Repurposing Alternators as Motors: Promoting Sustainability and Circular Economy in Low-Cost Mobility Systems

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Abstract: The automotive industry is undergoing a transformation driven by electric mobility, automated driving, and value creation. However, this shift often overlooks developing regions, where unique challenges restrict access to affordable, low-emission transportation. This paper explores how repurposing parts from end-of-life vehicles can promote sustainable mobility solutions in developing regions, where access to transportation is limited. We focus on converting alternators from internal combustion engines into electric motors, benefiting both the environment and resource-constrained populations. Our approach follows seven requirements for a sustainable mobility system, emphasizing affordability, sustainability, and circular economy principles over high-performance, costly solutions. By applying circular economy principles, we highlight the reuse of available alternators from scrap vehicles, providing a cost-effective and eco-friendly solution suited to the needs of developing regions. This approach addresses several Sustainable Development Goals, enhancing access to clean energy, economic growth, and responsible consumption. Engaging with local communities provided insights into specific needs and ensured practical applicability. To validate our approach, we conducted rig tests and field studies in Africa and Germany to assess the performance and viability of the repurposed alternators in real-world conditions. Successful testing in both regions demonstrates that this mobility system offers a practical solution to real-world challenges.

1 INTRODUCTION

Mobility in Africa faces significant challenges, as inadequate transportation infrastructure and high costs hinder development and limit access to essential services. These issues not only contribute to social inequality but also impede economic growth in many regions. Many communities are left with little choice but to rely on expensive transportation options, which are often not sustainable nor accessible for lower-income populations. Moreover, there is a considerable amount of scrap material, including vehicle alternators, that could be repurposed for alternative uses, alongside solar energy resources that remain underutilized.

This research addresses the conversion of vehicle alternators into electric motors as a low-cost solution to mobility challenges in resource-limited environments. By repurposing alternators, originally designed to convert mechanical energy into electrical energy for battery charging, this approach offers a sustainable alternative to conventional electric motors, especially when vehicles are no longer operational.

Grounded in circular economy principles, this conversion minimizes environmental impact by extending the life cycle of existing components, reducing the need for new motor production. Furthermore, it addresses the economic limitations of developing regions and supports the achievement of *Sustainable Development Goals* (SDGs) related to accessibility and sustainability, particularly in African contexts where financial resources are limited.

The goal of this research is not to improve the electrical performance of the alternator in its new application, but rather to maximize its applicability as an electric motor within the constraints of affordability, technical limitations of the given alternator, and sustainability. This includes addressing challenges such as the performance of the alternator in low speed sce-

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narios and identifying cost-effective modifications, such as the integration of Hall sensors, to improve its usability. These modifications is evaluated both under field conditions in The Gambia and through controlled testing in Germany to assess their practical impact on vehicle performance.

This paper contributes to the state of the art by:

- Showcasing a practical implementation of circular economy principles in the automotive sector through the reuse of vehicle alternators for mobility solutions.
- Presenting a structured approach for optimizing the performance of repurposed alternators as electric motors, focusing on cost-effective modifications.
- Linking circular economy, reuse, engineering optimization, and sustainability to address real-world mobility challenges.
- Conducting a field study to demonstrate the feasibility of a low-cost solution for providing affordable and sustainable transportation in resource-limited regions.
- Addressing a gap in the literature by focusing on the transportation needs of developing countries through reused, low-cost components.

2 MOBILITY IN AFRICA

The mobility situation in many African countries, especially in rural areas, faces distinct challenges. Economic constraints and poor infrastructure are major factors affecting transportation. In Malawi, Tanzania, and Uganda, households spend 62% of their income on food and 15% on utilities, leaving little for transportation (De Magalhães and Santaeulàlia-Llopis, 2018). With an average monthly GDP per capita of $156.29, many cannot afford regular vehicle ownership (Statista, 2024d). In addition, fuel prices, with octane-95 gasoline averaging $1.478 per liter across seven African countries, further complicate affordability for many (Statista, 2024c).

Rural transportation costs are also disproportionately high. In Zimbabwe, the availability of motorized vehicles is limited, with an average of only one vehicle per 300 people. In addition, the cost of transportation for a 30 km trip is 2.5 times higher than in comparable Asian regions. Poor road conditions, unreliable transport services, and high travel costs make it difficult for rural residents to access essential services such as markets, health care, and education (Porter, 2002). Non-motorized and animal-powered transportation, including bicycles and ox carts, remain common due to economic and infrastructure constraints, while motorized transportation is scarce in many regions (Porter, 2016).

In urban areas, the growing use of cheap imported cars, coupled with underdeveloped public transport, has led to congestion and pollution. In Freetown, Sierra Leone, car ownership remains below 20%, leading many residents to rely on walking or public transportation. While these options may provide environmental benefits, it is crucial that they facilitate universal access and provide pathways for other opportunities to align with the SDGs on inclusion and economic growth. This highlights the need for more sustainable and accessible mobility solutions (Teoh et al., 2020; Cavoli, 2021; Pojani and Stead, 2017; Koroma et al., 2021; Oviedo et al., 2024). Additionally, outdated vehicles contribute to environmental and health risks that cause one in eight premature deaths worldwide each year (World Health Organization, 2016).

In many African countries, vehicle regulations are often loosely defined or inconsistently enforced, particularly in rural areas (DW, 2018). This lack of strict regulation presents an opportunity for more self-built solutions, as they can be deployed without the rigid compliance requirements typical of more regulated markets. In addition, low income levels, as indicated by average GDP per capita, necessitate reliance on small and community-based ventures, such as vehicle maintenance and modification (Moos and Sambo, 2018; Izogo, 2015). The limited financial resources, coupled with restricted access to formal automotive services and new vehicles, drive local communities to depend on these smaller enterprises.

In terms of energy, Gabon achieved the highest *Environmental Performance Index* (EPI) score in Africa in 2024, with 53.1 out of 100, compared to Estonia's highest European score of 75.3 (Statista, 2024b; Statista, 2024e). This highlights the environmental challenges faced by the continent, as the continent's best score of 53.1 indicates that overall performance in other regions is considerably lower. In response, many African countries have implemented regulatory measures, including restrictions on the import of older, more polluting vehicles, to reduce harmful emissions. In 2020, all 15 member states of the *Economic Community of West African States* (ECOWAS) agreed on provisional regulations to promote cleaner fuels and vehicles in the region (Ayetor et al., 2021). This aligns with Africa's increasing renewable energy generation, reaching 218.3 TWh in 2023, up from 140 TWh in 2015, underscoring the continent's commitment to sustainable energy sources and their long-term availability (Statista, 2024a).

2.1 Requirements for Low-Cost Mobility Systems

Based on the analysis of the mobility situation in Africa, *requirements* (**R**) are derived for a mobility system applicable in this domain:

R1: The mobility system must be affordable, taking into account the financial constraints of the general population to ensure widespread adoption.

R2: The production process of the mobility system must be sustainable, incorporating the use of recycled materials and environmentally friendly practices to minimize ecological impact.

R3: The operation of the mobility system must be sustainable, prioritizing renewable energy sources and minimizing dependence on fossil fuels to ensure environmental compatibility, economic viability, and social equity over the long term.

R4: The energy source for the mobility system must be accessible and affordable to the majority of the general African population.

R5: The mobility system must be integrated into existing value chains, using existing resources to facilitate rapid deployment without the need for new supply chains.

R6: The mobility system must comply with local regulations, ensuring compliance with existing laws on vehicles and mobility systems.

R7: The mobility system shall promote local business opportunities, supporting community-driven enterprises in the sale, customization, maintenance and modification of the system, thereby fostering local economic growth and innovation.

3 RELATED WORK

In recent years, several mobility solutions have been developed with the goal of providing sustainable, low-cost transportation suitable for use in Africa.

3.1 The aCar

The aCar, developed by Evum Motors, is a multi-purpose electric vehicle designed for agricultural transport and small public transport (Šoltés et al., 2018; Minnerup et al., 2018). Equipped with two 8 kW motors, the aCar has a range of 80 km, a top speed of 50-60 km/h and a payload capacity of up to 800 kg. Although promoted as a low-cost solution for the African market, the aCar is manufactured exclusively in Germany, with sales today limited to European markets and acquisition costs unspecified. This production model increases costs and limits accessibility for African users. The aCar's design relies on purpose-built electric motors and a large battery, relying on components that are not widely available in Africa. This reliance disrupts local value chains and reduces the potential for community involvement in assembly. While complying with European regulations, the aCar's distribution model excludes local businesses, limiting opportunities for community-driven economic development.

3.2 The B-Van and Bee Models

Bako Motors' B-Van and Bee vehicles are solar-assisted electric vehicles designed for urban transportation and last-mile delivery in African cities (Bako Motors, 2024). The B-Van, priced between $7,345 and $12,915 (excluding import tax), has a 7.5 kW motor, a range of 100-300 km, a payload capacity of 400 kg, and a top speed of 70 km/h. The Bee, priced from $5,271 to $8,049 (excluding import tax), has a 2 kW motor, a range of 50-120 km, and a top speed of 45 km/h. While solar charging extends battery life, these prices limit affordability for many African users. Both models rely on custom-made components, creating a dependency on external supply chains and imported parts, which increases costs and hinders local integration. With assembly in Tunisia, the vehicles are primarily available in that region, limiting the accessibility and participation of local businesses in broader African markets.

3.3 The Jidi Electric Motorcycle

In collaboration with a Chinese company, Kofa developed the Jidi electric motorcycle as part of a battery-swapping network in Accra, Ghana (Kofa, 2024). The Jidi has a top speed of 85 km/h, a payload capacity of 223 kg, and a range of 100 km per charge. The battery swapping stations provide a convenient option for users, reducing downtime associated with charging. Although positioned as an affordable alternative to internal combustion motorcycles, the exact cost of the Jidi is not specified. Its reliance on a centralized battery swapping network limits scalability outside of supported regions. Without local manufacturing or assembly, reliance on imported components limits integration into local economies, reducing opportunities for local job creation and entrepreneurship in African communities.

Table 1: Mapping of mobility solutions of the related work to the *requirements* (**R**) of a low-cost mobility system for Africa.

	R1	R2	R3	R4	R5	R6	R7
(Šoltés et al., 2018)	-	-	✓	✓	-	✓	-
(Bako Motors, 2024)	-	-	✓	✓	-	✓	-
(Kofa, 2024)	-	-	✓	✓	-	✓	-
(ITQ, 2024)	-	✓	✓	✓	✓	✓	✓
(Dayang Naki, 2024)	-	-	-	-	-	✓	-

3.4 The Bamboo Solar Car

The Bamboo Solar Car, developed by ITQ GmbH, is a prototype for low-cost, sustainable mobility using bamboo and recycled materials, designed for regions with limited infrastructure (ITQ, 2024). Powered by a solar panel with an energy output of up to 4 kWh, it has a range of 30 km and a top speed of 40 km/h. Despite the use of recycled materials, the core of the system relies on a purpose-built electric motor, adding to the overall cost. According to an interview with the developer, the prototype cost approximately $3,000, highlighting the limitations of affordability despite the project's focus on sustainability and accessibility.

3.5 The DY-H6 Tricycle

The DY-H6 tricycle, produced by Chongqing Beiyi Vehicle Co., Ltd. in China, is designed for cargo transport in Africa, featuring a 250cc water-cooled petrol engine and a maximum speed of 60 km/h (Dayang Naki, 2024). With a payload capacity of up to 1,500 kg and a price of approximately $1,313 (excluding import duty), it offers utility for heavy loads. However, the DY-H6's fossil fuel engine aggravates greenhouse gas emissions and does not meet long-term sustainability goals in Africa, demanding environmentally friendly transport. Furthermore, its construction lacks integration with local renewable resources, limiting potential economic benefits for communities.

Despite the interest in sustainable solutions, achieving affordability, accessibility, and integration with local resources remains a challenge. These mobility solutions, while innovative in addressing Africa's mobility challenges, are constrained by reliance on imported components and varying degrees of sustainability, which impact their overall effectiveness and accessibility.

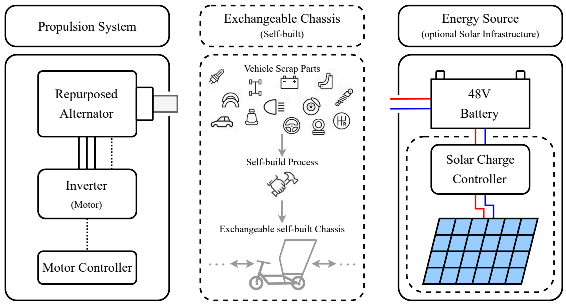

Figure 1: Adaptable architecture of the proposed mobility system that promotes sustainability and circular economy to meet **R1-7**.

4 METHOD

The analysis of current mobility systems reveals that no existing concept is fully suitable as a low-cost and sustainable solution for the African market, as none of the available technologies meets all of the outlined requirements (Tab. 1). While existing concepts may not fully address these needs, the topic of repurposing components has not yet been explored and holds significant potential in this context. To address this gap, a novel method is proposed, targeting the specific constraints and opportunities of the African market.

The core structure of the proposed mobility system is designed to be cost-effective, sustainable, and easy to implement by utilizing repurposed components to meet the requirements **R1-7**. It promotes the principles of a circular economy, emphasizing reuse, resource efficiency, and local economic empowerment. To achieve this, the mobility system is divided into three primary subsystems derived from the fundamental systems of any vehicle: the propulsion system, the chassis, and the energy source. The proposed mobility system includes a repurposed alternator that functions as a motor, an exchangeable self-built chassis that allows for flexibility, and a battery for energy storage with the potential for solar energy integration (Fig. 1). Each subsystem needs to be considered on its own to provide an affordable and sustainable solution suitable for potentially widespread adoption in the African market.

4.1 The Propulsion System

The propulsion system consists of a motor and a controller. To reduce costs, a repurposed vehicle alternator, in this case a $164 truck alternator, is repurposed to function as an electric motor. This component is readily available within existing value chains, facilitating easy access and implementation. Typically used in conventional vehicles to generate electricity, this alternator has been retrofitted with a motor controller to enable its use as an electric motor. This modification brings the alternator closer to the performance level of a purpose-built electric motor, which would cost between $262 and $313 (Zhyt, 2024; QS Motors, 2024).

To ensure safety, especially in the absence of comprehensive regulatory requirements, the system voltage is limited to 48V, providing a balance between safety and performance. Since the alternator is a key component of the propulsion system, it remains a standardized, non-interchangeable element, ensuring that all requirements **R1-7** are met. Since vehicle alternators are primarily optimized for generating electrical energy from mechanical energy, they do not provide sufficient power when repurposed for use as electric motors, especially given their sensorless design. Therefore, an optimization process is implemented to enhance their performance and reliability, ensuring long-term functionality in the target domain.

4.2 The Chassis

Given the propulsion system and in accordance with circular economy principles, the chassis can be assembled from any modular components, allowing end-users to build their own vehicles using locally available materials. This approach supports local entrepreneurship and innovation, as users can use scrapped vehicles, bicycles, tricycles, motorcycles, or fabricate new chassis using scrap metal and other reused materials. This flexibility enables individuals to create a wide range of mobility solutions tailored to specific needs, while keeping costs low and encouraging local economic participation.

4.3 The Energy Source

The choice of energy source is driven by accessibility, affordability, and sustainability. Fossil fuels, as outlined in the analysis in Chapter 2, are economically prohibitive, consuming a significant percentage (0.95%) of monthly income per liter. Instead, electric energy is identified as the most viable and sustainable option, as reusing old 12 V vehicle batteries for energy storage supports both renewable energy and circular economy goals. In addition, accessibility can be improved by using existing solar infrastructure, as Africa receives up to 9.5 hours of sunlight per day (Luxman Light, 2019) with solar panels producing 263 W/m² (European Union, 2022). This solar resource makes electric power the most suitable low-cost energy source for the proposed mobility system.

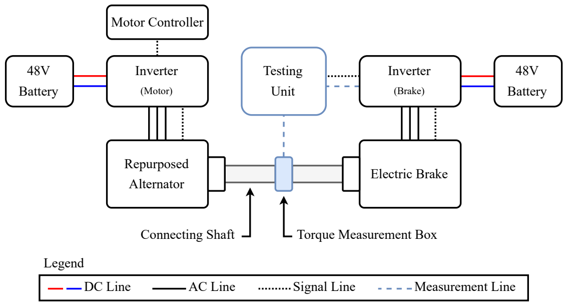

Figure 2: Measurement setup for rig testing in Germany.

4.4 Evaluation of the Propulsion System

As core component of the mobility system, the propulsion system is evaluated in two key ways:

1. Rig testing is conducted to evaluate the technical feasibility and performance of the alternator-based propulsion system. This testing focuses on ensuring that the repurposed alternator will function effectively under realistic operating conditions.
2. A field study analysis in Africa and Germany is used to test the applicability of the system within the target domain, evaluating how well the solution fits with local needs, infrastructure and user capabilities.

By integrating low-cost, reusable components and focusing on circular economy principles, the proposed approach provides a sustainable, affordable and scalable solution for mobility in Africa that meets the requirements outlined in **R1-7**.

5 EXPERIMENTS

5.1 Measurement Setup

The measurement setup is designed to evaluate the electrical performance in terms of power output of the repurposed alternator acting as a motor (Fig. 2). The test rig includes a dedicated electric motor that acts as an electric brake. This brake motor is mechanically coupled to the motor under test via a joint shaft, allowing the motor under test to operate against a variable resistance. This setup allows characterization of the motor performance under different load conditions.

A torque sensor is mounted on the shaft to measure the torque output of the motor under test. In addition, the speed (in rpm) is monitored at the electric brake, which remains synchronized with the motor under test due to the direct mechanical coupling.

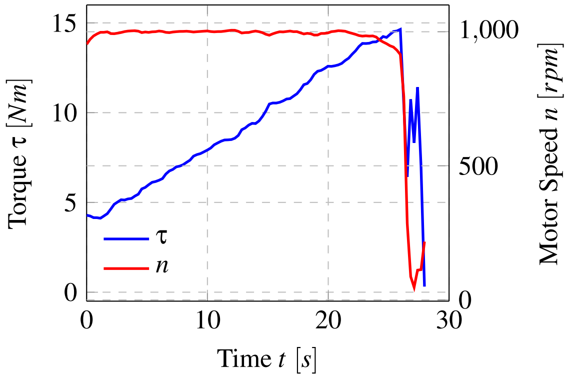

Figure 3: Exemplary measurement of the performance at the operating point of the motor under test at 1000 rpm.

To generate a performance map, the motor under test, in this case the repurposed alternator, is evaluated over a range of operating points. The motor controller of the motor under test is configured to maintain a constant, predefined speed. Meanwhile, the electric brake incrementally increases the resisting torque in a linear pattern. When the speed of the motor under test drops more than 50 rpm from the set point, the corresponding torque value is recorded (Fig. 3). This procedure is repeated at various speeds to produce a complete torque-speed map of the motor under test.

5.2 Low-Cost Optimization Process

The direct use of a repurposed alternator as an electric motor results in performance limitations, especially at low speeds, which reduces the overall usability of the propulsion system for the intended application. These performance limitations were particularly evident during acceleration, where very fine throttle control was required, causing the vehicle to start in a jerky rather than smooth manner. This is due to the lack of rotor position sensors which support accurate motor control. To address this issue, a low-cost optimization is introduced by integrating three Hall sensors to measure the rotor position. This optimization adds only $3.17 (Reichelt Elektronik, 2024) to the total system cost (excluding labor), making it a cost-effective solution for improving performance.

To ensure accurate sensor placement, the Hall sensors are embedded directly into the stator by milling recesses in its winding slots at 120° electrical intervals (Fig. 4). This arrangement ensures precise phase alignment and improves the overall control of the motor during operation. Rotor position data is a crucial parameter for the motor controller as it allows precise phase switching during operation. Without this data, the controller must estimate the optimal timing for phase activation, resulting in inefficiencies and reduced performance. By integrating Hall sensors, the motor controller receives direct feedback on the rotor position, allowing more accurate control of each phase. This improves motor performance in both start-up scenarios and continuous operation.

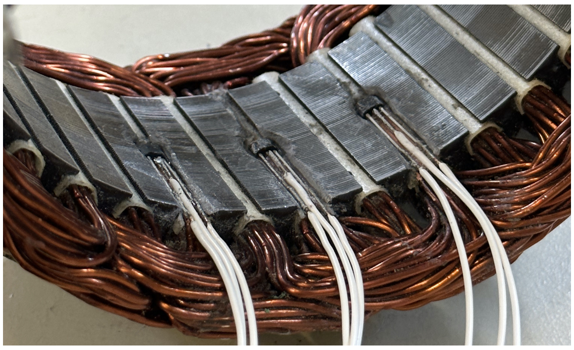

Figure 4: Low-cost integration of three Hall sensors into the stator of a repurposed alternator.

5.3 Optimization Results

In scenarios where the motor operates without Hall sensor optimization, start-up oscillations occur, lasting about 3.79 seconds with an amplitude of 2.43 Nm and 60 rpm. These oscillations cause instability in both torque output and rotational speed (Fig. 5), delaying the motor's ability to reach a stable state and reducing its suitability for real-world driving due to compromised driving behavior.

After the optimization of integrating three Hall sensors, the motor's performance in start-up scenarios is significantly improved. The motor reaches a stable operating state almost immediately, with no observable oscillations. Additionally, the torque during the start-up phase is increased by 3.7 Nm, ensuring smoother acceleration and better handling in low-speed conditions (Fig. 6). This improvement enhances the overall driving experience, particularly in scenarios requiring frequent stops and starts, such as urban driving or off-road mobility, and enables higher payloads or steeper inclines in practical applications.

Experimental testing of the motor at various operating points indicates a significant improvement in driving performance after optimization. The motor's torque-speed characteristic shows a consistently higher torque output at equivalent rpm levels. The optimized motor setup with Hall sensors shows an 18.74% increase in the area under the torque-speed curve, corresponding to an increase in performance over the entire operating range (Fig. 7). This performance gain allows the motor to handle a wider range of driving conditions while maintaining the low-cost goals of the concept.

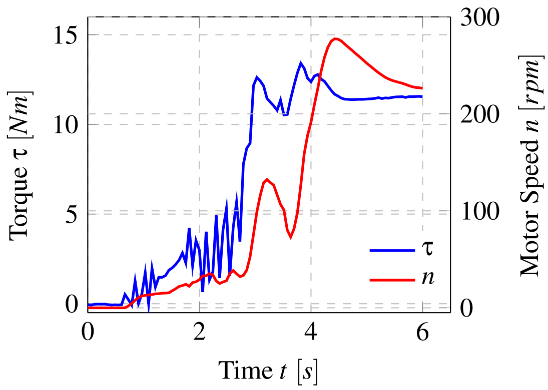

Figure 5: Start-up scenario without optimization.

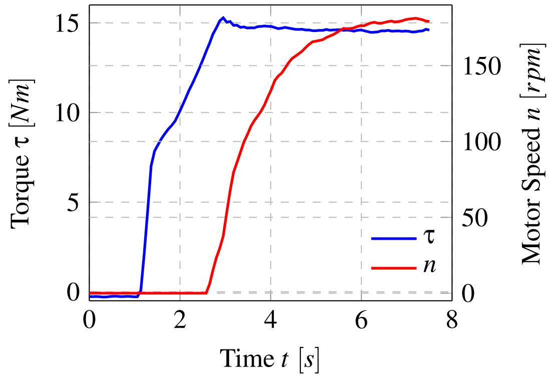

Figure 6: Start-up scenario optimized with Hall sensors.

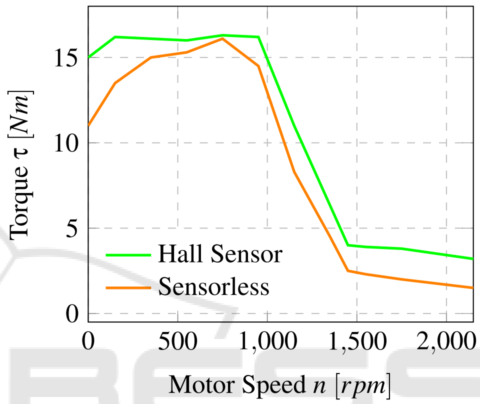

Figure 7: Performance maps of both repurposed alternators under test with and without optimization.

6 FIELD STUDY

Since technical feasibility is not sufficient to prove the applicability of the mobility system with the repurposed alternator as the propulsion unit in the given domain, a field study was conducted in Africa. In this field study, a participant from The Gambia has constructed a self-built vehicle by following a multi-step process. These tasks involved both mechanical and electrical work to repurpose an alternator and self-build a chassis, with the goal of creating a functional vehicle capable of daily use in the local environment. The results of this field study in The Gambia is complemented by controlled performance evaluations conducted in Germany.

6.1 Field Study in the Gambia

A 37-year-old car mechanic from The Gambia was selected for the study. Using scrap parts from two motorcycles, he constructed a self-built steel chassis (Fig. 8(a), 8(b)). While the participant had sufficient mechanical knowledge to build the chassis, his electrical knowledge was limited. However, with the help of a detailed manual for the conversion process, he was able to repurpose a $35 used car alternator and complete the electrical integration of the motor and controller into the vehicle. To improve energy efficiency and reduce dependence on external charging infrastructure, the participant was also tasked with installing a solar panel on the roof of the vehicle and connecting it via an inverter to the provided 48V lithium-ion battery.

Despite the challenges of self-building the chassis and performing the electrical integration, the participant was able to complete the construction of the vehicle and get it operational. While exact performance metrics such as range and energy consumption were not measured due to the lack of suitable test equipment, the participant was able to drive the vehicle under real-world conditions, demonstrating the feasibility of the system's design and integration in the target domain.

6.2 Controlled Performance Evaluation in Germany

Due to the limited measurement capabilities in The Gambia, the propulsion system was also evaluated under controlled conditions in Germany. This involved a comprehensive assessment using dedicated measurement equipment to quantify key performance parameters of the prototype vehicle (Fig. 8(c)).

The converted tricycle used for testing had a dry mass of 490 kg, with a payload capacity of 145 kg. During testing, the vehicle was driven over paved and unpaved roads with a payload of up to 180 kg to simulate intensified real-world conditions.

The propulsion system showed an average power consumption of 576 W during regular driving at 17 km/h, with peak power consumption reaching 1600

(a) (b) (c)

Figure 8: Prototype vehicles for field tests in (a) Africa and (c) Germany, and a sample of the chassis construction process (b) in Africa.

W under higher loads on steep inclines. The integration of the solar panel allowed a 36% range extension during operation, reducing the dependence on external charging infrastructure. The battery charging time for 50% of the 93 Ah capacity, under typical German solar conditions in July with daylight charging, was recorded at 10.7 hours. Under regular driving conditions on level, paved roads and without additional payload, a full charge provided a calculated range of approximately 132 km using battery power solely.

In terms of performance, the vehicle reached a top speed of 24 km/h, limited by a gear ratio of 5.17. This ratio, which can be adjusted for higher speeds, limits top speed but increases torque at low speeds. Issues were observed during the start-up scenarios without rotor position sensor optimization, where smooth acceleration required very fine throttle control. Implementing Hall sensor optimization significantly improved responsiveness and torque during the initial acceleration phase as shown in Figures 5, 6.

No major mechanical or electrical failures were observed during the test phase, demonstrating the robustness of the propulsion system in terms of durability in day-to-day operation. Minor adjustments to the motor controller settings were required to optimize the balance between power output and energy consumption.

7 EVALUATION

Existing mobility solutions in Africa often lack cost-effectiveness, local adaptability, and environmental integration. While some focus on sustainability through electric or solar power, they typically depend on imported components and centralized production, which limits local assembly and maintenance opportunities. Moreover, these concepts frequently overlook the specific needs of African users, reducing their potential to promote community-driven economic growth. This highlights the necessity for an alternative approach that prioritizes affordability, resource availability, and local adaptability. The following evaluation demonstrates that the proposed approach fulfills all requirements **R1-7**, based on findings from rig testing, a field study in The Gambia, and controlled testing in Germany.

The mobility system has been designed to be economically viable for widespread use. Repurposing a truck alternator into an electric motor can reduce the cost of the motor component by close to \$150, or up to \$280 using scrap alternators in The Gambia, compared to the significantly higher cost of purpose-built electric motors. The low-cost optimization, which integrates three Hall sensors for rotor position sensing add an additional cost of only \$3.17, ensuring both affordability and enhanced functionality. By lowering the financial barriers to adopting sustainable propulsion technologies, this approach enhances accessibility to mobility solutions, particularly for underserved populations. The reduced cost allows broader participation in mobility, thereby addressing inequalities in access to transportation (SDG 10: Reduced Inequalities). Results from the Gambia field study demonstrated that, even with limited resources, the participant could affordably implement the propulsion system in a self-built chassis using a repurposed alternator, a solar panel, and locally sourced materials, validating the system's suitability within financial constraints (**R1**).

The production process emphasizes the use of reused and repurposed components to lower costs and reduce environmental impact. The alternator, a standard automotive part, is commonly available from scrap vehicles, promoting a circular economy and waste reduction (SDG 12: Responsible Consumption and Production). The use of scrap metal and salvaged materials for chassis construction, as observed in the Gambian field study, further reinforces sustainable production. Controlled testing in Germany confirmed that repurposed components deliver adequate performance, demonstrating that reliance on recycled materials does not compromise functionality, thus meeting **R2**.

The mobility system emphasizes renewable energy, particularly solar power, as a primary source of energy without reliance on fossil fuels. During testing in Germany, a solar panel extended the vehicle's range by 36%, demonstrating that solar charging can sufficiently supplement battery power to improve energy sustainability (SDG 7: Affordable and Clean Energy). The field study in The Gambia confirmed the feasibility of integrating locally sourced solar panels, aligning the system with renewable energy goals. These results demonstrate the sustainable operation of the system, fulfilling **R3**.

The use of electric energy, combined with solar power, ensures broad accessibility, low operating costs, and independence from local power grids. Data from German tests indicated that solar charging could reduce the reliance on external charging infrastructure, which was confirmed in the African field study. This system design effectively meets **R4** by providing an accessible, cost-effective energy solution (SDG 9: Industry, Innovation, and Infrastructure).

The mobility system is designed to be compatible with existing automotive and energy supply chains. By using a standardized vehicle alternator, it leverages the existing automotive parts supply without requiring specialized production. The field study demonstrated that local mechanics could successfully repurpose components and integrate them into a self-built chassis, satisfying **R5** and supporting rapid, resource-efficient deployment (SDG 17: Partnerships for the Goals).

To ensure safety in the absence of explicit regulations, the system voltage was limited to 48 V, a threshold generally considered safe. Both the Gambian field study and controlled tests in Germany confirmed usability at this voltage, indicating compliance with local regulatory expectations in areas with limited formal vehicle regulations, satisfying **R6**.

The system design promotes local entrepreneurship by enabling end-users to build, maintain, and customize vehicles using locally available resources. The Gambian participant constructed a customized vehicle chassis from scrap materials, showcasing the system's adaptability and promoting relevant skills within the local economy. This potential for local assembly fosters small businesses focusing on parts sales, maintenance, and modification, supporting economic growth and aligning with **R7** (SDG 8: Decent Work and Economic Growth).

In conclusion, the proposed mobility system addresses the defined requirements **R1-7** through a focus on cost-effectiveness, sustainability, accessibility, and adaptability. Evaluation results from rig and field testing confirm the system's compliance with financial, environmental, and regulatory requirements specific to the African market while supporting key SDGs such as Affordable and Clean Energy (SDG 7), Decent Work and Economic Growth (SDG 8), Reduced Inequalities (SDG 10), and Responsible Consumption and Production (SDG 12).

8 CONCLUSION AND FUTURE WORK

The proposed method of repurposing vehicle alternators as electric motors demonstrates a feasible approach to advancing sustainability and circular economy principles in low-cost propulsion systems suitable for the African market. By reusing available components such as alternators and utilizing locally sourced materials for chassis construction, this system not only minimizes waste but also reduces production costs. Its compatibility with solar power maximizes the benefits of Africa's sunlight, creating an affordable and renewable energy solution that reduces dependence on fossil fuels.

The system's modular design supports local businesses by allowing for local assembly, maintenance, and customization, fostering economic growth and community-driven innovation. This adaptability positions the proposed system as a valuable tool for increasing mobility access in resource-poor regions, providing a scalable solution that can meet diverse transportation needs, contributing to the achievement of SDGs focused on inclusive transportation.

The proposed method is subject to several limitations. The speed controller of the motor is restricted by the inability to adjust its control parameters, which affects the measurement results since no parameter fine-tuning is possible. In the measurement process, torque inaccuracies and slight noise from the test rig limit the accuracy of the measurement results, which were mitigated by filtering. In addition, the tests conducted in Germany used a new truck alternator rather than a reused one to ensure comparable results. This may affect generalizability compared to repurposed components in field applications.

Future research will include a larger field study that will deploy multiple vehicles equipped with the proposed propulsion system across Africa to operate under different local conditions. This might enable further refinements to improve adaptability, durability, and overall user satisfaction in target markets. In addition, motor performance optimizations are aimed at improving the handling and speed capabilities of the drive system, thus optimizing it for a variety of real-world applications. The motor controller, while significantly impacting the propulsion system's performance, was not included in this research project. Future studies should conduct a comparative analysis of different controllers, focusing on both cost-effectiveness and performance. Additionally, the environmental and economic impact of using end of life components for the presented mobility solution should be elaborated quantitatively.

REFERENCES

Ayetor, G., Mbonigaba, I., Sackey, M., and Andoh, P. (2021). Vehicle regulations in africa: Impact on used vehicle import and new vehicle sales. *Transportation Research Interdisciplinary Perspectives*, 10:100384.

Bako Motors (2024). Website Bako Motors. https://bakomotors.com. Accessed: October 2, 2024.

Cavoli, C. (2021). Accelerating sustainable mobility and land-use transitions in rapidly growing cities: Identifying common patterns and enabling factors. *Journal of Transport Geography*, 94:103093.

Dayang Naki (2024). DY-H6 Hot Selling Africa Cargo Tricycle Models with Powerful Engine of 250cc. https://www.dayangnaki.com. Accessed: October 1, 2024.

De Magalhães, L. and Santaeulàlia-Llopis, R. (2018). The consumption, income, and wealth of the poorest: An empirical analysis of economic inequality in rural and urban sub-saharan africa for macroeconomists. *Journal of Development Economics*, 134:350–371.

DW (2018). Durch Autoexporte dicke Luft in Afrika. https://www.dw.com/de/a-44805459. Accessed: October 11, 2024.

European Union (2022). Could a giant solar array in the sahara resolve our energy needs? https://cordis.europa.eu/article/id/442711. Accessed: October 8, 2024.

ITQ (2024). Bamboo solar car – smart green island projects. https://stetter-itq.com. Accessed: October 8, 2024.

Izogo, E. E. (2015). Customers' service quality perception in automotive repair. *African Journal of Economic and Management Studies*, 6(3):272–288.

Kofa (2024). The TAILG Jidi - Powered by Kofa. https://www.kofa.co. Accessed: October 7, 2024.

Koroma, B., Oviedo, D., Yusuf, Y., Macarthy, J., Cavoli, C., Jones, P., Levy, C., and Sellu, S. (2021). City profile: Freetown, base conditions of mobility, accessibility and land use. *T-SUM*. UCL.

Luxman Light (2019). The influence of average annual sunshine and total solar radiation intensity in africa for solar street light. https://luxmanlight.com/the-influence-of-average-annual-sunshine. Accessed: October 8, 2024.

Minnerup, K., Kalt, S., Lin, X., Koberstaedt, S., and Lienkamp, M. (2018). A 48 v drive train for a utility vehicle designed for rural africa - review and analysis. In *2018 21st International Conference on Electrical Machines and Systems (ICEMS)*, pages 2477–2482.

Moos, M. and Sambo, W. (2018). An exploratory study of challenges faced by small automotive businesses in townships : the case of garankuwa, south africa. *Journal of Contemporary Management*, 15(1):467–494.

Oviedo, D., Cavoli, C., Yusuf, Y., Koroma, B., and Chong, A. Z. W. (2024). Everyday accessibility practices and experiences in a context of transitions to sustainable mobility: Qualitative evidence from sub-saharan africa. *International Journal of Sustainable Transportation*, 18(4):328–343.

Pojani, D. and Stead, D. (2017). *The Urban Transport Crisis in Emerging Economies: An Introduction*, pages 1–10. Springer International Publishing, Cham.

Porter, G. (2002). Living in a walking world: Rural mobility and social equity issues in sub-saharan africa. *World Development*, 30(2):285–300.

Porter, G. (2016). Mobilities in rural africa: New connections, new challenges. *Annals of the American Association of Geographers*, 106(2):434–441.

QS Motors (2024). QS120 QSD120A-7. https://www.cnqsmotor.com. Accessed: October 12, 2024.

Reichelt Elektronik (2024). Tle4905l. https://www.reichelt.de. Accessed: August 16, 2024.

Statista (2024a). Afrika: Erzeugung erneuerbarer Energien in Afrika nach Quelle von 2000 bis 2023. https://de.statista.com. Accessed: October 5, 2024.

Statista (2024b). Afrika: Rangliste der 20 umweltfreundlichsten Länder nach dem Environmental Performance Index (EPI) im Jahr 2024. https://de.statista.com. Accessed: September 25, 2024.

Statista (2024c). Average retail prices for gasoline in Africa as of February 2024, by country. https://www.statista.com. Accessed: October 6, 2024.

Statista (2024d). Entwicklung des durchschnittlichen Bruttoinlandsprodukt (BIP) pro Kopf in Afrika von 2010 bis 2028. https://de.statista.com. Accessed: September 25, 2024.

Statista (2024e). Rangliste der 20 umweltfreundlichsten Länder nach dem Environmental Performance Index (EPI) im Jahr 2024. https://de.statista.com. Accessed: October 18, 2024.

Teoh, R., Anciaes, P., and Jones, P. (2020). Urban mobility transitions through gdp growth: Policy choices facing cities in developing countries. *Journal of Transport Geography*, 88:102832.

World Health Organization (2016). Ambient air pollution: A global assessment of exposure and burden of disease. Technical report, WHO. Accessed: October 1, 2024.

Zhyt (2024). 1500 W Electric Tricycle Motor 48 V. https://www.amazon.de/dp/B0CXXJ5TSD. Accessed: October 11, 2024.

Šoltés, M., Koberstaedt, S., Lienkamp, M., Rauchbart, S., and Frenkler, F. (2018). Acar - a electric vehicle concept for sub-saharan africa. In *2018 IEEE PES/IAS PowerAfrica*, pages 301–306.