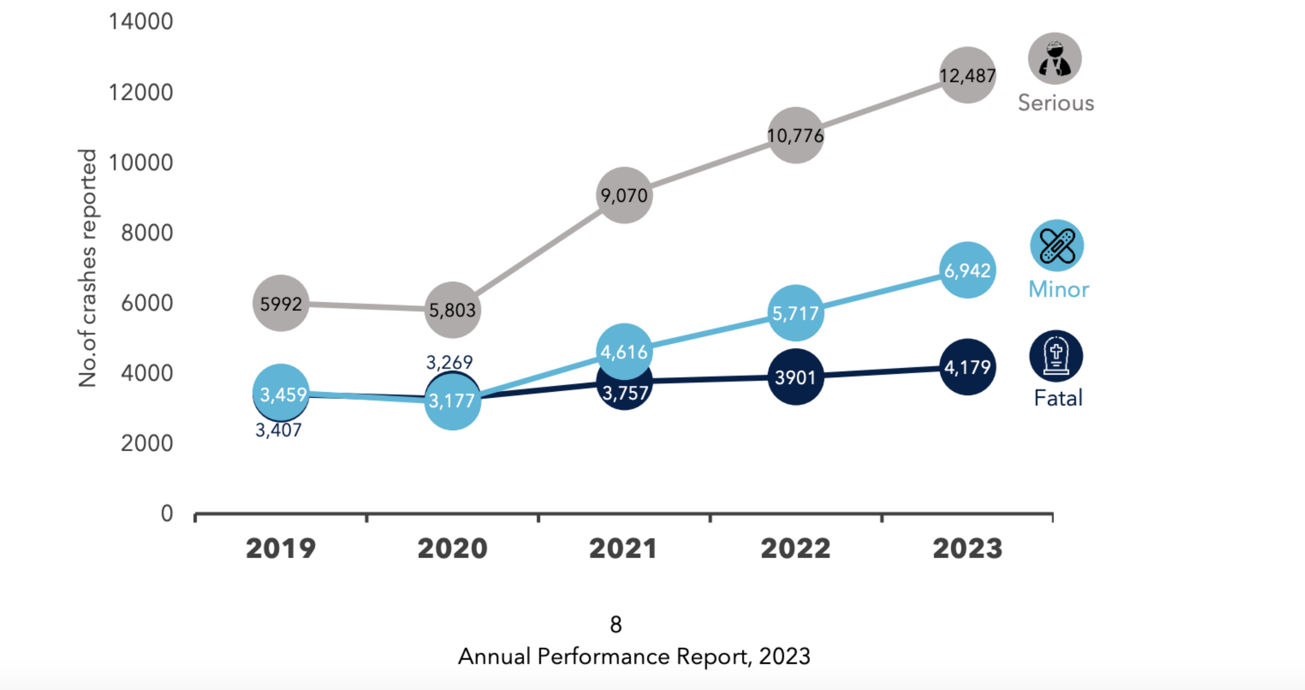

Figure 1: Insights from Uganda's 2023 road safety report

Vehicles in Uganda, of which over 80% are used imports, are poorly maintained. Many would fail roadworthiness tests in exporting countries. The poor, unregulated maintenance practices in Uganda further compromise inbuilt safety and emission control systems. This is often due to the limited capacity and capability of over 85% of the local mechanics who tend to the vast majority of vehicles in the country. Moreover, the lack of actionable data and concerted action around vehicular emissions, and the poor mechanical condition of most automobiles, means transport-induced pollution throughout Africa is likely to be far worse than estimated, and the number of fatal or serious injury road accidents will continue to rise given the rapid urbanisation that partly fuels the demand for used vehicle imports.

Poor air quality and road crashes are not the only problems associated with Uganda's transport system. A lack of standards around automotive waste handling often means toxic substances including, used engine oil and battery acids, among others, are dumped or spilt, ultimately ending up in water bodies or are absorbed by soils. This further damages an economy built almost entirely on agriculture, and exacerbates an already chronic pattern of injustice and poverty in the country. The trend of making use of used vehicular spare parts to maintain the highly unsustainable fleets in servicing also hinders Uganda's climate action plans and is a significant threat to public health, especially in poor communities.

Significant revenue is collected through environmental levies on used imported vehicles and spare parts, resulting in a form of double taxation. This has led to a lengthy debate regarding the suitability of both automobiles and spare parts, both of which impact the overall quality of the nation's vehicle fleets.

This project took a community-driven, bottom-up approach to gathering information aimed at improving public engagement and understanding of the problems caused by the condition of Uganda's vehicles, and building the capacity for tackling them. In doing so it aimed to influence extensive policy reforms around the nation's transportation system.

There is a need for a strategy to prevent African countries, Uganda in particular, becoming a dumping ground for used vehicles from developed countries. These vehicles are then driven on poor road infrastructure, maintained by practices which leave them unsafe and hazardous to the environment. Even a relatively low-emission vehicle like a hybrid will lose its environmental advantage after a short time in Africa, irrespective of the age or mileage before importation due to poor maintenance or inappropriate use such as not making use of the battery system in a hybrid vehicle.

The current maintenance structure of Uganda's mechanics exposes vehicles to many factors that render emission and safety control systems ineffective or non-functional. The ready availability of counterfeit and fake spare parts, accessories, and consumables on the local market increases its potential for high emissions and an increase in road accidents if the counterfeit spare parts do not work as intended, are not robust enough and fail. Because mechanics and autoparts dealers want to maximise profits while their clients look for budget friendly services; substandard, cheap parts are usually ignorantly considered; and this gradually compromise vehicular emission and safety control systems.

A key objective of this project was to improve the integrity of inbuilt vehicular emission and safety controls while working towards transitioning from reliance on fossil fuels.

1.3 Objectives of the Project

The project aimed to promote road safety and improved access to clean air within Kampala City by pushing for a structured, augmented automobile maintenance system in Uganda through community-driven approaches.

2. Methodology

This project employed varied methodologies to cover different work streams simultaneously, designed to address several gaps in Uganda's road transport system. It aimed to supplement existing intervention measures by the government and development partners, some of which are relatively slow-moving or fail to cover critical areas of concern.

The informal sector dominates road transportation in Uganda, which is highly underregulated despite the existence of several regulations and guidelines but these are not always enforced.

The project takes a bottom-up, community-driven approach, accounting for nearly every stakeholder focusing on the informal sector but with close attention also paid to the formal sector, linking the two through their different work streams and roles.

2.1 Research Project Design

With a core objective of promoting a structured, safe and sustainable low-carbon road transportation for Uganda, the project leverages partnerships with related government agencies and other private, technical and academic stakeholders to disseminate evidence-based information on the current technical, regulatory, and policy gaps. It simultaneously engages communities in affordable mitigation measures designed to enable individual or collective actions.

The project design is elaborated in the operations cycle in Figure 2 below.

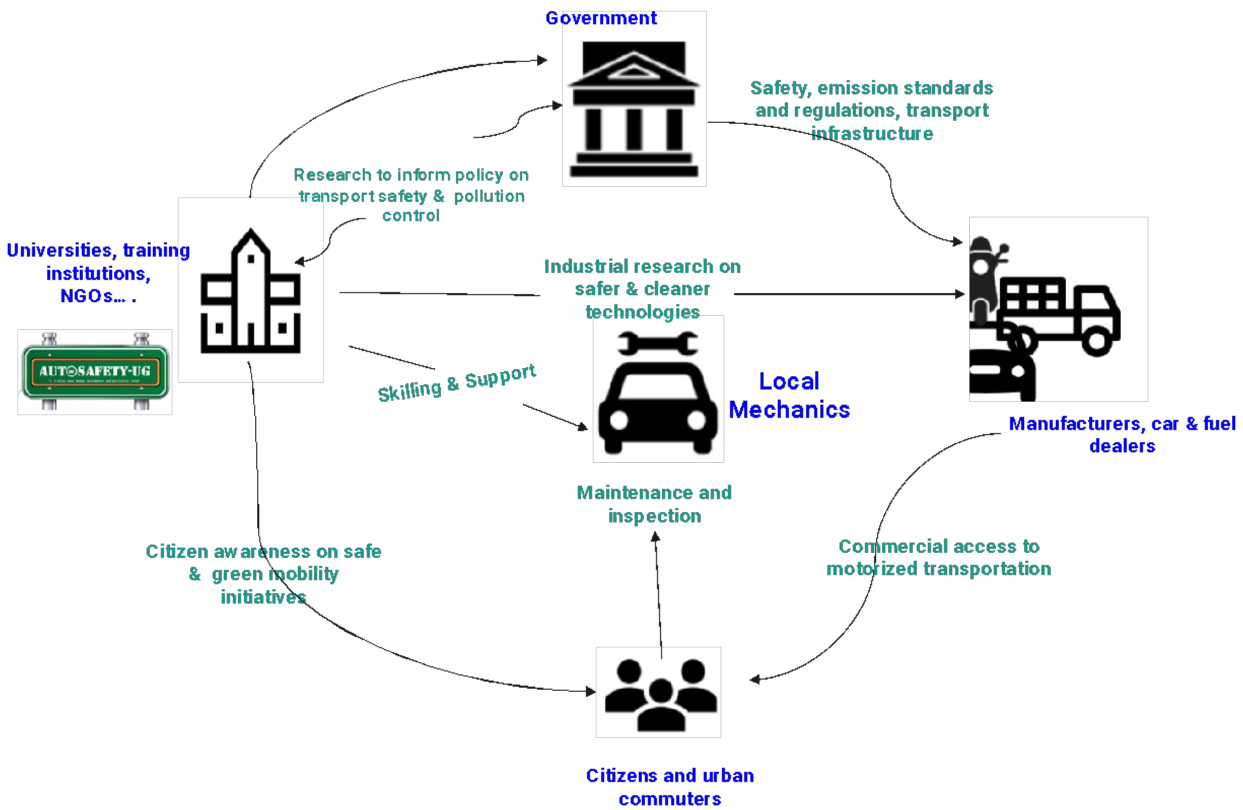

Figure 2: The project's intervention framework

3. Project Activities

3.1 Community Engagement: Mobilisation

The project focused on motorists and automobile-related workers in Rubaga Division, Kampala District, aiming to raise awareness about road safety, pollution, and their health and environmental impacts. It sought to build capacity for mitigation through behavioural changes and up-skilling, emphasizing the use of proper materials and spare parts. The project also aimed to empower communities by helping them understand the link between their actions and global issues like climate change. Communities were selected based on the density of automobile repair garages, with a focus on makeshift settings.

3.1.1 Community Mobilisations

Through this project, many mechanics and technicians have been mobilised to participate, especially at the community level. These key individuals needed to be educated about the benefits of innovations designed to reduce road accidents and the alleviation of transport-induced pollution in Uganda.

The targeted community members are expected to be positive agents of change regarding the discussions and priorities on automobile safety, and pollution control.

3.1.2 Participant Mobilisations

Participants were recruited through proper a vetting procedure which identified their potential to provide feedback. They were attached to the project for a specified period and included garage owners, transport groups and associations.

Among the participants, vehicle spare parts and accessories dealers were a relevant target since they could quickly disseminate information about the sources of such materials or imports. This could enable engagement at the point of effective implementation of project findings and execution of appropriate interventions.

3.1.3 Community Leader Onboarding

An onboarding process involved reaffirming and energising different Rubaga division community leaders. They were expected to provide inspiration and leadership on the adoption of new, and more sustainable practices.

The relevance of community leaders involved in the project is remarkably high and their participation undeniably transits them into agents for change. Their involvement will be sustained through routine engagements in the future.

3.1.4 Transport Business Association/Ownership Onboarding

Bringing transport business associations like the Masaka Taxi Operators group on board with the project has led to the opportunity for high level engagement with a range of decision-makers including NGOs and non-profit making transport groups.

These are the key targets to push the innovation and research agenda, and further the cause for adapting to better measures and recommendations towards the alleviation of road accidents and vehicular pollution.

3.1.5 Focus Group Discussions

A total of 218 young automobile technicians, both men and women, aged 18 to 35, working in makeshift settings within Rubaga Division were engaged in four focus group discussions held in various parishes. These discussions aimed to explore their understanding of inbuilt vehicle safety features and emission control systems, as well as their awareness of air quality issues and transport-induced air pollution in Kampala. The sessions also focused on how certain maintenance practices could unintentionally contribute to road accidents and air pollution. The discussions also sought to identify the specific challenges these mechanics face in their daily work, particularly regarding access to proper tools, knowledge, and regulatory compliance.

Interview questionnaires were used to capture participants' demographic data as well as their responses to different questions pertaining to vehicular emission control and safety. The responses differed, showing a varied perception of these issues, and correlated with the average formal education level attained before joining mechanic apprenticeships in motor repair garages. Only about 8% had attended technical vocational training, 25% reached secondary school while 67% of them could not exceed primary or elementary school.

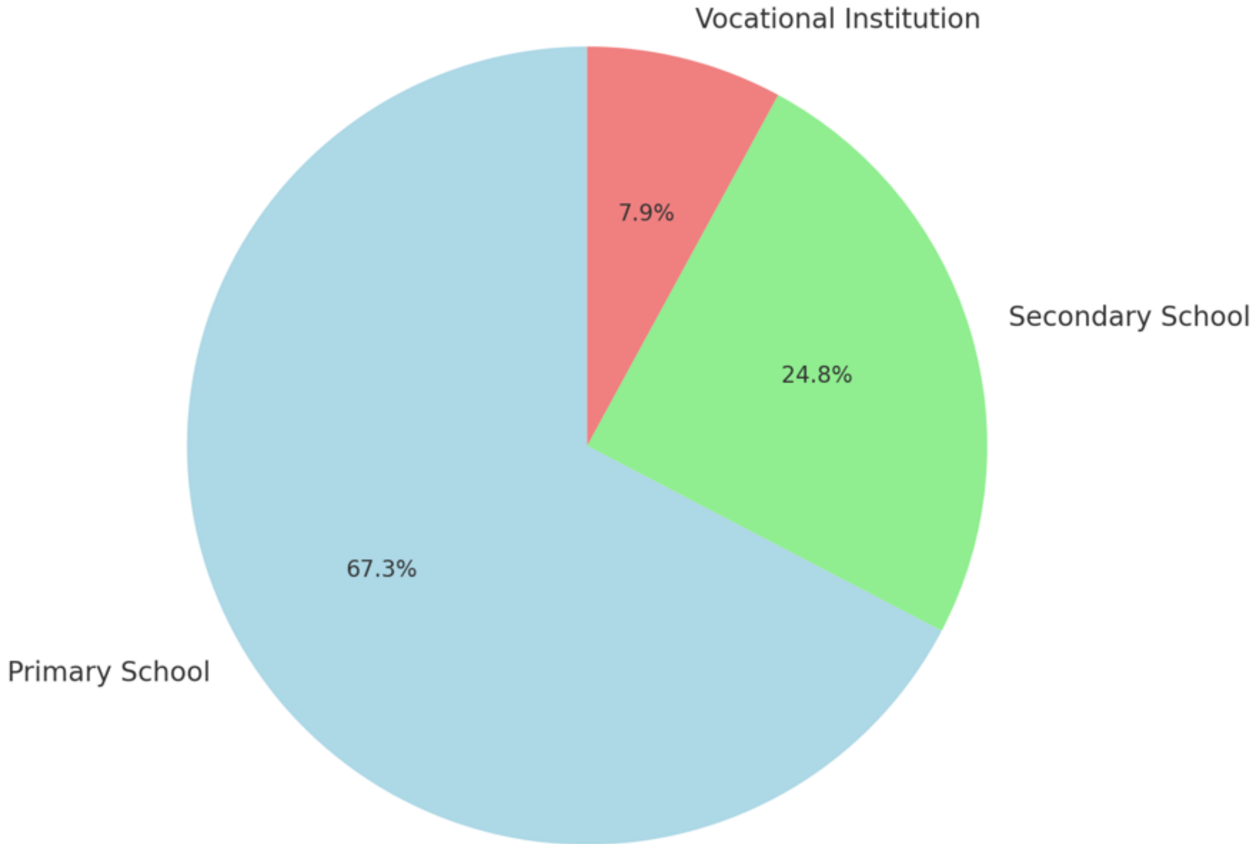

Figure 3: Participant Education Levels

When asked who is mostly responsible for excessive road transport-induced pollution and crashes, for example, **46.9%** reported that car owners are responsible. The reason given was that customers wait for long intervals between services for their vehicles and that they always want the cheapest possible service. Some visit garages and ask for used oil from other vehicles (a common case with motorcycle taxi riders) and it's sold to them because the mechanics also need the money

31.3% responded that mechanics are responsible because many of them modify systems such as ABS and steal catalytic converters (locally known as "obusaanyi") meant for exhaust treatment. They also reported that some mechanics don't communicate to owners if other defects are found on their vehicles beyond assigned tasks. They said the government contributes **21.9%** to road crashes and pollution because of high taxation on genuine servicing and consumables, making maintenance too expensive.

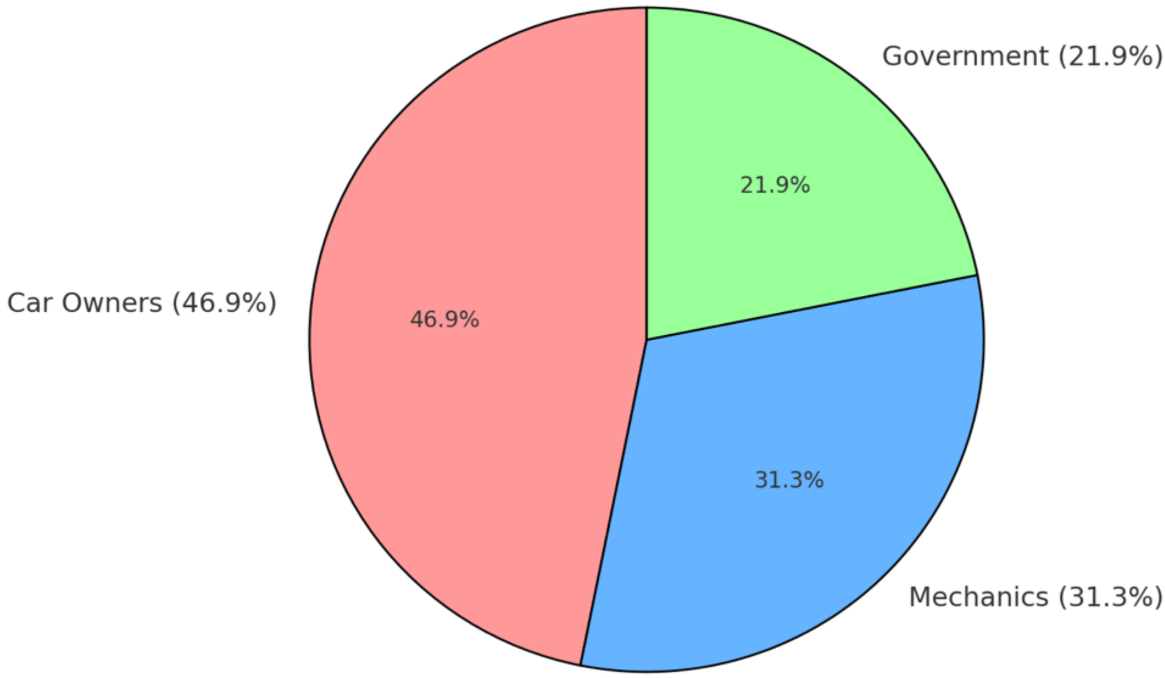

Figure 4: Participant interview responses

When mechanics were asked about their knowledge of emission control and safety enhancement technologies in vehicles, **45.8%** of the mechanics were unaware of any technologies to reduce vehicular pollution and couldn't mention safety systems beyond basic brakes and seatbelts. **25%** suggested electric cars as a solution because they don't emit fumes. **16.7%** recommended proper vehicle servicing to reduce emissions. **8.3%** mentioned electric vehicle technology and **4.2%** proposed hybrid cars as a solution.

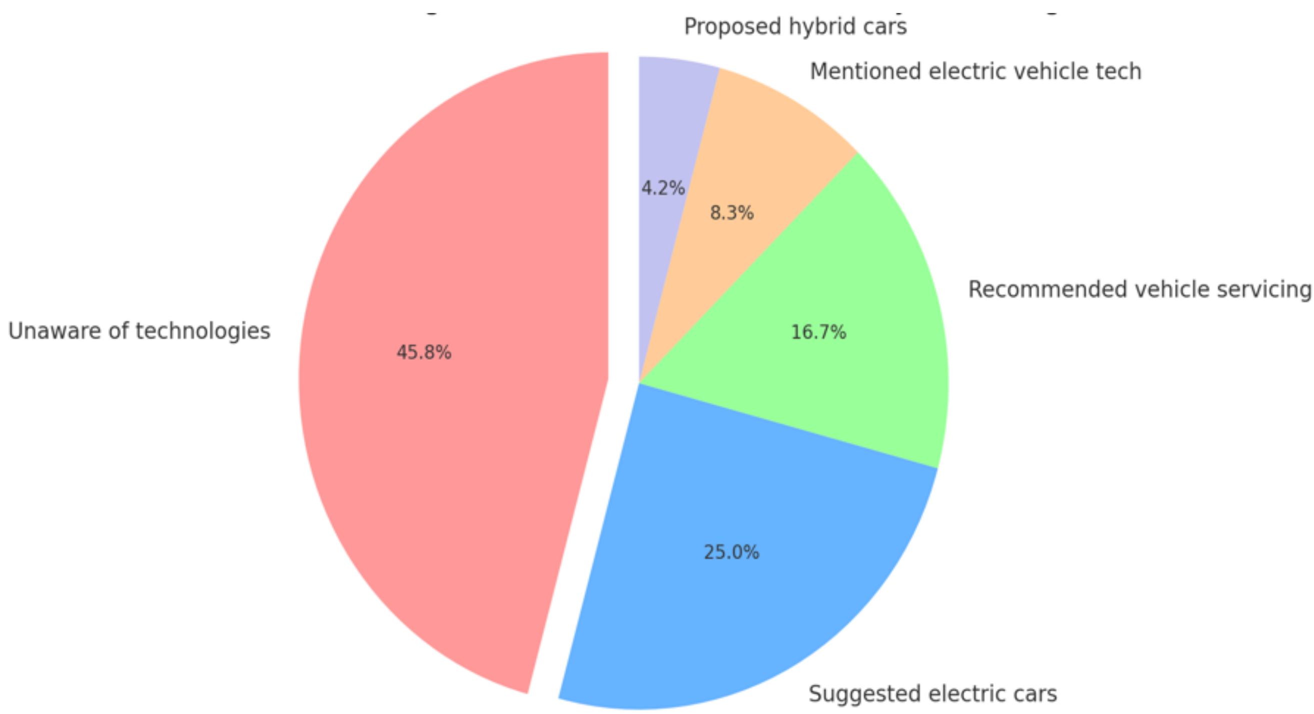

Figure 5: Participant Interview Responses

Focus group discussion participants further highlighted several barriers to practicing sustainable vehicular maintenance. **42.3%** pointed to a **lack of tools** as the main issue; **30.8%** cited a lack of knowledge and skills for handling new vehicle technologies, emphasizing the need for training and specific tools; **15.4%** blamed **customers**, noting that some bring fake parts or request used oil to save costs; **3.8%** held the **government** responsible due to high taxes on oil and genuine spares, leading to the use of lower-quality alternatives; and **7.7%** attributed the issue to **unethical mechanics** who don't perform proper work.

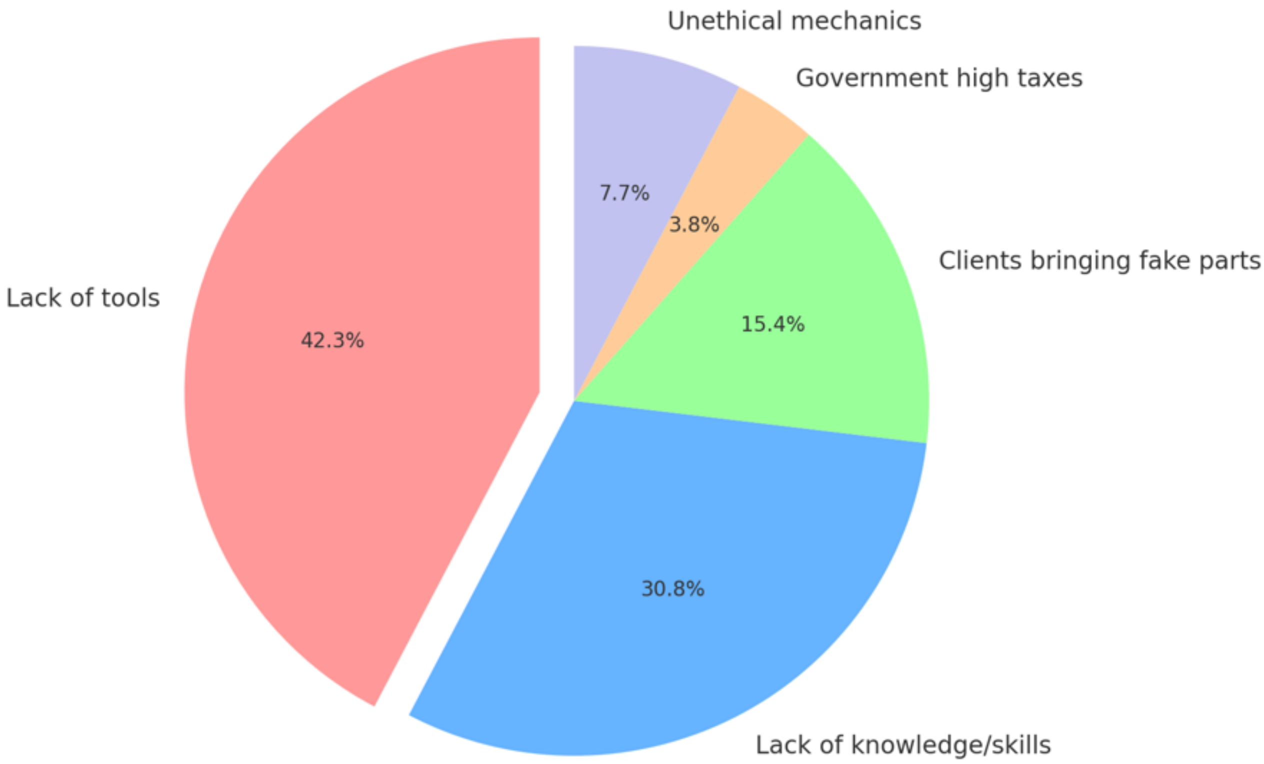

Figure 6: Participant interview responses

From the findings of all focus group discussions, four training workshops were designed and conducted to equip local auto-technicians with the skills and essential tools they needed to institute best practices around vehicular maintenance to promote road safety and improve air quality within Kampala and beyond.

The feedback indicates that improving road safety and reducing vehicular pollution requires a joint effort from car owners, mechanics, and the government. Key issues include poor vehicle maintenance practices by owners, unethical practices by some mechanics, a lack of awareness about modern pollution-reducing technologies, and government policies that make quality maintenance unaffordable. Addressing these issues will involve better training and equipping of mechanics, policy reforms to lower taxes on genuine parts, and encouraging responsible vehicle maintenance practices.

Figure 7: Images from focus group discussions

3.1.6 Training workshop design and toolkits

A thorough needs assessment, conducted through four focus group discussions, identified key areas where local mechanics required upskilling in handling automobile safety and emission control systems during maintenance and repairs. Based on these findings, a tailored training manual and toolkit were developed. The manual included a list of essential automobile components and tools to facilitate hands-on, interactive practical sessions, aiming to equip local technicians with the knowledge and skills necessary for best practices in automobile maintenance.

3.1.7 Community-based training workshops

The WHO has reported that road traffic fatalities disproportionately affect low- and middle-income countries, where 90% of global road deaths occur.

Participation

503 mechanics took part in the training program from 12 communities/parishes in the Rubaga Division of Kampala City. The proposed target was four hundred (400) participants – showing an increase of more than 25% in the turnout - which also brought some budgeting challenges.

The participants were mainly light vehicle and motorcycle mechanics, spare parts dealers, and fabricators who modify or build vehicle parts and add-ons locally. Out of 503 participants, 37 were female, with 466 male. Among the females, only five were technicians, and the rest dealt with selling spare parts.

3.1.8 Participant feedback and conclusion

After the training workshops, participants were followed up at their different garage locations to acquire feedback and lessons learnt from their participation in the training workshop. This was done in the form of video interviews with participants.

The main reason for collecting feedback in video/interview format was that participants preferred to express themselves verbally in their local language—a method that easily accommodates all participants, including those who had challenges reading and writing.

The training workshop was very enriching to the participants. Still, there's a need for the provision of post-workshop support, resources, or additional training opportunities to reinforce learning and ensure the application of newly acquired knowledge and skills.

Figure 8: Images from training workshops with mechanics

3.2 Focus Group Discussions

One of the critical project deliverables concerned exhaust pipe emissions, with datasets demonstrating how used vehicles in Africa operate under certain conditions, and how certain road infrastructure makes them emit pollutant gases exceeding the manufacturer's specified limits.

Before and after servicing, exhaust emission analyses were carried out on 50 vehicles commonly found in Kampala, including three-axle goods vehicles, light passenger vehicles and motorcycles. These vehicles operate primarily around Kampala but receive maintenance and repair services from garages around Rubaga Division. Physical inspections of inbuilt emission controls were carried out and vehicles with electronic systems based on 12-Volt DC power were checked for emissions-related failures logged in the engine control units.

All 50 vehicles had GPS trackers installed to enable the collection of further information for the final analysis and to differentiate between the emission levels of two vehicles of the exact technical specifications but operating under separate road conditions (paved or unpaved.

Data was collected and analysed in two phases from 50 gasoline and diesel-engine vehicles, including three-axle goods vehicles, light to medium passenger service vehicles and light trucks, as well as two- and three-wheeled vehicles (motorcycles) locally known as boda-boda and tut-tuk, respectively.

Data from two- and three-wheelers revealed that, even though all vehicles had very small engines ranging from 80 - 150 cubic centimetres (cc), they had relatively high emission levels due to the absence of emission controls. Others had 2-stroke engines that burn fuel and oil simultaneously. Interactions with technicians who repair this type of vehicle further revealed why they emit at dangerously high. The WHO has reported that road traffic fatalities disproportionately affect low- and middle-income countries, where 90% of global road deaths occur. Many myths exist in the sector. For instance, some believe that due to the lightweight nature of motorcycles, it's okay them to carry out oil changes using oil that was previously used in vehicles.

The second phase was conducted several weeks afterwards to determine the changes in emission levels given various factors including road conditions and workloads the vehicles were subjected to, mechanical conditions, increased mileage and age.

Results from the data analysis indicated a significant increase in exhaust emissions from vehicles driven on unpaved roads, those that received poor-quality maintenance servicing, and those that had their emission control systems modified or removed.

3.2.1 Determing what information to collect

Based on the concept and design of the project work-stream, vehicular emissions data was collected to establish a case of the level of emissions from the average vehicle in Uganda, depending on several parameters that are not fully accounted for in the current vehicle importation and operational regulations in Uganda, as described in the table below.

Table 1: Emissions data collection parameters

PARAMETER	DESCRIPTION
Vehicle Make & Model	Vehicle Make & Model
Year of Manufacture	Year of manufacture or first registration in exporting country
Local Operation Span	Amount of time of operation in Uganda
Engine Size	Engine displacement in cubic centimetres (CC)
Type of Fuel Intake	Type of fuel used
Current Mileage	Current odometer reading
Common Route	Road(s) in Uganda that the vehicle frequents
Road Quality	How bad or good the common route is (paved, unpaved, potholed)
Workload	Type of load the vehicle frequently carries
Pre and Post Exhaust Analysis	Collection of exhaust gas compositions before and after maintenance service
DTC Analysis	Extra analysis of errors or faults logged by the vehicle ECU through OBD2
Emission Control Measures	Analysis from a physical inspection of the inbuilt emission controls

3.2.2 How was data collected and reported

Exhaust emissions data was collected using a combination of the following:

- manual/physical inspections,
- electronic onboard testing using a portable exhaust five-gas analyser or portable emissions measurement systems (PEMS) for unburned hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), oxygen (O2) and carbon dioxide CO2),
- vehicle on-board diagnostics version two (OBD-II), to access data from the engine control units (ECU).

Most test results or observations were recorded manually to collect specific information and input it into a computer MS Excel database, as shown in the figure below. Additional tests on select front wheel drive vehicles were performed with the help of a chassis dynamometer combined with a five-gas exhaust analyser to emulate driving conditions. This equipment was a donation from USA.

No.	Vehicle Make	Vehicle mo	Year of manufacture	type of fuel intake	engine size	Current Mileage (KM	Common Route	Road Quality	Local Operation Span (yrs)	Workload	CO (%)	CO2 (%)	HC (ppm)	Nox (ppm)	DTC Analysis	Emission Control Measures/Comments
1	Mitsubishi	Mitsubishi Fuso Fighter	1981	Diesel	7.0L	6,346,455	Masaka Road	Moderate quality	10	Heavy goods	1.26	7.4	179	533	N/A	EGR valve was fixed/replaced, exhaust smoke reduced
2	Mitsubishi	Mitsubishi Fuso Fighter	1985	Diesel	7.0L	723,632	Wakiso - Hoima road	Moderate quality	13	Heavy goods	0.91	6.83	239	660	N/A	No functional emission controls noted
3	Toyota	Toyota Coaster	2009	Diesel	4.0L	325,813	Buziga – Muyenga - Mamuwongo	Poor quality	2	School Van	0.83	6.71	174	216	N/A	DPF/SCR Functional (functionality declining)
4	Toyota	Toyota Hiace Van	1990	Diesel	2.8L	Faulty mileage Counter	Kabuusu-Kitebi	Moderate quality	20	Passenger service	2.76	5.88	225	903	N/A	No functional emission controls noted (misfiring)
5	Toyota	Toyota Hiace van	1997	Petrol	2.0L	540,821	Busabala Road	Very poor quality	12	Passenger service	3.05	2.66	1,301	737	Failed Communication with ECU, Misfires	The catalytic converter removed
6	Toyota	Toyota Hiace Van	1998	Petrol	2.0L	505,020	Nakawuka road	Poor quality	14	Passenger service	2.86	5.7	1047	391	Faulty O2 sensor, EGR malfunction	Catalytic Converter removed
7	Toyota	Toyota Hiace Van	1998	Petrol	2.0L	Faulty Mileage Counter	Lungujja	Moderate quality	11	Passenger service	1.33	6	613	490	Bad O2 sensor, EGR disabled,	Catalytic converter removed
8	Toyota	Toyota Hiace Van	2000	Petrol	2.4L	481,200	Kampala - Masaka	Moderate quality	9	Passenger service	1.42	6.8	771	35	ECU communication failed	Catalytic Converter Removed
9	Toyota	Toyota Hiace Van	2003	Diesel	3.0L	404,901	Masaka road	Moderate quality	7	Passenger service	0.94	7.49	239	741	EGR Valve error	Fuel pump replaced
10	Nissan	Nissan Caravan Van	1999	Petrol	2.0L	Faulty Mileage Counter	Ssentema Road	Poor quality	15	School Van	2.55	3.9	1298	42	Bad Ignition Coils	Catalytic Converter Removed
11	Suzuki	Suzuki Grand Vitara	2004	Petrol	2.5L	250,037	around Kampala	Moderate quality	5	Personal Commuter	0.63	11.24	301	36	No DTC Errors	All emission Controls seem Ok
12	VW	VW Golf MK4	1999	Petrol	2.0L	279,133	Countrywide	Moderate quality	13	Personal Commuter	1.43	6.95	294	26	No DTC Errors	Catalytic Converter Removed
13	Toyota	Toyota Ipsum	2000	Petrol	2.0L	227,003	Around Kampala	Poor quality	16	Personal Commuter	2.49	4.99	921	83	ECU communication Failed	Catalytic Converter Removed,
14	Subaru	Subaru Forester	2001	Petrol	2.0L	263,329	, Countrywide	Moderate quality	12	Personal Commuter	1.44	5.3	328	51	NO DTC Errors	Catalytic Converter removed
15	Toyota	Toyota Landcruiser VX	1999	Petrol	4.6L	275,710	Kampala - Mbarara	Moderate quality		Personal Commuter	0.62	11.9	287	44	No DTC Errors	Primary emission controls OK
16	Toyota	Toyota Hiace Van	2003	Diesel	3.0L	349,628	Rubaga-Nateete-Mengo	Moderate quality	7	School Van	0.79	8.22	130	421	Faulty o2 sensor	Catalytic Converter Removed,
17	Honda	Honda CR-V	1997	Petrol	2.0L	269,804	(Special Hire) Kampala	Poor quality	14	Passenger service					Broken down not running	Broken down not running
18	Toyota	Toyota Hiace Commuter	2007	Diesel	3.0L	215,451	Kampala - Masindi	Moderate quality	2	Passenger service	1.09	6.65	133	610	ECU Communication Failed	DPF not functional
19	Isuzu	Isuzu Elf Truck	1986	Diesel	3.6L	814,060	Entebbe Road	Moderate quality	17	Construction Material Delivery	2.88	2.61	220	1587	N/A	No functional emission controls noted, smokes exccessively
20	Toyota	Toyota Mark X	2010	Petrol	2.5L	165,803	Kampala	Poor quality	1	Personal Commuter	0.56	7.99	328	66	No DTC Errors	All Primary emission Controls Ok
21	Toyota	Toyota Vista	2000	Petrol	2.0L	531,280	Ssentema Road	Poor quality	15	Personal Commuter	2.86	4.2	1187	265	Multiple DTC errors, faulty O2 sensor	Catalytic Converter Removed
22	Toyota	Toyota Hiace Van	2008	Diesel	3.0L	256,073	Kampala - Iganga	Moderate quality	3	Passenger Serv	1.22	8.9	55	311	No DTC Errors	All Primary emission Controls Ok

Final Data | Initial Data | Tables | Settings

Figure 9: A snapshot from the emissions database

The initial before-service tests were done and recorded at engine idle speeds of 700 – 1,000 revolutions per minute (RPM), and the after-service tests were at approximately 2,000 RPM. The average testing time with the portable exhaust gas analyser was five minutes or 300 seconds. A baseline was established against the initial idle speed test. Still, we couldn't fully relate to the manufacturer-specified vehicle emission datasets because most had issues with inbuilt emission controls to facilitate comparison with standards set in the year the vehicle was built.

For example, the figure below illustrates the percentage of carbon monoxide concentration in the exhaust of a 2000 Toyota Vitz before and after a maintenance service. With the help of OBD2 diagnostics, it was determined that the oxygen sensor was faulty, giving an out-of-range signal when the sensor was replaced (with a used one) during service. It's worth noting that without proper equipment, the repair of the above vehicle wouldn't be effective, and a simple oil change would not make much difference without replacing the defective oxygen sensor. However, the reason CO levels were still above 0.5% even after the maintenance service was not fully established. It was probably due to unbalanced air-fuel ratios in the intake.

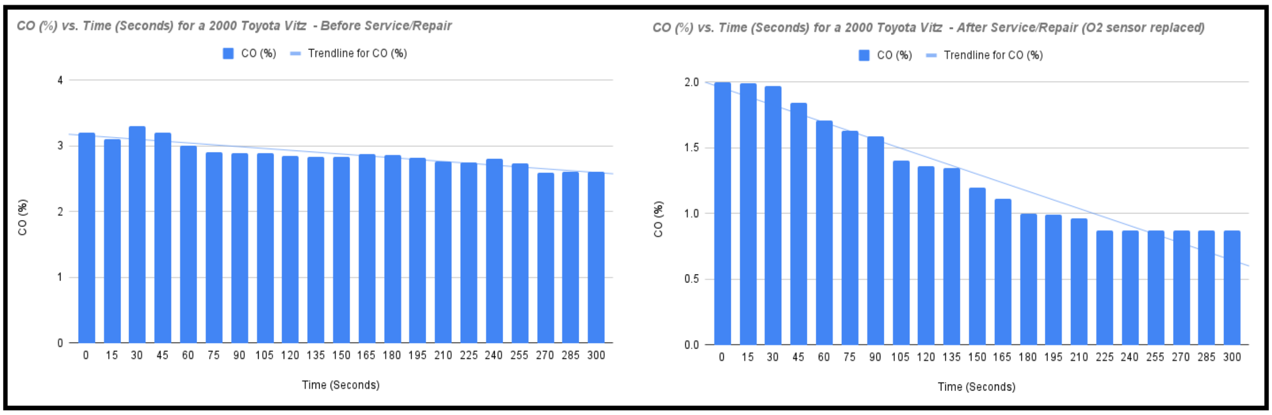

Figure 10: Illustrating an effective repair

Figure 11: Images from the emissions data collection

3.2.3 Corrective action and follow-up

For each vehicle tested for emissions and currently being monitored, a corrective action/measure in the form of technical advice to the technicians tending to it was taken to fix the underlying faults, and follow-ups will be made during the final round of tests towards the end of the project.

3.2.4 The data collection team

Emissions data was collected by a team of technical persons from **Wanyama Autosafety Initiatives** in partnership with a team from **Makerere University's Air Quality Project** and mechanics at partner garages where tests were being carried out.

3.2.5 Who will use the information

All parties involved in the project will use some data, including mechanics trained to adopt sustainable vehicle maintenance practices. Collected information will be available for continued data analysis and reporting, making it easily accessible to all relevant transportation stakeholders.

The project intends to lobby stakeholders, including relevant government agencies and automobile import and dealership companies, to voice the need to regulate vehicular emissions and adopt standards in line with local or regional settings.

3.3 Electric mobility uptake: through retrofitting old convectional vehicles

This involved a pilot on converting conventional vehicles from running on internal combustion engines (ICE) to battery electric motors for light-duty vehicles.

For this pilot, a 1980 VW kombi/transporter was used. It was retrofitted with a 31KWh custom lithium-ion phosphate (LiFeP04) battery pack and a Nissan EM61 motor from a Nissan leaf, coupled to the original manual transmission.

The vehicle was not running and had been kept for several years pending acquisition of a replacement compatible ICE. Figure 13, 14 and 15 show the original appearance of this vehicle before and during the conversion process. Figure 16 shows the retrofitted vehicle being tested on dirty, smaller secondary roads that connect settlements to primary roads or highways because it's pending a re-registration by the transport licensing board. However, acquisition of a garage license will facilitate further testing of the vehicle on major public roads. As far as the scope of this project is concerned, a proof of concept has been made but more work is needed before it can be deemed road worthy given the fact that it was decommissioned over a decade ago.

The idea of retrofitting vehicles could create the basis for a circular economy around transport in the informal sector where new vehicles are unaffordable for the average Ugandan. High polluters like taxis running short distances could continue serving for an extra five or six years, allowing owners to save on service and fuel expenses for other vital priorities while keeping a clean environment.

Related projects have reportedly been initiated in Uganda involving motorcycles that depend on rechargeable batteries doing errands around metropolitan Kampala.

The occurrence of **lithium,** which is a highly reactive precious mineral in some parts of Uganda, provides an opportunity for appropriate and feasible investment in renewable energy projects including automobile charging stations. This would limit the impact of fossil fuel usage and improve air quality in Rubaga division and in metropolitan Kampala as well as the entire country. However, investment in lithium technology in Uganda is hindered by inadequate infrastructure, regulatory uncertainty, limited exploration data, and unreliable energy supply. Additional challenges include environmental concerns, competition from established producers, and a lack of skilled labour. Overcoming these barriers is crucial to attract investment in the sector.

3.3.1 Draft designs, fabrications and assemblies

In this retrofit designs, fabrications and assemblies played crucial roles in ensuring a successful conversion from a conventional internal combustion engine vehicle to an electric vehicle.

- **The Design**: This involved planning the integration of the electric motor, battery pack and related components into the vehicle's existing structure. The team designed custom mounts and brackets to fit the new components within the vehicle's engine bay and undercarriage. Additionally, design modifications were made to the vehicle's cooling, electrical and control systems to accommodate the new powertrain.
- **Fabrication:** This involved creating and modifying parts to fit the design specifications including custom motor mounts, battery containments, adapter plates and the coupler to connect the electric motor to the existing drivetrain. Fabrication also extended to modifying or reinforcing the vehicle's frame to support the additional weight of the electric components and ensuring proper weight distribution for optimal handling.
- **Assemblies:** During the assembly phase, all the fabricated components were installed into the vehicle. This involved mounting the electric motor, securing the battery pack, and connecting the power electronics, such as the inverter and charger. The process also included integrating the new wiring and control systems, ensuring they are properly connected and tested. Once all components were assembled, the vehicle underwent some extensive testing to ensure that all systems functioned correctly.

Figure 12: the kombi before and during conversion

Figure 13: Modifications to adapt the electric motor to the gearbox

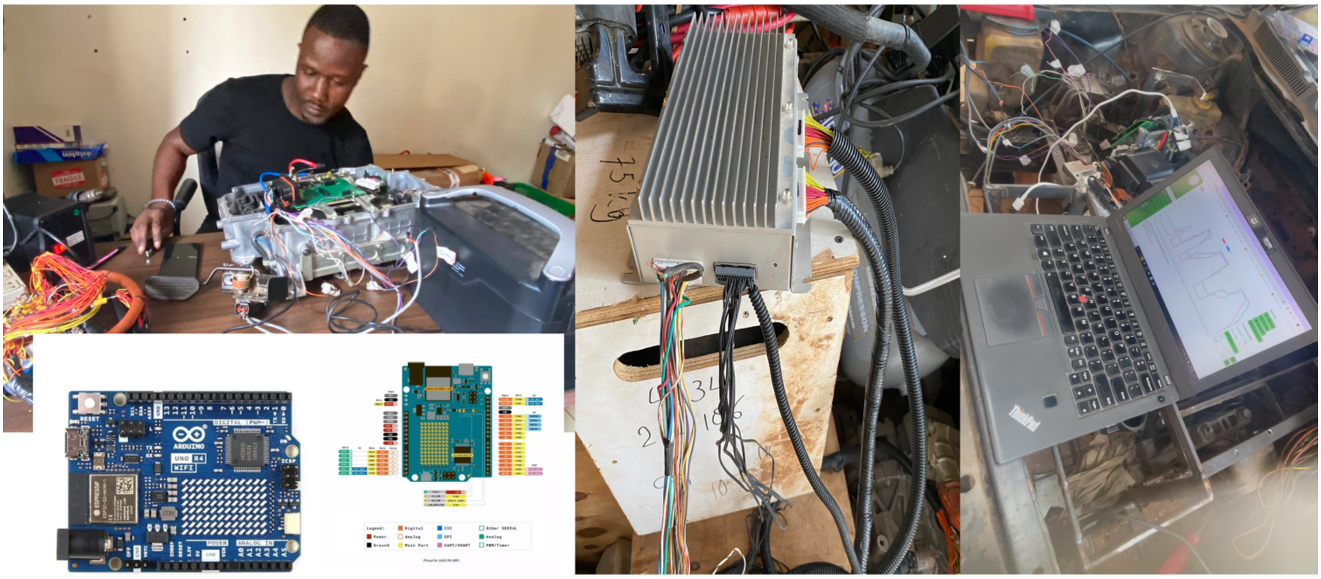

Figure 14: The wiring and firmware/software configurations

3.3.2 Testing, modifications and showcasing

In this EV retrofit project, there were stages of testing and modifications, starting from the bench before assembling to ensure the final vehicle demonstrates its new capabilities effectively.

After assembly, testing is crucial to verify that the retrofit meets safety, performance and efficiency standards. Initial tests covered acceleration, braking, range and battery charging/discharging cycles; and checking for any electrical faults or integration issues, ensuring that all systems work harmoniously.

Road tests were conducted on nearby private roads to simulate real-world driving conditions but this was only for proof of concept, more work needs to be done before the vehicle's reliability and performance can be confirmed. A provisional range of 110KM per charge was achieved and it takes about six hours to charge the 31KW battery of the retrofitted “e-Kombi”. There are some inefficiencies to iron out which would improve the range.

Based on the results from testing, future modifications will be required to refine the vehicle’s performance. These might involve tuning the motor controller settings, adjusting suspension components to accommodate the changed weight distribution, and fine-tuning control systems to optimize efficiency and driving experience.

Showcasing the retrofitted EV is scheduled for early 2025 during an e-mobility expo in Kampala. By then, we thorough tests and modifications will have been completed. Future modifications and testing will ensure that the retrofitted vehicle not only performs well but also stands out as a successful example of sustainable automotive technology and meets local standards.

Figure 15: Testing the e-kombi

3.3.3 Specifications

The 1980 VW kombi/transporter, now dubbed the "100% electric Kombi", has a 31KWh custom lithium-ion phosphate (LiFeP04) battery pack powering an 80KW Nissan EM61 motor with a matching inverter, DC-DC converter, a 6.6KW onboard charger motor from a Nissan leaf, coupled to the VW's original manual transmission. Other retrofits included an electric steering system from a 2009 Toyota Corolla, a custom on/off switch incorporating forward and reverse as well as neutral or stationary positions for the drivetrain.

There's also an electric water pump for the cooling system and an Orion brand battery management system (BMS) plus a custom braking system enhanced by an electric vacuum pump to compensate for the absence of the original ICE. Electrical accessories like headlamp bulbs were all upgraded to LED for reduced energy consumption.

So far, no significant issues have been noted relating to retrofitting the vehicle from ICE to electric power, but some mechanical stability issues, such as shifted weight distribution, chassis and suspension strain, and space constraints for new components could be realised during further testing.

3.4 Policy engagement

Wanyama Autosafety Initiatives' deep understanding of the informal transport sector and related businesses and its partnership with Makerere University means it can be instrumental in supporting the government towards extensive policy reform. The initiative has previously participated in formulating draft regulations for automotive repair businesses. The safety and emissions data collected from Rubaga throughout the project was used in the formulation of a policy brief, accompanying this report. The policy brief highlights critical issues and recommendations concerning road safety and vehicular emissions that relate to the automobile maintenance industry in Uganda as follows:

- Africa is undergoing rapid urbanization, leading to an increase in the number of vehicles on the roads. In Uganda, this growth has resulted in alarming rates of road crashes and significant vehicular emissions, posing severe threats to public health and environmental sustainability. The main issue lies in the automobile maintenance sector, where the predominance of informal garages staffed by poorly trained mechanics has created a breeding ground for substandard repairs and compromised vehicle safety. Data reveals that most vehicles over five years old lack functional emission controls, contributing to a sharp rise in exhaust emissions that adversely affect air quality. In Kampala, the theft of catalytic converters exacerbates the situation, underscoring the urgent need for comprehensive reforms to improve vehicle safety and emissions management.

- Addressing these challenges requires a multifaceted approach that not only improves maintenance practices but also strengthens regulatory frameworks. The Ugandan government must prioritize the formalisation of makeshift garages by establishing certification and licensing systems for informal mechanics. This will raise industry standards and facilitate the provision of essential training programs focused on modern vehicle technologies. By equipping mechanics with the necessary skills, we can ensure that vehicle repairs meet safety and emissions standards, ultimately reducing the risks associated with poorly maintained vehicles. Furthermore, re-establishing and enforcing a mandatory vehicle inspection program is crucial for ensuring compliance with safety regulations and preventing high-emission vehicles from remaining on the roads.
- The proliferation of counterfeit and substandard spare parts on the local market remains a significant barrier to sustainable vehicle maintenance in Uganda. The government must take decisive action to regulate the sale of these parts, promoting genuine alternatives that are essential for vehicle performance and emissions control. By offering incentives, such as fair taxation on quality spare parts, the government can encourage consumers and mechanics alike to prioritize safety and sustainability over cost-cutting measures. Alongside these regulatory efforts, extensive public awareness campaigns are essential to educate vehicle owners about the importance of proper maintenance. Collaborating with local governments, NGOs and transport associations can amplify these messages, ensuring that motorists understand the critical link between vehicle upkeep, road safety and emissions control.
- Finally, fostering a sustainable transport system in Uganda necessitates the adoption of cleaner vehicle technologies. Key stakeholders should encourage the transition to electric vehicles (EVs) and hybrids by implementing tax incentives, import duty reductions and subsidies. Promoting research on retrofitting existing vehicles with cleaner technologies can also provide viable alternatives for reducing emissions from older models. By embracing these innovations and creating a supportive environment for cleaner mobility, Uganda could achieve enhanced road safety, improved air quality, and realise sustainable urban transport goals. The time for action is now, as the nation stands at a crossroads, poised to transform its transport sector for the benefit of both its citizens and the environment.

Overall, this project has the potential to contribute to policy in Uganda including:

- stricter vehicle emission standards
- used vehicle importation regulations
- urban vehicle management policies
- the periodical vehicle inspection programme
- stricter fuel standards
- electric mobility policy
- public health policy
- vehicle end of life policy
- waste management policy
- tax policy
- vehicle management and repair policy and
- infrastructure design (roads, fuel stations charging infrastructure).

4. Key project outcomes

The project had several outcomes, some of which will take time to fully unfold. The outcomes were tied to the specific workstreams of the project.

4.1 Outcomes from mechanics training

- Building The mechanics engaged by the project gained improved skills in handling vehicle safety and emission control systems, leading to more effective maintenance practices.The improvement in their skills and maintenance practices was measured using pre- and post-training assessments, through focus group discussions before the trainings and participant feedback after the training. Furthermore, the effectiveness of training the mechanics could be determined when more vehicles pass emission tests during mandatory periodic inspections by government, unfortunately this program isn't being enforced yet but there are indicators of near-future implementation.
- With new knowledge and some basic tools, several of the trained mechanics are better equipped to reduce vehicle emissions and contribute to cleaner air in Kampala. Their move towards adopting sustainable maintenance practices and advocating for better vehicle care among their customers could potentially reduce road accidents and environmental impacts.
- The training fostered collaboration among local mechanics, community leaders and transport associations, creating a network of change agents focused on road safety and pollution control. A good example is the newly formed National Auto Garage Owners Association (NAGOA).
- Data and feedback from the training workshops may support advocacy for policy reforms towards improving vehicle maintenance standards.

4.2 Outcomes from emissions data collection

- There is evidence of increased vehicular emissions based on several factors including poor-quality maintenance, emission control systems removed or modified, or frequent driving on unpaved roads.
- Identification of high polluters. Two- and three-wheeled vehicles, particularly those with small or two-stroke engines, showed notably higher emission levels due to the absence of effective emission controls.
- There are now real insights into local vehicle maintenance practices. Data revealed that inadequate maintenance practices, such as using substandard parts or failing to address emission system faults, contribute significantly to increased pollution. The findings highlight the urgent need for better regulatory standards in Uganda's automobile industry.
- The collected data establishes a baseline for future assessments and monitoring of vehicle emissions, aiding in the development of targeted interventions and policy adjustments. For instance, WAI aims to build on the vehicular emissions database covering up to 3,000 units.

4.3 Outcomes from electric vehicle retrofitting

- The project extended the operational life of the converted vehicle, reducing the need for new vehicle purchase and promoting a cleaner environment while saving on fuel and maintenance costs. This vehicle had been already decommissioned before retrofitting (Fig. 13), and still pends re-commissioning to acquire a registration plate. This will be accomplished in the coming months as more testing and fine-tuning is carried out.
- As a pilot, it was a great learning experience that might foster more conversions for public transport and taxis. The cost of buying a vehicle could be used for other essential needs, enhancing economic benefits for the owners. This could also potentially support the development of a circular economy within the informal transport sector, where affordability constraints make new vehicles inaccessible for many Ugandans.

- The pilot demonstrated the feasibility of electric retrofitting in Uganda and raised awareness about the benefits of electric vehicles, paving the way for broader adoption and investment in clean transportation technologies.

4.4 Other outcomes

- There is increased community involvement in road safety and environmental protection efforts, leading to stronger local support for sustainable practices and policies.
- Data and insights from the project provide a foundation for advocating policy changes to regulate vehicle emissions, reduce taxes on genuine parts, and promote sustainable maintenance practices.
- Improved public awareness of the impacts of vehicle emissions on health and the environment will potentially lead to more responsible vehicle ownership and maintenance practices.
- There is more potential for investment opportunities to support infrastructure, such as renewable energy projects and charging stations for electric vehicles, to further reduce pollution and support sustainable transportation.
- Future Research and Innovation. The project has set a precedent for future research into vehicular emissions and electric mobility, driving further innovation and development in sustainable transportation solutions.
- The project fostered the formation of the first association for individuals and companies in the automobile maintenance industry within Uganda (NAGOA), which has so far attracted over 300 members countrywide.
- The project also inspired the consideration of Kampala for Africa’s first project on vehicular emissions data collection using the plume chasing method, implemented by Uganda’s Ministry Energy with support from UNEP, ICCT and FIA Foundation.

5. Ideas and lessons learned on project implementation

- Community-centric approach. Engaging local communities, especially mechanics and automobile workers, from the outset fosters ownership and ensures that interventions are relevant and impactful. Mobilizing and educating these stakeholders proved crucial for the success of the project.
- Needs assessments like focus group discussions are essential for designing effective training workshops. Customizing content based on local challenges and existing knowledge gaps enhances learning outcomes and practical application.
- Collecting and analyzing emissions data provided valuable insights into the sources and impacts of vehicle pollution. This data supports targeted interventions and informs policy recommendations.
- Building partnerships with local authorities, academic institutions and community leaders enhances project effectiveness and sustainability. Collaboration facilitates knowledge sharing and resource mobilization.
- Pilot initiatives, such as electric vehicle retrofitting, offer practical solutions to environmental challenges and demonstrate the potential for sustainable transportation in the informal sector.

These ideas and lessons learned emphasize the importance of community involvement, data-driven decision-making, and collaborative approaches in achieving project goals and driving sustainable change.

6. Recommendation for future project implementation

- There is a need to establish a continuous training programme for mechanics with regular updates on new technologies and practices. It should provide post-training support and resources to reinforce learning and ensure the application of new skills, and this requires government support.
- Extending the project to other districts and regions with high automobile activity could broaden the impact and address similar issues in different settings.
- Increasing and continuing with the involvement of community leaders, local organizations, and stakeholders in project planning and implementation will ensure broader support and more effective outreach.
- Increased collaboration with potential industry partners like automobile manufacturers and environmental organizations can facilitate access to quality tools, training materials and resources.
- There is a need to explore the integration of emerging technologies, such as electric vehicles and advanced emission control systems, into training programmes to keep mechanics up-to-date with industry trends.
- Project implementers need to seek additional funding and resources to support the expansion of the project, including the provision of essential tools and equipment for mechanics

Wanyama Autosafety Initiatives,
Plot 16 Mobutu Road
Kampala - Uganda
Tel: +256 782 082 467
Email: safety@autosafety-ug.org
Web: https://www.autosafety-ug.org

HIGH VOLUME TRANSPORT
APPLIED RESEARCH

UK International Development
Partnership | Progress | Prosperity