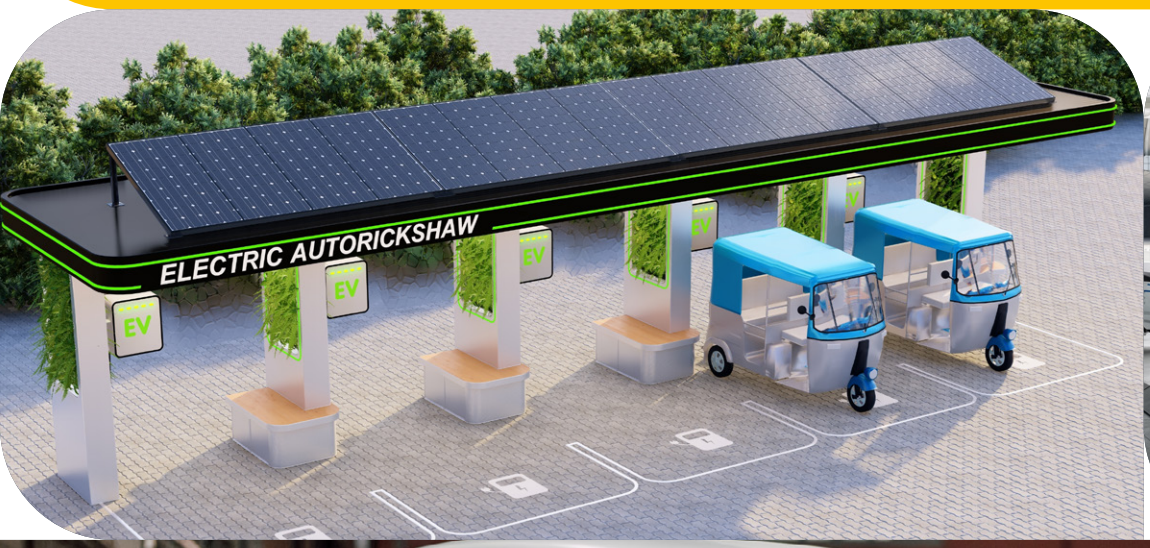
ELECTRIC MOBILITY TRANSITION & LOCALISATION

Towards Unlocking the NEV Value Chain for Africa

SITUATIONAL AND BASELINE ANALYSIS REPORT SERIES REPORT 1: MICRO-MOBILITY







AIH GROUP

IDC
Industrial Development Corporation

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1. Introduction

New Energy Vehicles (NEV) are seen as an important step towards achieving global climate change objectives. This study has undertaken a comprehensive review of the relevant literature as it relates to the current NEV industry globally, for South Africa, and the Rest of Africa (RoA), whilst identifying key role players and stakeholders, and highlighting current and emerging gaps, and opportunities, in the NEV market.

In order to evaluate the NEV segments, markets and policy along the value chain, the literature review has been structured to provide a comprehensive overview of the most important NEV sectors in a logical framework:

1. NEV Landscape Overview:

NEVs are vehicles that are powered by electricity or fuels made from non-fossil fuel sources. In May 2021, the dtic released the green paper on NEVs[1] for public comment and the intention was clear that the South African Automotive Value Chain was ready to transition from Internal Combustion Engines (ICE) to NEV. The Just Energy Transition Implementation Plan (JET IP) provides a means to achieve the transition through investments spearheaded by various government authorities, private institutions, and development finance institutions (DFIs).

2. Micro-mobility:

The context and rationale for micro-mobility, market developments, and particularly the rise in electrified two- and three-wheelers, four-wheeler 'last mile' delivery vehicles, conversions and eco-tourism markets, together with closing comments.

3. Public Transport:

This section reviews buses from a global perspective and for best practice lessons; 'battery swapping' as an emerging trend; South African trends and developments; minibus taxis; and case studies for Kenya, Ghana, Rwanda and Zimbabwe.

4. Machinery and Equipment:

A review of the production and sale of zero emission heavy duty vehicles and equipment is undertaken, with trucks, mining equipment, agricultural equipment, and the general electrification of various categories of machinery and equipment, together with ownership models being analysed. Conversion of fossil fuel-driven vehicles to NEVs is also considered, and then role players and stakeholders are identified, together with opportunities in the NEV value chains and for FCEV components.

5. Infrastructure Providing Energy for NEV:

The NEV industry requires support infrastructure in the form of fuel supply infrastructure, charging stations and equipment, policy and incentives, together with other support and enabling investments, including finance and insurance. These issues are traversed, and opportunities identified.

6. Battery Value Chain:

The batteries in various NEV are becoming an important technology in itself, and underpin certain elements of the NEV industry and opportunities. Battery types have been analysed with smaller and larger mobility issues traversed, and a brief review of battery studies conducted in South Africa.

[1] DTIC, 2021. Auto green paper on the advancement of New Energy Vehicles in South Africa, the South African road to production of electric vehicles (The Roadmap, 18th May 2021)

7. Trade Policy Conformity:

A range of trade policies, incentives and tax schemes is considered from various countries in order to accelerate the transition to NEVs. Tariffs and regional integration for trade enhancement are considered, including Rules of Origin (RoO) and the implications of the African Continental Free Trade Agreement (AfCFTA) on the emerging NEV industry in Africa.

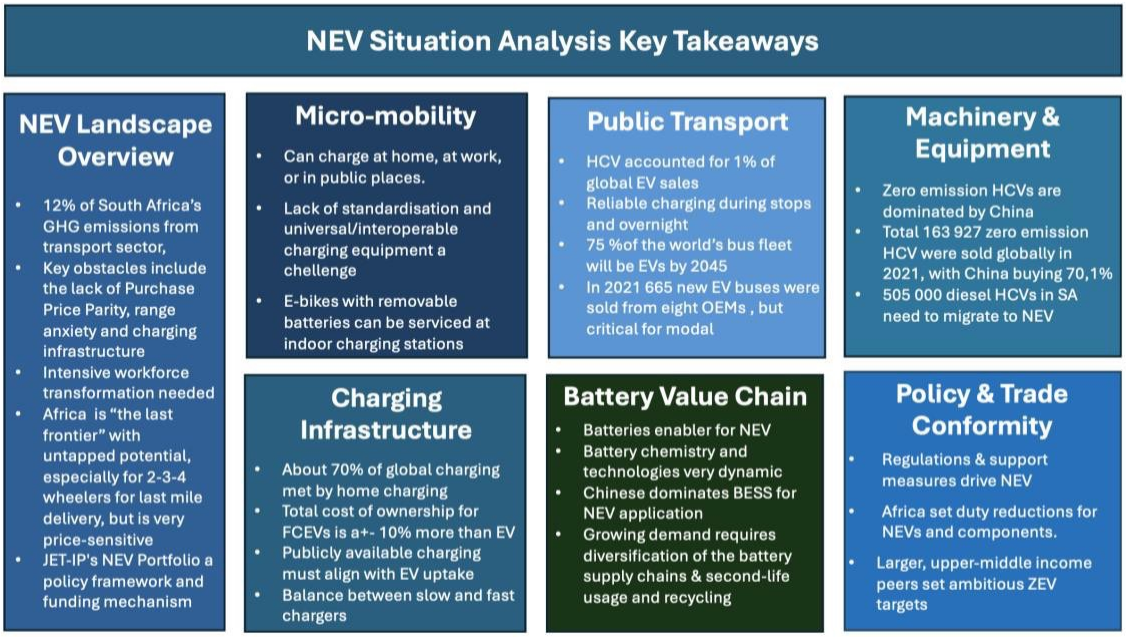


Figure 1: NEV Situational Analysis Key Takeaways

The key takeaways from each of the segments are summarised in the figure above. Each of these is dealt with in a separate chapter in the series review, highlighting key role players and stakeholders, culminating with an overview or statement of the opportunities which have been identified in the NEV segment considered.

[1] DTIC, 2021. Auto green paper on the advancement of New Energy Vehicles in South Africa, the South African road to production of electric vehicles (The Roadmap, 18th May 2021)

2. MICRO-MOBILITY

2.1 Context

2.1.1 Rationale for Micro-Mobility[2]

The demand for mobility in cities has been increasing and with passenger vehicles as the preferred mode of transport, congestion is a growing problem which brings increased energy consumption and exhaust gas emissions. This leads to the pollution of air and the release of greenhouse gases responsible for climate change. Particulate matter emission (of which road transport is a major contributor) has become a concern for urban air quality, causing more than 400 000 premature deaths each year in Europe.

To limit these emissions, targets are becoming stricter and the methods and technologies for urban mobility are being reconsidered. Plans for future mobility see a modal shift from cars and trucks to lighter, smaller, more specialised and environmentally friendly alternatives; this means lighter and smaller-sized electric vehicles which have a more favourable mass-to-payload ratio.

Micro-mobility transportation involves the use of lightweight vehicles, typically two- to three-wheelers with limited speed (less than 25km/h) like bicycles or electric scooters. These vehicles can be conveniently borrowed through self-service systems, allowing individuals to hire them for short-term use. Electric L-category vehicles provide alternative solutions for the above issues with two-, three- and four-wheeled vehicles which can transport either passengers or cargo.

2.1.2 Market Developments for Micro-Mobility

According to a market study by Nova1Advisor[3], the global light-EV market size was US$81.3 billion in 2022 and is projected to hit around US$ 206.1 billion by 2032, growing at a CAGR of 9.75% during the forecast period 2023 to 2032.

They listed a few important key points:

- North America dominates the global light-EV market.
- By vehicle category, the two-wheeler segment captured the largest revenue share in 2022.
- By application, the commercial segment is predicted to generate the maximum market share in 2022.
- By power output, the 6 to 9kW segment is expected to capture the largest market share in 2022.
- By component, the battery pack segment is projected to record the highest market share in 2022.
- By vehicle type, the e-bike segment is expected to account for the biggest market share in 2022.

[2] Mario Santucci a, Marco Pieve a, Marco Pierini. Electric L-category vehicles for smart urban mobility. ScienceDirect. Transportation Research Procedia 14. (2016)

[3] Nova 1 Advisor, Light Electric Vehicles Market (2023)

The market size for micro mobility in another report[4] was valued at US$ 78.5 billion in 2022 and is expected to grow to US$ 122.7 billion in the next five years as shown in Figure 2 below. This includes electric bikes, scooters and motorcycles, industrial vehicles, neighbourhood EVs and any other small two-, three- and four-wheelers.



Figure 2: An indication of the market for micro mobility in the USA

Global electric two-wheeler sales totaled about 9.2 million in 2022, a drop of nearly 18% from 2021. This drop was almost entirely attributable to the dip in sales of electric mopeds and motorcycles in China, which fell from 10.2 million in 2021 to under 7.7 million in 2022, even as the overall two-wheeler market there continued to grow. Despite the decline in sales, likely due to the Covid-19 pandemic, China continued to dominate the electric two-wheeler market in terms of size, accounting for nearly 85% of global sales.[5]

Vietnam's two-wheeler market has contracted since 2018, from 3.6 million vehicles in 2018 to 2.8 million in 2021, the lowest level in 15 years. Although the two-wheeler market declined, the market share of electric two-wheelers increased significantly and reached 10% in 2021.[6]

In India, sales of electric three-wheelers, which play an important role in urban mobility for both cargo and passenger services, soared to 425 000 units in 2022. Sales have been strong in India for several years, with hundreds of thousands of electric three-wheelers sold every year since 2012, except for 2020, when the Covid-19 pandemic reduced sales volumes to 30% of the previous year.

More than half of India's three-wheeler registrations in 2022 were electric, demonstrating their growing popularity due to government incentives and lower lifecycle costs compared with conventional models, as well as higher fuel prices. The International Energy Agency's analysis on the total cost of ownership in India suggests that electric three-wheelers are already 70% cheaper than their gasoline-power ICE equivalents over their lifetime.[7]

China trailed India in terms of electric three-wheeler sales, with nearly 350 000 units sold in 2022. Together, China and India accounted for almost 99% of global electric three-wheeler sales.[8]

The Filipino-publication [9] titled "Philippines Light Electric Vehicle Market Outlook to 2027: Driven by government initiative to develop the EV industry and increasing consumer preference towards limiting carbon footprint" provides a comprehensive analysis of the light-EV industry by analysing historical statistics and corresponding developments in the light-EV market. The report covers various aspects including market size of two-, three-, and four-wheelers, and the consolidated light-EV industry based on revenue, average price & volume.

[4] Market Study, Light Electric Vehicles Market, Markets and Markets (October 2022)
[5] IEA, Trends in Electric Light-Duty Vehicles (2023)
[6] Le H., Posada F., Yang Z.: Electric Two-Wheeler Market in Vietnam: An Overview (October 2022)
[7] Market Study, Light Electric Vehicles Market, Markets and Markets (October 2022)
[8] Ibid
[9] Mayukh Sen, Philippines Light Electric Vehicle Market Outlook to 2027 (September 2022)

The light-EV market in the Philippines recorded a positive CAGR of 117.6% based on revenue between 2017 and 2022 as shown in Figure 3. The increasing growth is attributed to the surging sales of electric two- and three-wheelers across the Philippines due to a rise in delivery and logistics services availing two-wheeler EVs coupled with usage of e-trikes as a form of public transportation medium.

The four-wheeler EV market recorded a surging growth of 110.9% based on revenue generated between 2017 and 2022, but the passenger four-wheeler EV segment has not been able to contribute a substantial share on the overall light-EV market.

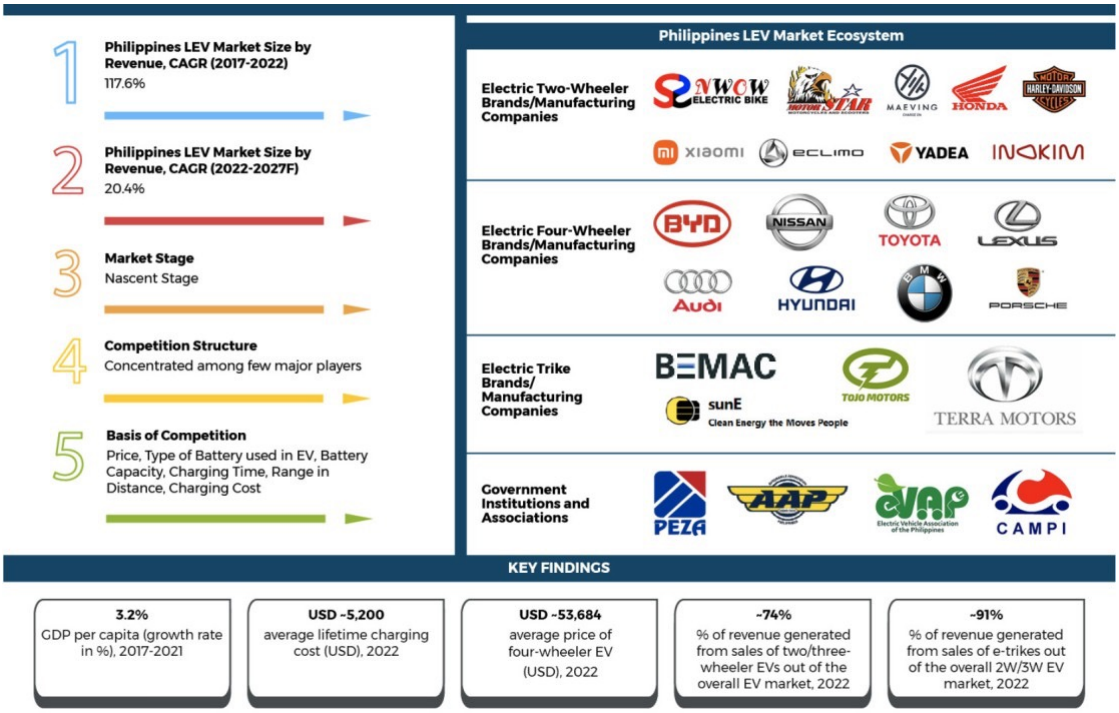


Figure 3: Philippines LEV Market Ecosystem

From the above information (OpenPR, 2022) it can be concluded that policies and regulations responding to traffic congestion, and the limiting of urban air pollution and harmful environmental exhaust emissions, are limiting the use and sales of ICE vehicles and thus creating a market for small EVs in cities.

2.2 Battery Electric Two-Wheelers

The global electric two-wheel market size was US$78.5 billion in 2022 and it is estimated to grow up to US$122.7 billion by 2027 as shown in Figure 4.

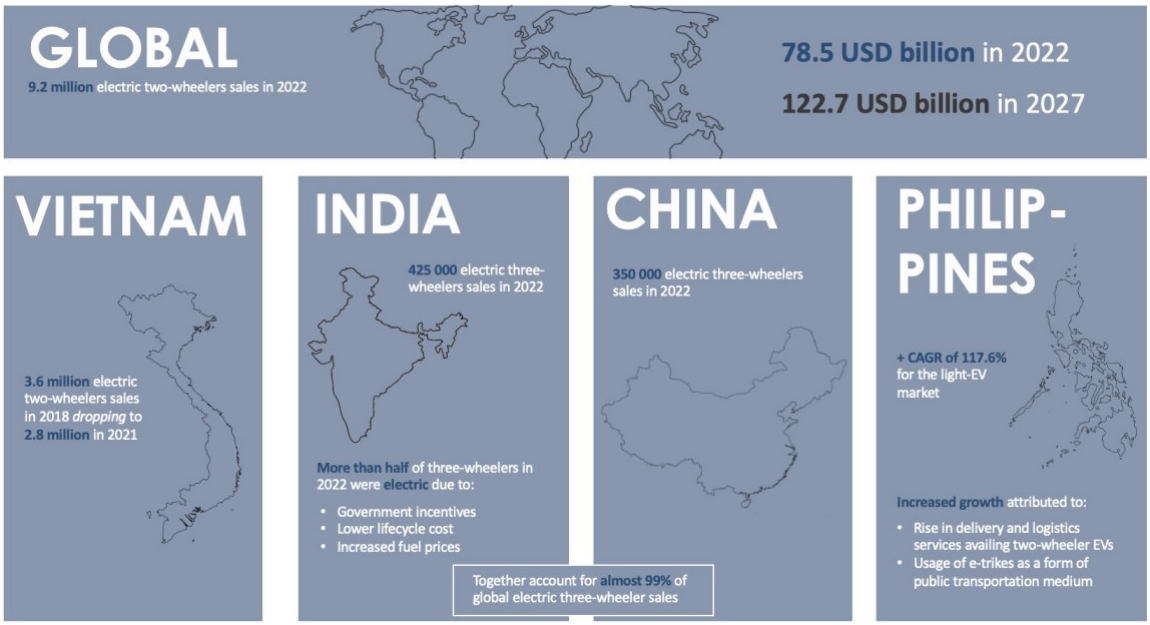


Figure 4: Global Electric 2-Wheeler Sales and 3-Wheeler growth in India and China

2.2.1 Product Description

The bicycle has evolved from being an old-fashioned recreational product to a more purposeful means of transport - a personal mobility tool that offers flexibility and can be compact and ultra-light (pedal-assisted electric bicycle). It can also be slightly bigger with greater performance and capabilities (electric super bikes).

Figure 5 below shows a variety of these two-wheelers to provide an impression of vehicle types:



Figure 5: Electric 2-Wheeler Examples (Shutterstock Images)

The electric bicycle (two-wheeler with pedals) is based on the traditional bicycle to which an electric motor and battery have been added to assist the rider in terms of propulsion.

The electric bicycle is economical and does not produce any emissions. The energy consumption of the electric bicycle is about 11kWh/100km for a person with a mass of up to 90kg, making it the most energy efficient and cost-effective personal mobility tool. However, in some countries (Africa and India) due to high traffic congestion, electric two-wheelers are used as taxis.

This two-wheeler collection spans a great variety of products: From the stand-on small scooter to the pedal assist electric bike to super bikes. For vehicle homologation purposes, they are classified into various L-Class categories as indicated above.

2.2.2 Two-Wheeler Market:

According to an example by Global Market Insights report[10], Figure 6 shows the market size was US$30 billion in 2022 and is expected to grow to US$55 billion by 2032. This is driven by increasing government support for e-mobility across the globe, stringent emission regulations, rising concerns about air pollution in Asia Pacific and growing awareness of the benefits of electric propulsion.

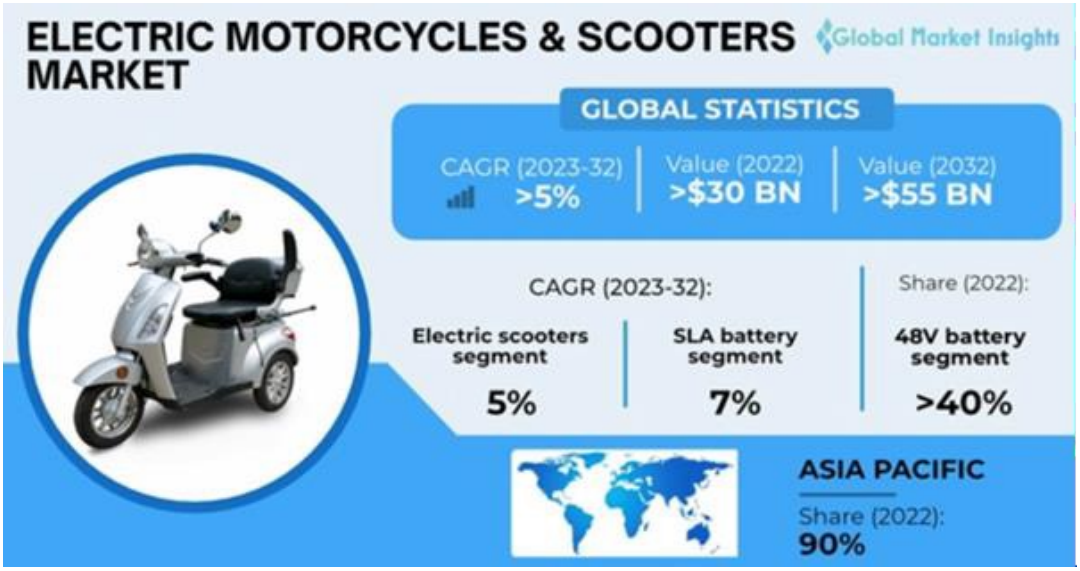


Figure 6: The Electric Two-Wheeler Market according to the Global Market Insights Report.

The worldwide market for e-bikes is growing but varies geographically. Worldwide sales of e-bikes were estimated to be 36 million units in 2015 and 100 million by 2035, with most sales being in Asia. In the USA, e-bikes are a small but growing market, increasing from 200 000 units in 2016 to 250 000 units in 2022.[11] These units are growing in popularity due to increased sustainability concerns and the energy resources crisis. Electric two-wheelers can be used for a multitude of mobility needs. In this report two applications will be mentioned:

1. The electric two-wheeler taxi (just for information) and
2. The electric two-wheeler delivery bicycle.

[10] Global Market Insights, Electric Motorcycle & Scooter (EMS) Market Size (November 2023)

[11] Benjamin E. and Jamerson, F.E., Electric Bikes Worldwide Reports - Light Electric Vehicles / EV Technology. (2015) In A North American Survey of Electric Bicycle Owners. (2018)

The first for its wide and increased use in Africa as shown in Figure 7, and the second for it being a perfect example of two-wheeler deliveries.

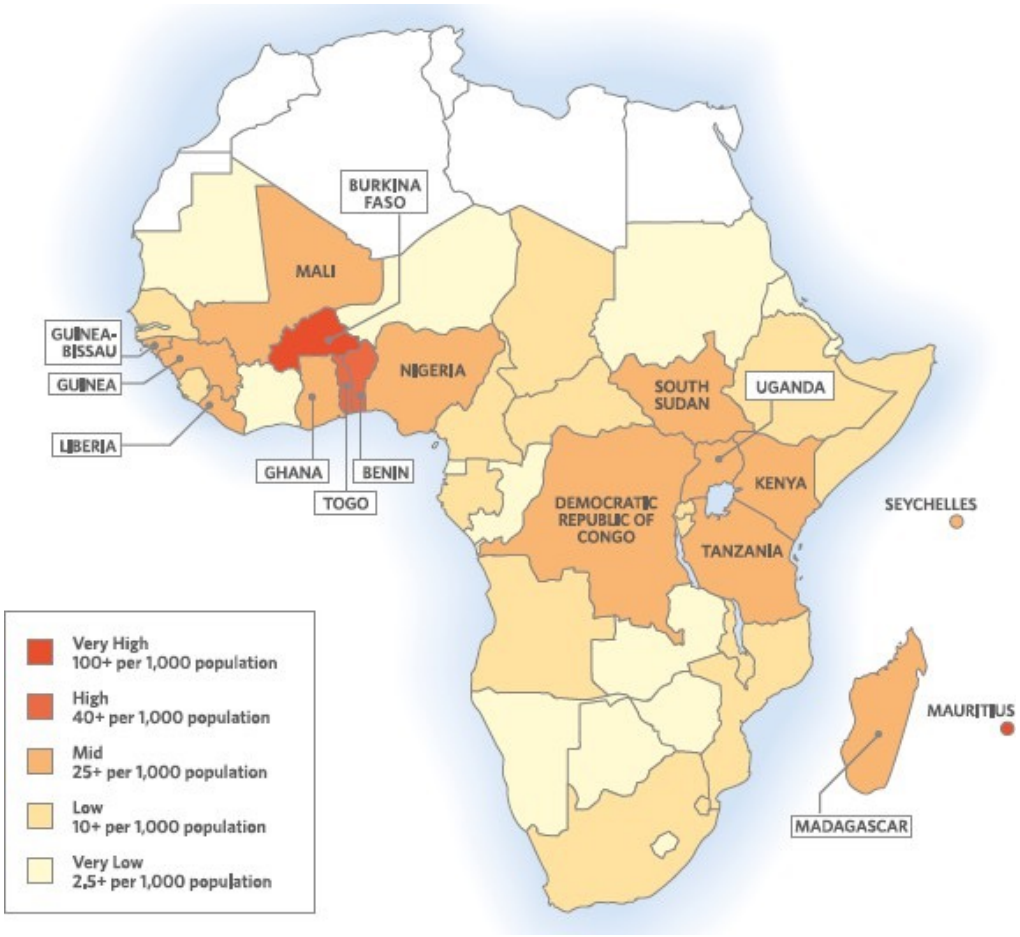


Figure 7: Estimated Number of Motorcycles per 1,000 of the Population, 2020[12]

2.2.2.1 Two-Wheeler Taxis[13]

UN Environment (formerly UNEP) estimates there are 5 million motorcycle taxis, known locally as motars or boda bodas, in five of the core East African Community countries. Extended to Sub-Saharan Africa, it is estimated that there are over 30 million motorcycle taxi drivers. The drivers are generally hard-working, low-income individuals taking home on average a few dollars per day, supporting on average four- to five-person households.

Nearly all the motorcycles used in Sub-Saharan Africa are driven by petrol-powered engines with capacity of between 100cc and 150cc and are produced without complying to any standard European regulations on emissions. The 150cc motorcycles used in Rwanda likely produce 16 times more harmful exhaust emissions than Euro 3 standard cars. They travel an average of 160km per day, six days a week. The population of Africa is expected to grow from 1.4 billion today to an estimated 2.5 billion by 2050. It is important to plan for reducing the threat of an approximate potential 7.1 gigatons of CO_2 emissions.[14]

[12] The Wheels of Change: Safe and Sustainable Motorcycles in Sub-Saharan Africa, Bishop and Courtright (2020)

[13] Mass-Market Electric Motorcycle Taxis. USAID. (2022)

[14] US AID, Final Report: Mass-market electric motorcycle taxis, 2022

Due to the high use and high volume of motorcycle taxis, they are regarded as significant contributors to urban air pollution and negative effects on community health. Current data shows that electrifying all East Africa's motorbike taxis by 2030 would reduce motorbike GHG emissions by up to 93%. Therefore, electrification of this fleet is required to meeting GHG reduction targets. In Rwanda there are 100 000 two-wheeler taxis, of which at least 25 000 are operating in the capital city of Kigali.

An additional motivation for electrification of the taxis is that the price of fuel is high. It is estimated that drivers spend approximately 90% of their income on fuel and maintenance for their fuel motorbikes.

Historically, there have been four challenges raised by motorbike-taxi operators:

- **Low quality batteries:** Widely available, off-the-shelf electric motorbike batteries are low quality and their power and reliability do not meet the needs of motars (local name).
- **High upfront costs:** The cost of high-quality batteries that could meet this market's needs are very expensive, more than doubling the cost of the motorcycle if sold together with the motorcycle. Most customers are unwilling or unable to pay that cost, or to take on that level of debt with a lender (if they could even obtain such a loan).
- **Long charging time:** Motorcycle taxi drivers who work 13-hour days, 6 days a week cannot afford to wait hours for batteries to recharge. Even fast charging solutions, which are still slower than re-fuelling, are costly and degrade the lifespan of batteries to the extent that it is not possible to recoup the battery costs of production and still offer cheaper power than fuel.
- **Minimal energy network availability:** Even with the battery type, battery cost, and charging time solved, a user still requires a sufficiently extensive, conveniently located, user friendly and reliable network of locations to obtain energy, approaching or exceeding the comparable options, offered by gas stations which do not exist.

These challenges are typical for all electric vehicles. Things are improving as the industry matures with growth in volumes of components and products.

2.2.2.2 Two-Wheeler (Bicycle) Deliveries

An example of a local company using an electric two-wheeler is Green Riders, as shown in Figure 8 below:[15]



Figure 8: Examples of Green Riders' Electric Pedal Assist Delivery Bikes

The company is proudly South African, and recruit unemployed, underprivileged youths (both men and women) and teach them, in the areas in which they live, to become professional delivery drivers. Using e-bikes for deliveries is not only environmentally friendly, but also much cheaper (by up to 50%) to operate compared to petrol scooters. They also do not have any exhaust emissions thus, saving the operator money while reducing harmful emissions to the atmosphere. The aim is to create jobs while displacing petrol delivery scooters, motorbikes and cars normally used for deliveries or to go shopping.

As of 9 November 2023[16] the 741 company riders have completed 221 139 deliveries and

travelled 2 921 025 km. The business aims to have 50 000 bikes in the next five years.

Using traditional pedal bikes for this application will not work as it requires too much effort from the driver. With electric pedal assist it is much easier to travel up hills and do deliveries throughout the day. This method and technology work well for deliveries in the city (short distances). Due to business growth and with this the delivery distances, the company is considering the use of electric delivery scooters for longer distances, more challenging terrain and when more speed is required.

2.3 Battery Electric Three Wheelers

These are mobility options with three wheels propelled by an electric motor, powered by electricity stored in a battery. Also, they are perfect for running on narrow streets because of their small size. Electric tuk-tuks are becoming one of the preferred modes of transport on streets because of their low maintenance cost, eco-friendliness, zero noise pollution, and easy driving. The vehicles in this collection are used to transport passengers and products for deliveries, and leisure activities in both urban and rural areas.

Recently though, there has been a development of these vehicles with two wheels in the front and one wheel at the back. This is aimed for use as a city vehicle. This size vehicle uses less space in the city while using less energy when driving, thus saving the owner money.

Class L4, the category for motorcycles with a side car and three-wheelers for leisure, are not further considered in this study due to low market expectations.

[15] Green Riders, Home (2023)
[16] Green Riders, About (2023)

Figure 9 below shows a variety of these three-wheelers to provide an impression of vehicle types:



Figure 9: Battery electric three-wheeler variants

2.3.1 The Electric Tuk-tuk

The market for the electric tuk-tuk variant is expected to reach US$ 843.5 million by 2031 from US$ 461.1 million in 2021.[17] The increase in fuel prices, growth in pollution, traffic congestion, are all motivations for micro-mobility (including electric tuk-tuks world-wide).

According to MMR's Global Industry Analysis and Forecast (2023 - 2029)[18], the size of the market was US$ 489.7 million in 2022 and is expected to reach US$ 746.1 million by 2029 as shown in Figure 10.



Figure 10: Tuk-tuk Marketing Developments and Expectations

[17] Abhay S, Sonia M: Electric Tuk-tuks Market Size, Share, Competitive Landscape and Trend Analysis (September 2022)

[18] Maximize Market Reseach, Electric Tuk-tuks Market: Global Industry Analysis and Forecast (November 2023)

2.3.1.1 Key Market Points:[19]

- By power output, the above 1 500W segment is the most popular in terms of growth.
- By battery type, the lithium-ion segment is projected to drive demand.
- By range, the up to 50km total range segment is projected to be most acceptable.
- By price range, the high segment is projected to be selected.

2.3.1.2 Driving the Transition to Electric

In **Sweden**, the company BZZT offers an Uber-like service, but instead of cars it uses tiny electric tuk-tuks that can travel up to 45km/h. They call the vehicles podtaxis as is depicted in Figure 11 below. The company's vision is to make taxi services available to everyone in the inner city, by offering prices comparable to public transport. A podtaxi can be ordered through the Bzzt-app anywhere within the inner city of Stockholm. The customer only pays for kilometres travelled, which means a fixed fee of 30 Krona (US$ 3) per kilometre, regardless of traffic. So how does Bzzt manage to make the service so cheap? Wolf explains: "A normal taxi operates, on average, 15 to 20 minutes per hour, which is very inefficient. We have a system, and a proprietary software, that optimizes our fleet. It gives us a better occupancy rate, and that is why we can ask lower prices and still pay our drivers a good salary."[20]



Figure 11: BZZT's podtaxi service

In **Australia**, Ikea, and ANC (a logistics company) have opted to use tuk-tuks only for last-mile deliveries motivated by "residents, city and national governments being sick and tired of trucks polluting their local area". These specially designed electric tuk-tuks are manufactured by Biliti Electric in India and imported exclusively by Brisbane-based company EMoS. "The electric three-wheelers will be used by Ikea's Tempe store in Sydney, and will feature swappable 9kWh batteries, although they will be limited to speeds of 50 km/h due to Australian homologation rules."[21]

In **Thailand**, the two-stroke inefficient petrol-burning tuk-tuks are being replaced by a zero emission, more energy-efficient electric model, offering travellers a more environmentally friendly way of getting around in what is one of the world's worst countries when it comes to air pollution. In 2021, the levels of the PM2 pollutant, (particulate matter smaller than 2.5 micron) were four times higher than World Health Organisation's guidance. Inhalation of PM2.5 can cause respiratory problems, heart issues and premature death. In 2019, air pollution was to blame for more than 31 000 deaths in the country. In this year the number of petrol burning tuk-tuks reached 20 000.[22]

[19] Allied Analytics LLP, Electric Tuk-tuks Market Development, Market Trends, future development Key Driven Factors and Forecast to 2031 (March 2023)
[20] Tom Turula, These tiny electric tuk-tuks are taking on Uber in Stockholm (June 2017)
[21] Giles Parkinson, Electric Tuk Tuks in Australia: Ikea and logistics giant ANC get serious about last mile delivery (November 2022)
[22] Rebecca Root, Thailand's tuk-tuks go green amid rising demand for electric models (January 2023)

Sri Lanka has about 1.2 million tuk-tuks on the road and a serious air pollution problem. The government voted to, within the next five years, convert half a million fossil-fuelled tuk-tuks to electric tuk-tuks. Part of the motivation for this electric tuk-tuk program was a fuel supply crisis in the country and the growing cost of fossil fuels. "Electric three-wheelers will not only benefit individual operators but also contribute to spring boarding the country's economic recovery process," Transport and Highways Minister Bandula Gunawardena said.[23]

In East Africa, **Uganda** launched electric tuk-tuks in 2020. According to Peter Muzoora, Country Manager for Uganda Sokowatch: "In Kampala, air quality is six times worse than global standards and as a company built around improving the livelihoods of local communities, we took the direct approach to address the issue. We launched in Kampala last year and when we arrived, we made a commitment to be a business that would add and not take away from our local communities and the launch of our electric tuk-tuks shows this was not just lip-service. Every day, we witness the impact of carbon emissions and noise pollution on this city, which is why this project is so important and why we are proud to be a company leading active change in Kampala."[24]

2.3.1.3 The PIAGGIO APE-É-CITY[25]

In 1947, after the world was at war, the inventor of the Vespa Scooter, aircraft designer Corradino D'Ascanio, decided to build a light three wheeled commercial vehicle to provide a mobility solution to Italy to enable its economic reconstruction. The very first Piaggio Ape model, shown in Figure 12, was mechanically a Vespa Scooter with two wheels added to the rear and a flat-bed structure on top of the rear axle.



Max Power (KW)	5.44kW @ 3500rpm
Max Torque (Nm)	29NM
Top Speed	50 km/h
Typical Driving Range(On Road)	145kms - 150kms
Battery type	Lithium Ion, 51.2V
Battery capacity (kWh)	8kWh
Wheel Base (mm)	1920
Overall length (mm)	2700
Overall width (mm)	1370
Overall height (mm)	1725
Min. Ground Clearance (mm)	200
Seating Capacity	Driver + 3 passengers
GVW (kgs)	713
Kerb Weight (kgs)	413
Home Charger	Off-board charger 48V/3000W
Charge Duration	3 - 4.5 hours
Battery life	1.500 cycles in 4 years
Gradeability (%)	20%

Figure 12: The APE-É-CITY's specifications

The popular brand, Apé, has been improved over several years of expertise and powered by the latest technology. The cost of the electric e-city 3–4-seater is approximately US$ 9 500.

[23] Zachary Shahan, Sri Lanka Aims to Reach 500,000 Electric Tuk-tuks (July 2023)
[24] Ishani Chetty, Uganda startup launches first commercial electric tuk-tuks in East Africa (December 2020)
[25] Piaggio, Apé-E-City Electric Tuk-tuk (2023)

2.3.1.4 "First and Last Mile" Delivery Business:

The SmarTuk [26]

The e-Tuk Factory is a manufacturing company in Europe that has developed the SmarTuk shown in Figure 13. "Fun, friendly and zero emission was our goal to make the cities greener and cleaner. The transportation of people in the inner city was our focus. Today, we have our focus on the last mile delivery of the Smart City." It can be made to be customisable in line with the customer's needs regarding range and / or volume of the box on the back. The box can also be heated or cooled.



Figure 13: The SmarTuk

The Cargo model has a payload of 800 kg, and the Limo model has six seats. Interesting statistics relating to the SmarTuk business can be seen in Figure 14 below:

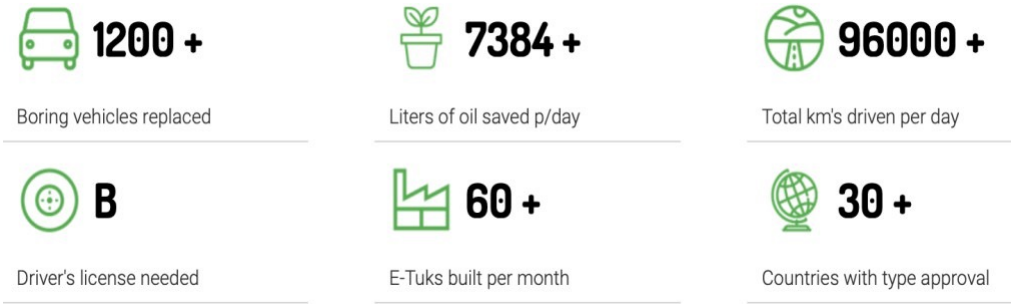


Figure 14: Interesting Statistics regarding the SmarTuk

Battery packs come in three sizes: 7, 14, or 20kWh. The vehicle is IoT ready – so, it can be monitored and tracked all the time.

[26] Piaggio, Apé-E-City Electric Tuk-tuk (2023)

2.3.1.5 Local MellowVans:[27,28]

MellowVans are three-wheeled electric vehicles, depicted in Figure 15, designed to provide an efficient on-demand delivery service in urban areas. Developed in South Africa, MellowVans offer 10 times the delivery capacity (2.5m^3) of the typical delivery motorbike (0.25m^3).

Specially developed, scalable lithium batteries offer a high energy density and safety, while the 48V motor supplies maximum thrust. The three-wheeler has a range of about 120km. On-board, active cooled chargers provide simple charging when connected to the common 230V domestic power sockets.

MellowVans also offers an innovative and environmentally friendly medium for advertising. The electric delivery vehicle offers a location-specific, mobile billboard exposure exactly where needed, and better yet, potential income of the advertising revenue generated.



Figure 15: MellowVan Prototype

Originally, the plan was to design a light electric vehicle for passenger transport. The company, MellowCabs, was established in 2014 and started gaining some media attention for its use of recycled material and environmentally friendly approach. Prototypes were tested and then in 2019 the team realised that there was more potential in deliveries of parcels and cargo. DHL was interested at the time to obtain an electric delivery vehicle. MellowCabs changed its name to MellowVans and the horizon broadened to Namibia and Botswana, and later Europe.

Work was done to meet homologation requirements for Europe, starting in the Netherlands. Various design changes followed, and a leasing business model adopted. The vehicle was also equipped with a fully functional IoT connectivity system.

"The demand for the vehicles has always outstripped the supply. MellowVans could simply not produce enough units to supply both South Africa and Europe. The plan is to ship the fully built models to European clients as a start, moving towards local assembly in the destination market as soon as it makes sense from a price point approach. We are using European components in the vehicle, so we would have to have local assembly there. We are looking at possible locations in the Netherlands, Hungary, as well as Egypt."

Operating costs for the MellowVans are roughly 15c/km. That is about R3.47 per day in electricity costs. Cost of deliveries in Europe is around 28% of the cost of the product while in Africa, this cost increases to around 35% - 55%. "You can imagine, many delivery drivers would never be able to finance a vehicle, but we are willing to lease it to them," said du Preez.[29]

[27] Mellow Vans (2023)
[28] Jeanette Clark, South African electric delivery vehicle poised to enter European market (February 2023)
[29] Bradley Prior, The little electric cars used for ecommerce deliveries in South Africa (May 2020)

"If you look at lifecycle costs, the MellowVans beats every other last-mile option. There is almost no maintenance required, and each vehicle travels with its own charger. Our dream is to become a world player in last-mile solutions, which is possible if you can secure a foothold with a large international retailer. Our team is passionate that South Africa can produce a relevant, competitive product for the international market."[30]

2.4 Battery Electric Four Wheelers

This vehicle collection spans a great variety of products. It starts with electric quads for recreation, electric golf karts for golfing and personal mobility in big estates – called "neighbourhood vehicles" in the USA, up-sized golf karts used in agriculture or for transport of people, and then lastly the micro-mobility vehicles aimed at logistics.

The rationale for developing micro-mobility vehicles of this kind is found in their lower energy requirement and therefore lower emissions. Significant reductions in greenhouse gas emissions in the transport sector require system changes in transport behaviour, supported by technological progress and resource-saving vehicles. Replacing large and heavy vehicles with micro-mobility options is a solution. These very small and light electric vehicles (LEVs) will enable the mentioned objectives. LEVs have a more favourable weight-to-payload (passengers or goods) ratio and, in addition to low vehicle weight and small frontal area, the efficiency of electric propulsion minimises energy consumption during operation. In contrast to large and heavy passenger cars, the traction batteries in LEVs could be considerably smaller, so that the consumption of critical raw materials is also reduced, thus lowering production-related greenhouse gas emissions.

For example: a class L7, four-wheel LEV weighs around 500kg as shown in Figure 16. The passenger payload on average is 108 kg (1,4 persons per vehicle), whereas a standard four-wheeled petrol-driven passenger vehicle weighs about 1 600kg. The mass of the vehicle influences its energy consumption. However, the main purpose of the vehicle is to move the payload of passengers and objects, and not the vehicle itself. As small vehicles do not need much energy for moving the vehicle itself, small (right-sized) vehicles are much more efficient than standard passenger cars.

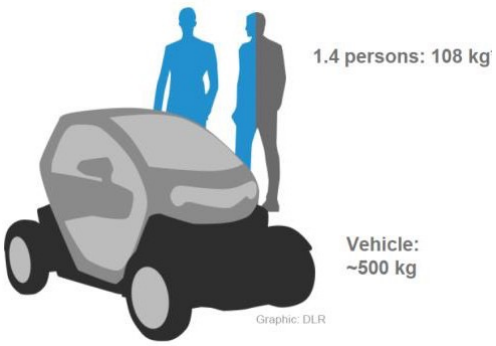


Figure 16: Weight of class L7 four-wheeler

Due to the low amount of energy that LEVs need for propulsion, batteries can be small, and hence production requires fewer critical raw materials. In addition, small batteries cause fewer production-related greenhouse gas emissions than large batteries. Figure 17 shows that greenhouse gas emissions increase proportionally with battery size (around 40 kg to 140 kg CO_2 equivalent per kWh), LEVs have an ecological advantage over heavier passenger cars with large batteries.[31]

[30] Irma Venter, South African-made MellowVan ready for rollout in 2021 (November 2020)

[31] M. Brost, et al. 2022. The Potential of Light Vehicles for Climate Protection through Substitution for Passenger Car Trips. Final report of the LEV4Climate Study. German Aerospace Centre. (2022)

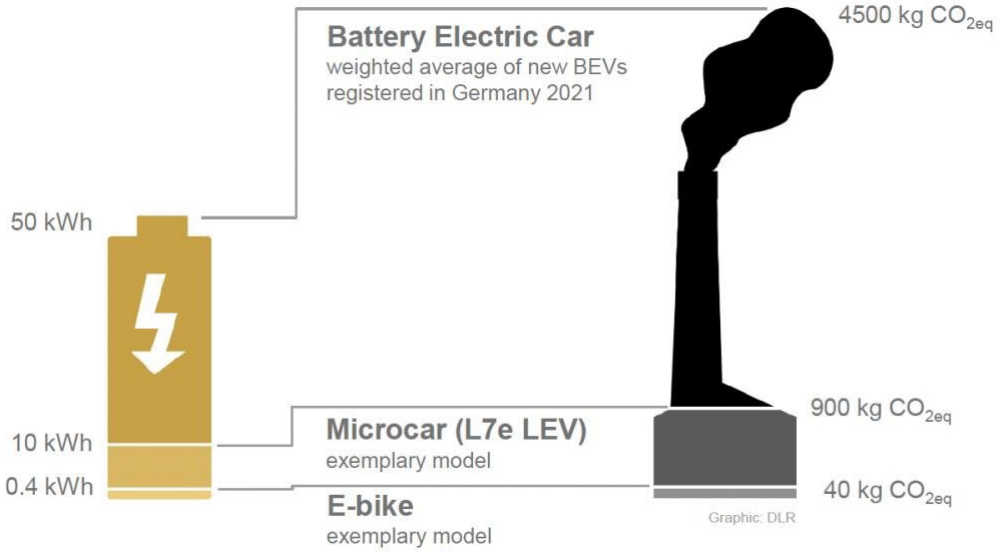


Figure 17: Correlation between greenhouse gases and battery size

Figure 18 below shows a variety of these "neighbourhood vehicles" to provide an impression of vehicle types:



Figure 18: Neighbourhood Vehicle Examples (Shutterstock Images)

2.4.1 The Battery Electric Wuling Hongguang Mini EV[32]

The Wuling Hongguang Mini EV, shown in Figure 19, is an example of a city vehicle in this category. It is a battery electric city vehicle manufactured in a joint venture between SAIC Motor, General Motors, and Liuzhou Wuling Motors Co Ltd., trading as Wuling Motors. Retail deliveries began in China in July 2020. As of February 2023, global sales have passed 1 100 000 units, and the Mini EV has become the best-selling electric vehicle in China. The Wuling Mini EV is 2.9m long, 1.5m wide and 1.6m high, with a 1.9m wheelbase. The electric motor used in the vehicle is rated at 20kW power with 85Nm torque, with the standard battery having a capacity of 9.2kWh or 13.8kWh for a bigger one. The weights are claimed to be 665kg (9.2 kWh battery) or 705 kg (13.8 kWh battery).[33]

[32] Wikipedia, SAIC-GM-Wuling (2023)
[33] Just Auto, GM future models – Wuling goes electric (August 2020)



Figure 19: Wuling Mini EV

The Wuling is allowed legally on public roads and has a top speed of 100km/h. Driving range is about 120km on the smaller battery and 170km on the bigger battery. Selling price for these cars start at CN¥ 28 800 (US$ 4 389).[34] Thanks to this low cost, albeit very basic mobility, the Wuling is very popular, and copies have emerged in South Africa. Two examples were the CityBug by ELEKSA[35] and the Funky EV by Funky Electric.[36] Both these vehicles are imports from China.

2.4.2 Examples of Battery Electric Four-Wheeler Delivery Vehicles

2.4.2.1 VOK: 4-Wheel eBikes

VOK is an Estonian-based company that manufactures electric cargo bikes. The company was founded in 2017 by a team of engineers who were passionate about creating a sustainable and efficient way to transport goods.



Figure 20: VOK 4-wheel cargo bikes

[34] Mark Andres, This Chinese EV Sells At Just Over $5,000. So We Tried It (May 2022)

[35] Gero Lilleike, Eleksa CityBug is the Cheapest EV in SA, but is 4kW enough? (January 2022)

[36] Funky Electric Ltd, The Benefit of owning a "Funky" electric car (2023)

VOK's cargo bikes, depicted in Figure 20, are designed to be easy to use, reliable, and durable. They are also equipped with a variety of features that make them ideal for commercial deliveries, such as a large cargo space, powerful electric motors offering two-wheel or four-wheel drive options, and a comfortable ride. Two sizes are available:

- VOK S: 0.4m^2, 120kg
- VOK XL: 2m^2, 200kg

VOK's cargo bikes are available in two models: the Standard and the XL. The Standard model has a cargo space of 420 litres and can carry a payload of up to 120kg. The XL model has a cargo space of 2 000 litres and can carry a payload of up to 200kg. Both models are powered by a 250W electric motor that provides up to 50km of range on a single charge or 100km with dual battery upgrade.

Characteristics:

- Instead of a high-maintenance chain, VOKs use series hybrid drive system.
- Regenerative braking extends the driving range and the lifetime of brakes.
- Optional dual battery
- Traction control and e-ABS keep the rider in control of the vehicle in all weather conditions.
- two-wheel drive or four-wheel drive
- four-wheel independent suspension
- Integrated IoT provides over-the-air updates to VOK's software.
- GPS tracking offers extra piece of mind.
- Temperature controlled batteries for longevity and year-round performance.

VOK's cargo bikes are already being used by several businesses around the world, including food delivery companies, postal services, and logistics companies. The company is also working to expand its reach into new markets, such as the United States and Canada.

The benefits of using VOK's cargo bikes include:

- VOK cargo bikes produce zero emissions, which helps to reduce air pollution.
- VOK cargo bikes can carry a large amount of cargo, which can reduce the number of delivery vehicles on the road.
- VOK cargo bikes are easy to operate, fit into cycle lanes (850mm to 900mm wide) and can be parked in tight spaces.
- VOK cargo bikes are equipped with several safety features, such as hydraulic disc brakes, e-ABS and independent suspension, lights and indicators, windscreen wipers and mirrors.

2.4.2.2 Mini Trucks

ChanLi Mini Truck[37]

In October 2021, electrek reported on the ChanLi minitruck, Figure 21, which was bought for US$ 3 500 on the trade platform Alibaba. The 3kW motor took it to a top speed of 40km/h. The lithium battery pack stored 6kWh electricity.



Figure 21: ChanLi Mini Truck

Melex – N.TRUCK[38]

N.TRUCK, Figure 22, is a modular utility electric vehicle with 3.5 tons GVW intended for transport in urban and industrial areas. It can carry loads of up to 2 tons. The lithium battery enables the N.Truck to travel about 150km at a speed of 70km/h. Owing to its compact size, light construction and width of 1 500 mm the vehicle is able to move around tight streets of old towns or inside warehouses without polluting the air. N.Truck will be available into two sizes: medium size with a wheelbase 2 500 mm, and large with a wheelbase 3 000mm. The modular structure will allow for any arrangement of the body, which will increase the wide range of vehicle's applications.



Figure 22: Melex N.Truck

[37] Electrek, I actually bought a cheap electric pickup truck from Alibaba. Here's what showed up (2021)
[38] Melex, POLISH, ELECTRIC MINI TRUCK 3,5 TONS HERE IS! (2020)

Alkè

Alkè XT series have two different wheelbases with different lengths for the cargo bed of 220cm ("E" models) or 270cm ("EL" models). The carrying capacity is up to 1 000kg on the cargo area and up to 4 000kg towing capacity. The electric truck is shown in Figure 23.



Figure 23: Alkè XT

There are various load configurations available: chassis version, flat cargo bed, cargo bed with drop sides, with steel mesh sides, with three sides electro-hydraulic tipping, aluminium waste collection body with or without bin lift, body tarp and box van with two shutters on sides.

XT electric trucks reach a top speed of 60km/h and up to 190km cruising range using the optional on-board double battery package. XT vehicles have been designed with a GPRS system that enables the remote diagnosis of possible problems on electronic parts of the vehicle (motor, batteries, battery charger, controller, electrical system, auxiliary devices, etc.). The trucks are available in 2WD and 4WD. Prices for the XT range start from US$ 46 000.

2.5 L Class Mobility Platforms[39]

A vehicle platform is a base layer structure, where components such as the body, drive unit, and suspension are built upon or fitted into the platform. The mobility platform is also called a rolling chassis or skateboard. It is designed to accommodate electric drive units, the battery pack, and other electronic and battery management systems as illustrated in Figure 24 below:[40]

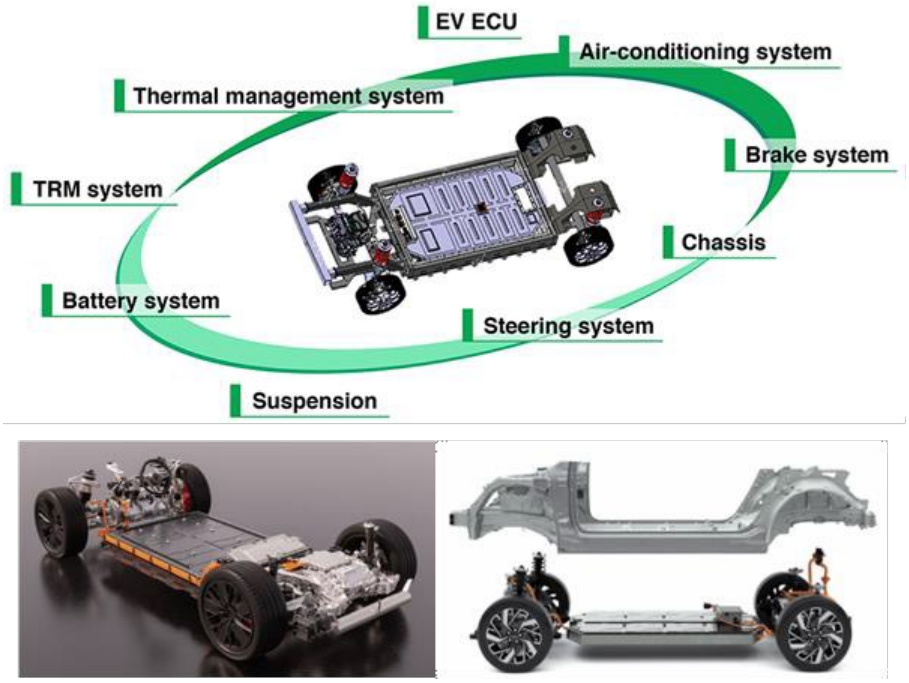


Figure 24: L Class Mobility Platform

Dedicated platforms enable a more spacious interior, larger batteries, less wasted space, and it allows vehicle brands to use and scale platforms on multiple-sized EVs with less effort and investment. Examples are Tesla Model 3 sedan, Hyundai Ioniq 5 and Volkswagen ID4 SUVs, Figure 25. The increased space and lower mass of the platform increases efficiency and allows for more batteries to be housed which increases vehicle driving range. Without the need to have space for an engine at the front, EVs can have shorter bonnets or overhangs, providing more storage space. The simplicity of EV technology enables this development that provides new opportunities for vehicle design and manufacturing. The EV requires much less parts in comparison with the internal combustion engine vehicle. These parts can be packed into a platform that can be shared to house various body types on top of it. [41]

[39] Zecar, Dedicated EV platforms: Everything you need to know (2023)

[40] Nidec Corporation, Nidec embarks on the development of a versatile wheeled platform – the crucial element to dissemination of EVs. (2023)

[41] Volkswagen-Newsroom, Modular electric drive matrix (MEB) (2023)

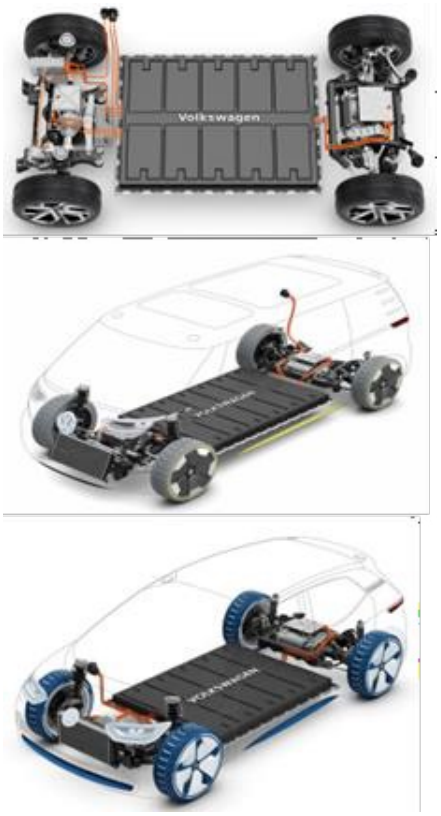


Figure 25: Volkswagen Mobility Platform

The platform of an EV needs to hold all its working components together and be able to cope with vertical and lateral forces applied to the vehicle while driving. These forces consist of bending, torsion, and dynamic forces. A popular design is based on the ladder frame chassis. This chassis also provides mounting points for the suspension, battery pack, steering, electric motor and gearbox, seats, and other body parts. The construction should be of sufficient strength, but also of light weight.[42]

The key component of the EV platform is the battery pack. Due to its mass, it makes good sense to place the pack in the platform between the wheels and below the seats to obtain a low-mid centre of gravity. This provides a smooth ride, adds stability, and road holding capability during all driving conditions.

Important to the development of an EV platform is a sound understanding of the desired performance of the vehicle and the capabilities of the propulsion components. The size and design of the platform vehicle is based on the battery volume – determined by the performance characteristics of the EV. In essence the energy consumption rate and range required of the vehicle. Then the strength requirements of the chassis are established and optimised considering battery layout and mass distribution. These considerations enable the designed body structure to meet the requirements of lightweight, dynamic performance, and structural integrity.[43]

This explains the use of a shared chassis for different vehicle types. The above information provides some understanding of the need and benefits of an EV platform. The rest of the discussion will now focus on L-class vehicle platforms and micro-mobility business models.

[42] Tejas Kale, Omkar Khalade, AyushShirke and Shrikant Pansare. International Journal of Engineering Applied Sciences and Technology, 2022 Vol. 6, Issue 12, ISSN No. 2455-2143, Pages 279-284

[43] Doi Organisation, Strength requirements of the chassis (2023)

2.5.1 Design and Development of an L Class Electric Vehicle Platform

L-class platforms are like M-class platforms, but smaller and lighter in weight. It follows the objectives for smart cities regarding energy efficiency, right sizing of mobility and Mobility as a Service (MaaS).

2.5.2 Open Motors[44]

Open Motors (formerly OSVehicle) is a B2B company, backed by Y Combinator, based in

Silicon Valley and Beijing, developing a complete Electric Vehicle called 'EDIT'.

'EDIT' is a strategic EV, engineered and cost optimized for MaaS (Mobility as a Service) providers (Uber/DiDi), that has:

1. the lowest total cost of ownership (TCO) thanks to the advanced modular technology of the entire vehicle based on an open architecture, including swappable batteries that allow a full energy charge in less than 5 minutes,
2. the lowest cost of infrastructure for swapping and charging stations, and
3. hardware upgradeability for the most advanced technologies in self-driving, connected cars and batteries giving every vehicle ten times longer lifespan over other cars."

When providing mobility as a service, it is important that the vehicles can operate for 24 hours per day as they are being used by various drivers for a variety of purposes. When the vehicle is static, it does not do work and therefore, does not earn money. For this reason, a battery swapping model has been developed for the vehicle design stage.

This is called HyperSwap. The swapping stations are designed to be easily implemented (plug & play) in the existing energy infrastructure, acting as a distributed Battery Energy Storage System (BESS) solution to stabilise and support the grid.

The system is simple: a depleted battery is removed from the vehicle and replaced with a fully charged one. This process takes approximately three minutes. The depleted battery is then charged for the next use. The battery swap station is connected to the grid, and it can be used as a power source for the grid during peak hours. The station has been designed to be automated, compact, and safe. It can accommodate various types of batteries. Using battery swapping for MaaS reduces total cost of ownership up to ten times.

[44] Open Motors, Open Motors® is a B2B company, backed by Y Combinator, based in Silicon Valley and Beijing, developing a complete Electric Vehicle called 'EDIT'. (2017)

2.5.2.1 TABBY EVO

TABBY EVO as shown in Figure 26 is a platform for electric vehicles. Completely modular, ready-to-use, open-source, and available to everyone. It is the second-generation EV platform of OpenMotors. It is stated to be harder, better, faster, and stronger. It is an open-source framework for the creation of complete electric vehicles and can be used to create new vehicles, for whatever purpose saving investment money and time. The platform includes all the mechanical and electrical components that make the vehicle move, including chassis, steering and suspension system, and complete powertrain.



Figure 26: The TABBY EVO platform and capacity

Previous customers have used the product to build city cars, autonomous vehicles, agricultural vehicles, military vehicles, multi-utility vehicles, and logistics vehicles. The TABBY EVO[45] can be ordered for between US$ 14 000 - US$ 25 000. The Joule project in South Africa has shown that the barriers to entry into the automotive are high: huge investments are needed to fund facilities, people, and years of R&D, not to even mention marketing and sales. OpenMotors "follows a new, disruptive, business model that is taking the automotive industry from a vertically integrated monolite, to a horizontally distributed network thanks to the power of open-source technology."[46]

[45] Open Motors, Detailed quotation for TABBY EVO (2023)
[46] Open Motors, Financial-Impact, (2023)



Figure 27: New Vehicle IoT Inputs[47]

New vehicle platforms will also include all the latest developments in terms of the IoT and apps fulfilling various needs and services as seen from Figure 27.

2.6 Conversions and Eco-Tourism

Zero Labs platform conversions are aimed at the conversion of classic ICE vehicles to EVs and extending the useful life of the vehicle, while maintaining the original look as seen in Figure 28 below:[48]



Figure 28: An Illustration of an ICE to EV Conversion Project

[47] Levc, LEVC LAUNCHES ITS NEW GLOBAL PURE ELECTRIC VEHICLE TECHNOLOGY - SPACE ORIENTED ARCHITECTURE (2023)
[48] Zerolabs, Zero Labs platform conversions (2023)

2.6.1 Electric Game Viewing Vehicles

Several companies exist in South Africa converting diesel-powered Land Cruisers to electric game viewing vehicles.

2.6.1.1 Eskom Research, Development and Demonstration Project

Eskom had an electric vehicle programme from 1992 to 2002. Eskom was investigating battery technology and doing research, development, and demonstration work with electric vehicles.

Together with Nissan, an electric 20-seat game viewer shown in Figure 29, was built and operated (as a demonstration of the technology) in the Kruger National Park and later the Leopard Sanctuary in Hoedspruit. It was during this time that Barker Performance Product contacted the Eskom team for some assistance in converting a diesel Land Rover to electric propulsion.



Figure 29: Nissan Electric Game Viewer

2.6.1.2 Barker Performance Products

Since 1997, Barker Performance Products have been providing maintenance and refurbishing services to the private game parks bordering the Kruger National Park. They have been offering full-service vehicle customisation to the game viewer market and have obtained homologation for both the Land Rover and Toyota brands, Figure 30.



Figure 30: EV Conversion for Game Viewer

The Eskom electric game viewer sparked their interest, and they became interested in electric game viewing. They approached Eskom for the conversion of a Land Rover to electric. With the assistance of the Eskom team, an electric Land Rover was produced and put into operation at the Londolozi game park. Later the focus shifted to the conversion of Land Cruiser vehicles, shown in Figure 31. Today the company is not active in the conversion of game viewers anymore.



Figure 31: Land Rover EV Conversion

2.6.1.3 FreedomWon

Anthony English started FreedomWon with the conversion of a Jeep Wrangler that he used as his own private vehicle. Later he did a few conversions for game parks in Botswana, but like Barker Performance Products, FreedomWon is not active in the electrification of game viewers.

2.6.1.4 Electric Powered Vehicles Africa (EPVA)

Owner Steve Blatherwick, Figure 32, started around 2015, producing Electric Safari Vehicles for the African market. The company is also involved in conversions of other vehicles for the commercial and agricultural niche markets such as tractors. Homestead Lodge is the main customer for EPVA's electric game viewer. Vehicles are built and customised to the request of the customer. The minimum cost to convert a small vehicle (22kW, 125V) is about R500 000. The cost of a Toyota Land Cruiser conversion can be as high as R2.1 million.



Figure 32: EPVA owner, Steve Blatherwick

2.6.1.5 Thula Solutions[49]

Recently Thula Solution got into the business of leasing electric game viewers to game parks and private lodges. They tested their market fit for six years, this identified pros and cons of their prototype as shown in Figure 33.



Figure 33: Thula Solutions Testing Market Fit

This after six years of testing vehicles in game reserves from the Kalahari to Limpopo and receiving 241 vehicle orders from 60 lodges. The total fleet size from these loges is 800 vehicles. Thula calculated that the saving to a game lodge per electric game viewing vehicle is R6 500 and 300kg CO_2 emissions per month.

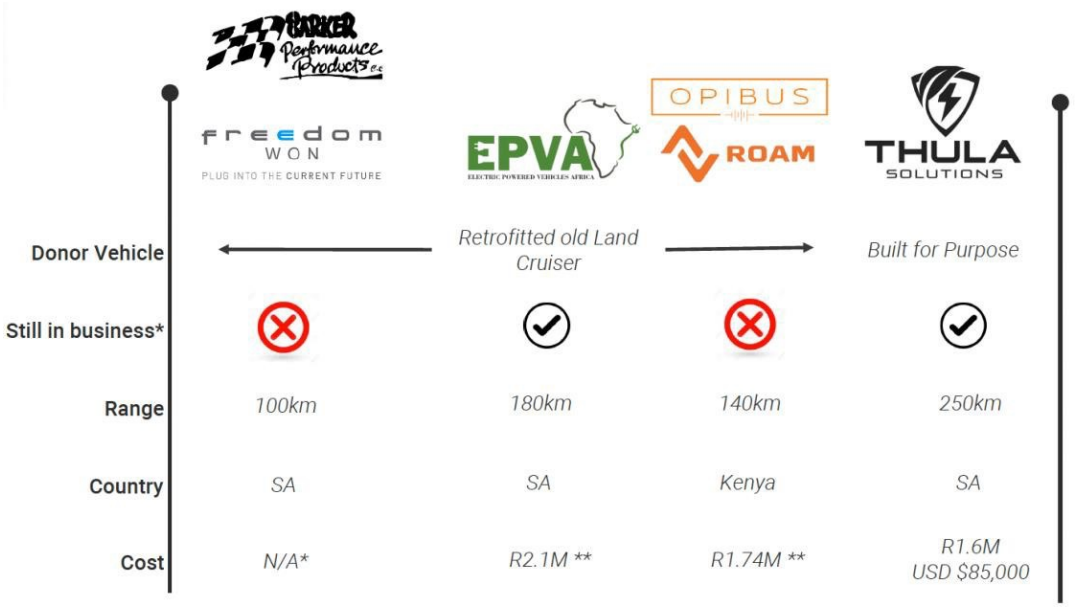


Figure 34: Summary of Electric Game Viewing Vehicles

[49] Personal communication with Gary Davies, CEO of Thula Solutions (Investment Slide Deck - Permission was obtained to share the information in this report.)

Further research into the technology and the markets for electric game viewers revealed that the market is attractive. Vehicles registered on Natis amounts to 45 000 with an estimated value of US$ 3.8 billion.

Analysing the existing competition showed that all competitors used previous diesel vehicles. Thula Solutions develops their own chassis and finds that total costs could be reduced, and a superior product can be provided to the customer. Figure 34 shows that Thula realised that technical conversions of vehicles was not the best way to go.

These vehicles were designed as ICE vehicles with specific space for the engine, drive shafts and fuel system. Replacing these with an electric motor and battery pack posed problems that could also influence compliance with homologation requirements and compromise safety of the occupants.

Thula went further and developed a comprehensive business model shown below in Figure 35.



Figure 35: The Unique Selling Proposition of Thula Solutions.

The Thula Solutions' electric game viewer offers an all-wheel drive with two powerful motors of 225kW with a range of 250km. Charge time is about four hours.

[49] Personal communication with Gary Davies, CEO of Thula Solutions (Investment Slide Deck - Permission was obtained to share the information in this report.)

2.7 Closing Thoughts

Micro-mobility offers a range of opportunities, but the following issues need to be considered:

- Petrol scooters and motorbikes need to be refuelled with petrol found only at filling stations. It is combusted in the vehicle engine, poisoning the air in the city, and believed to contribute in a significant way to climate change.
- Charging of electric micro-mobility options/vehicles can happen at home, at work, or in public places.
- Given the shorter distance of many trips taken with micro mobility devices, micro mobility charging infrastructure planning typically occurs at the community or on-site level.
- One challenge of micro-mobility infrastructure planning is the lack of standardisation and universal/ interoperable charging equipment. Micro-mobility devices use proprietary charging cables (which may or may not be affixed to the devices) or docks that connect to standard wall outlets. Micro-mobility devices may have removable or fixed batteries, with implications for charging infrastructure.
- E-bikes with removable batteries can be serviced at indoor charging stations. For example, lockers that contain proprietary charging cables where riders can charge their e-bike batteries. E-bikes with non-removable batteries, can be charged at charge points located outdoors.
- Micro-mobility EV can be used in the following indoor settings due to zero emissions: packing houses for fruits, DC centres, manufacturing plants, etc.

[49] Personal communication with Gary Davies, CEO of Thula Solutions (Investment Slide Deck - Permission was obtained to share the information in this report.)

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