FTVG

Future Transport Visions Group

RESEARCH REPORT

A feasibility of a universal battery charging/swapping infrastructure hubs for electric motorcycles in Uganda and electric vehicles in the United Kingdom (UK)

2025

Kyambogo University
Knowledge and Skills for Service

PRECISE
DATA TRAFFIC TECHNOLOGIES LTD

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The Future Transport Visions Group (FTVG) is an annual research and development competition funded by Rees Jeffreys Road Fund that encourages early career professionals across the transport industry to explore the challenges and opportunities posed by ongoing changes in the world around them. The FTVG runs as an annual competition; incentivising early career professionals to submit a paper, presentation, or product that delivers the vision and objectives of the group.

The vision of FTVG is to sustain a diverse group of early-career professionals to consider some of the challenges and opportunities posed by ongoing changes in the transportation industry and outline how these changes are pertinent to the future careers of transport professionals.

The FTVG is administered by a voluntary coordination group who help to organise entries and deliver the collaboration forums; this group is not involved in the submissions themselves. Decisions on funding and awards are managed by the FTVG Steering Group, in the form of selected trustees from the Rees Jeffreys Road Fund, former members of the Transport Visions Group and partner organizations.

It is a collaboration programme – both individuals and groups are welcome to submit ideas. Applicants are invited to a series of collaboration workshops to form cross-sector/cross-organizational teams. The initiative is targeted at people in the first ten years of their transport career and provides a platform for them to develop research and innovation in collaboration with other like-minded professionals.

This research report is a result of a collaborative team of researchers that were announced as successful applicants for the 2024 competition to conduct their research under the mentorship of Dr Ransford A. Acheampong, a Senior Lecturer in Transport and Urban Futures at the Department of Planning, Property and Environmental Management, University of Manchester (UK)

Further information about Future Transport Visions Group is available at
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EXECUTIVE SUMMARY

The problem

The transition to electric mobility is taking shape globally. As an example, in Uganda, electric motorcycles are becoming common on the streets of Kampala city. However, battery charging and swapping presents a big challenge to this transition, the situation exacerbated by lack of battery standards and policies. The absence of battery standardization and interoperability makes riders travel long distances and are at risk of running out of energy in the process of locating particular swap stations. This is limiting acceptability, accessibility and affordability of electric mobility. The current swapping services offered by electric mobility organisations are piecemeal and appear unsustainable. This research project introduces the concept of a universal battery charging and swapping infrastructure hub for electric motorcycles and thus conducted its feasibility. A universal hub is an idealized station with capacity to charge and swap more than one battery brand or type.

What we did

In the first part of the project, qualitative research was conducted by the Ugandan team to provide deeper insights into the battery charging and swapping industry for electric motorcycles with attention to stakeholder perspectives. Data that informed the findings in this report was collected from a consultative workshop conducted in Uganda as well as using a semi structured questionnaire. Field observations were also conducted as part of the methodology. It was difficult to do a comparative study between Uganda and United Kingdom (UK) because of the difference in operating conditions for electric motorcycles. Nonetheless, the required data for the feasibility was largely collected in Uganda and was supplemented with data collected from the UK to enhance the findings and recommendations. Data was analyzed qualitatively using words to shape findings and create a deeper understanding using the team's knowledge, expertise and experience.

The second part of the project, led by the UK team, focused on quantitative analysis to investigate electric vehicle users' perceptions and attitudes towards battery swapping initiatives. A questionnaire survey was designed to collect data from electric vehicle users in the UK (including electric car and electric cycle users) and electric motorcycle users in Uganda. We gathered 598 responses from the UK and 90 from Uganda. The questionnaire comprised three main sections: electric vehicle ownership and charging behaviour, attitudes towards battery swapping initiatives (with 15 attitudinal statements), and socio-demographic information. The data was analysed using descriptive statistics and dimension reduction techniques, such as Principal Component Analysis (PCA), to understand the attitudes of electric vehicle users towards battery swapping in both the UK and Uganda.

What we found

In Uganda, the riders rely on battery swapping with over 150 established battery charging and swapping stations across the main capital city Kampala unlike in the UK where swap stations are expected to be launched in 2025 as riders depend on home/work and public charging. Technically, economically and considering the current and future market for electric motorcycles, a universal battery charging and swapping hub is feasible. Our findings are further supported by the ongoing consortium by Honda, Yamaha, Kawasaki and Suzuki companies in developing standards for batteries and interoperability. Ugandan users are already familiar with battery charging and swapping systems and their attitudes towards this new way of charging their electric vehicles are more promising. In the UK, it is still in the discussion stage and the

users begin to realise the value and benefits of battery charging and swapping to reduce waiting times and range anxiety.

Our conclusion

The concept of a universal battery swapping and charging hub is feasible financially, technically and will have potential market given the increasing energy transition in the motorcycle industry. A universal hub appears to be the future of battery swapping for electric motorcycles with increased adoption rates and with the world's transition agenda to electric mobility. Specifically, the charging and swapping infrastructure development is still in its infancy stage with different batteries on market which is presenting challenges towards adoption and acceptability of electric motorcycles. A universal hub will provide some insights towards battery standardization and operation, facilitating interoperability.

What we recommend

Electric motorcycle organizations should start working together to solve some of their challenges regarding battery swapping and charging. In both countries, a key step in this direction is to develop some partnerships with existing fuel station organizations for business sharing models since the location of most fuel stations is strategic and ideal for battery swapping services. In the UK, since riders have their own chargers, more charging facilities at existing petrol stations, shopping malls and public spaces will be required with increased use and adoption of electric motorcycles.

As the adoption of electric mobility takes shape, it is expected that the mode of operation will equally change in the area of battery charging and swapping. The competition is likely to distort the market share and thus organizations should prepare and plan for future possibilities. Therefore, we recommend organizations should plan for swapping services and home charging in UK and Uganda respectively.

The charging and swapping infrastructure required to facilitate the adoption, acceptability and accessibility of electric mobility requires a concerted effort from all the key stakeholders including guidance from government; otherwise, the uncoordinated individual investments may not be sustainable with such unpredicted growing industry. Therefore, we recommend governments in both countries to develop standards and policies to guide the transition to electric mobility.

There is need for battery standardization and interoperability as a sustainable approach towards accelerating the shift from non – renewable to renewable energy. In the meantime, a universal battery and charging hub is recommended in both countries. However, research is needed towards developing high-capacity batteries that can sustain long distances without recharging. Alternatively, mechanisms for recharging the batteries during operation need to be explored as well.

In Uganda, the pay per use model is dominant unlike in the UK where a monthly subscription model is being introduced. As the market grows and with increasing competition, it is recommended that retailers in both countries should explore the use of other payment models as this may serve as a marketing strategy and increase the effectiveness of battery swapping services. As an example, it is recommended that organisations in Uganda explore the monthly subscription model with unlimited number of swaps subject to a standard swapping criterion.

1. Introduction

1.1. Background

Globally, there are great concerns for climate change driven by increasing greenhouse gas emissions from different human activities. The transport sector contributes about 16.2% of the global greenhouse gas emissions mainly from carbon dioxide (Ritchie and Roser, 2024). As part of the climate change agenda, decarbonization of transport modes appears to be a priority in most countries. The main points for renewables in the transport sector include electrification of transport modes using batteries. Motorcycles are particularly important because they emit more particulate matter (PM), nitrogen dioxide (NOx), Carbon monoxide (CO) and hydrocarbon than cars (Momenimovahed *et al*., 2014; Farquharson, 2019; Ehebrecht, Heinrichs and Lenz; 2018).

In many African countries, the motorcycle taxis (Boda–Boda) transport business is most common and lucrative for young people employing thousands of youths. The lack of an organized public transport system to meet the travel needs of urban people in these countries has led to the dominance of Boda–Boda motorcycles. In East Africa, Boda–Boda motorcycles have grown to become a major public transportation business despite having started as an illegal strategy of transporting goods across the Uganda/Kenya border. This resulted in the name Boda–Boda meaning crossing from one border to another border. This mode of transport is especially preferred because motorcycles can maneuver through traffic in addition to their flexibility since they pick and drop people and goods from their doors and can access locations where other means are not capable.

In developed countries, motorcycles are not a popular mode of transport, especially in passenger transport except for goods delivery where there is some growing demand in recent years. In the United Kingdom (UK), motorcycles registration and use increased by 7% in 2022 (DfT, 2023) compared to 2019 which was partly attributed to the global COVID 19 pandemic as rides become popular with a boom of delivery services. Consequently, in 2022, the UK launched a public consultation to phase out the sale of new fossil-fueled motorcycles by 2035 as part of the transport decarbonization plan (DfT,2022).

Globally, the start-up scene for transport decarbonization and more specifically with electric motorcycles is taking shape. The battery swapping infrastructure allows the riders to conveniently change their depleted batteries with a charged one overcoming the challenge of long battery charging duration. Some challenges related to lack of battery standardization, insufficient charging and swapping infrastructure, high investment and operation costs make battery swapping services ineffective. This has led to a lack of supportive swapping and charging infrastructure to meet the needs of all riders and this limits the acceptability and affordability of electric motorcycles. Setiawani *et al.* (2023) argue that swapping infrastructure is key in boosting battery service adoption and profitability and thus recommended subsidies on establishing swap stations than battery standardization. In Uganda, electric motorcycle retailers/manufacturers have made efforts by building some stations, but more sustainable solutions are required around the battery charging and swapping infrastructure. In the UK, riders rely on the home, work and public charging although there are plans to introduce battery swapping stations in 2025 by some companies.

In Uganda, different electric motorcycle companies have established charging and swapping infrastructure serving only their customers which may exacerbate the problem of profitability due to insignificant market demand. Although most of them have plans and continue to expand their network of charging stations, it may not be a sustainable and effective approach to the

growing electric mobility industry with a number of challenges. This research introduces the concept of universal battery charging and swapping hubs from two angles. Firstly, it is universal in the sense that different batteries may be charged and swapped from one station possibly under a franchise. Secondly, the concept also applies to future battery standardization and interoperability. However, the concept in this research relates to the former since efforts with battery standardization and interoperability are ongoing. Consequently, a proposal to conduct a feasibility study for a universal battery swapping and charging hub for electric motorcycles in Uganda and UK was approved as part of 2024 Future Transport Visions Group (FTVG) projects funded by Rees Jeffreys Road Fund. Therefore, this report presents the findings from this study specifically exploring the technical, market and economic feasibility of the proposed universal battery charging and swapping infrastructure station.

2. Methods

In the first part of the project, qualitative research was conducted by the Ugandan team to provide deeper insights into the battery charging and swapping industry for electric motorcycles with attention to stakeholder perspectives. The project adopted a participatory approach by collecting data from the key stakeholders in a bid to understand the different battery charging and swapping requirements. Specifically, the project targeted all the current suppliers/retailers and organizations that offer services of electric motorcycles in both countries. Data was largely collected in Uganda with established battery charging and swapping stations unlike in the UK where riders charge from home/work or public places. Data collected in the UK provides an overview of the situation in the UK and was used to enhance the recommendations presented in this report. Furthermore, the challenges and the experience so far regarding battery charging and swapping collected in Uganda provides insights to the UK with plans to introduce the battery swaps. In the initial stages, a stakeholder's workshop was organized in Uganda as part of data collection to capture key information regarding the challenges, business operation models and opportunities for synergies regarding battery charging/swapping. Interviews were also conducted using a semi structured open ended questionnaire that was developed by the project team with key subcomponents of general, market, financial and technical information. Field observations were also heavily relied on in this research given that some organisations were not ready to share information. Thus, the team was able to collect some data using this approach that was rich in detail and context. The key stakeholders in Uganda mainly retailers/manufacturers of electric motorcycles (Redvers E Mobility International Ltd, Zembo and SPIRO), Motorcycle/ Boda–Boda riders, Ministry of energy and mineral development (Uganda), Ministry of Science, Technology and Innovation (Uganda), Ministry of Works and Transport (Uganda) and Kampala Capital City Authority (KCCA) were involved in the study.

The data collected was analyzed qualitatively using words to shape findings and create a deeper understanding of the research topic. The team's knowledge, expertise and experience were used to shape findings and create a deeper understanding of the key research question. Through this, this research presents in-depth information providing great insights into the battery charging and swapping for electric motorcycles.

The second part of the project, led by the UK team, focused on quantitative analysis to investigate electric vehicle users' perceptions and attitudes towards battery swapping initiatives. A questionnaire survey was designed to gather data from electric vehicle users in the UK (including electric car and electric cycle users) and electric motorcycle users in Uganda. After piloting the questionnaire with 20 respondents, it was refined for data collection. Using the Prolific Market research polling agency, 598 responses were collected from the UK. Additionally, 90 samples were gathered from Uganda using QR codes linked to the survey. The

questionnaire consisted of three main sections: electric vehicle ownership and charging behavior, attitudes towards battery swapping initiatives (with 15 attitudinal statements), and socio-demographic information. The data was analysed using descriptive statistics and dimension reduction techniques, such as Principal Component Analysis (PCA), to understand the attitudes of electric vehicle users towards battery swapping in both Uganda and UK.

In this second part of the research, dimension reduction was employed to explore the relationships between variables and to understand the data structure (Saw *et al.,* 2020). Principal Component Analysis (PCA) is a popular dimension reduction process and that was utilized to decrease the number of random variables to a smaller set of principal components. This approach helps account for correlations, uncover underlying concepts, and aid in interpretation (McDonald, 1985). PCA is particularly effective in social science research as it retains the most vital information through data reduction (Mehmood, 2024). In this study 15 attitudinal statements were analysed using PCA to identify the underlying components.

Kaiser's criterion was utilized to ascertain the number of components to retain, suggesting the retention of all components with eigenvalues exceeding one. Additionally, the Scree test involves analyzing the eigenvalue graph to determine the components to retain, which are the data points above the 'break' (Cattell, 1978). The validity of data for PCA was examined using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity.

3. Findings

3.1. Feasibility of swapping and charging stations

The findings show contrasting operating conditions for electric motorcycles in both countries. In the UK, the electric motorcycle riders rely on home, work and public charging unlike in Uganda with established battery charging and swapping stations. However, there are efforts and plans to introduce battery swapping stations in the UK in 2025. One possible explanation for this contrasting mode of operation relates to the use of motorcycles for public transport in Uganda unlike the personal use and goods delivery in the UK. In Uganda, the number of swapping and charging stations are Redvers (01), SPIRO (27), Zembo (29) and GOGO (84). SPIRO has both automated and manual swapping stations. In all these stations, the riders pay for the battery swaps using the pay per use model. The map in Figure 1 below shows the location of current swapping and charging stations for electric motorcycles in Uganda. The collected data shows that the majority of stations are in Kampala, Uganda’s capital city. Further analysis shows that stations for different retailers are located close to each (as per the numbers shown in the map), an indication of duplication of services that may justify the need for the proposed universal hub. Further to this, the energy requirements for charging may be constrained with the current arrangements as the effect of piecemeal development of stations on the grid has not been established.

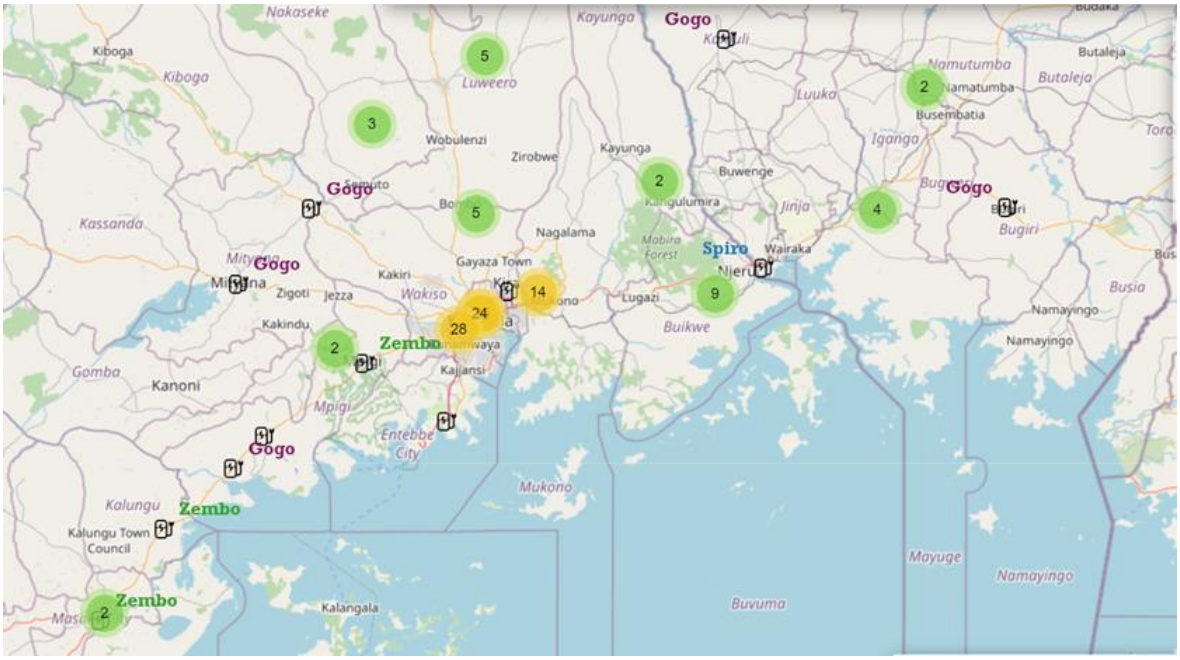

Figure 1 Map of Uganda showing battery swapping and charging stations

3.1.1. Market feasibility

Generally, the demand for electric motorcycles appears to be increasing steadily despite some of the challenges faced with the transition. As an example, the information from SPIRO which began operation in 2024 shows that over 5,000 motorcycles have been sold. Similarly, Zembo that began operations in 2018 have sold up to 6,000 bikes in Uganda. Redvers, founded in 2020, has an estimated 70 retrofit electric motorcycles. The increasing number of riders purchasing electric motorcycles coupled with the increasing demand for swapping guarantees the market for a universal battery swapping and charging hub.

The biggest challenge with electric motorcycles appears to be insufficient battery charging and swapping infrastructure that has been worsened by lack of coordination and partnerships to improve the battery swapping services. The other challenges include limited awareness and knowledge, high battery discharge rates, high infrastructure investment costs and technophobia. According to Redvers, they would have possibly expanded if there were working arrangements with different retailers so as to minimize the infrastructure investment costs required in establishing swap stations. In this direction, because of high operation costs, Zembo has been exploring the possibility of franchising swap stations to negotiate directly with franchisees over revenue sharing. Similarly, SPIRO has been exploring selling the swap stations to private investors for revenue sharing arrangements. Arguably, it makes more business sense with franchisees if they can offer electric battery services for the different organisations. It is expected that organisations in the UK recongnise this rather than individualised investments in swap stations. In this direction, Honda, Yamaha, Kawasaki and Suzuki reached an agreement in 2019 and the consortium has been developing standards towards universal battery swapping (Honda, 2023). Similarly, in 2021, Honda, KTM, Piaggio, and Yamaha signed an agreement to develop a battery swapping system (Reuters, 2021), synonymous with this universal hub.

In Uganda, over 80% of the respondents agreed with availability of market for a universal hub with potential of attracting some investors. Therefore, based on the increasing demand

for electric motorcycles in Uganda, a universal hub would have sufficient market for operations to break even.

3.1.2. Technical feasibility

Technically, the main requirements for battery swapping and charging relate to the power required to charge the batteries. The power voltage determines the number of batteries that can be charged simultaneously. Three options may be available: on – grid, hybrid and off – grid. The on – grid may be single phase or 3 phase and the hybrid is the on grid supplemented with another source of power like solar. The off grid generally may be applicable to rural areas with no source of energy where typically charged batteries are delivered and stored for swapping services only. Single and 3 phase power sources may consecutively charge up to 12 and 36 batteries respectively with a full charge taking 3-4 hours.

It may be economical to use 3 phase power when charging so many batteries given the high unit cost of grid electricity (US$0.21/kwh). This implies that a universal hub may require a minimum capacity to charge and swap 36 batteries, a figure comparable to an efficient design of a battery swapping station (BSS) by Putra, Hisjam and Jauhari (2023) consisting of 28 batteries with capacity to serve a swapping demand up to 72 motorcycles. With the proposal of a universal hub, a 3-phase photovoltaic system would be most ideal to charge many batteries at the same time using appropriate chargers to meet the demand from the different riders. In addition, such a system would reduce reliance on grid energy that is unreliable most especially in developing countries like Uganda. The technical feasibility of a universal hub is further supported in a study conducted by Charoen-Amornkitt *et al*. (2023) where a BSS with 3Kw photovoltaics consumed less energy and offered potential environmental benefits as compared to home charging. Therefore, it may be most appropriate for the UK to switch to battery swapping with increasing adoption rates that result in high utilization rates. It appears a hybrid charging system may be more profitable than a grid system for a battery charging infrastructure. Currently, SPIRO offers riders with restricted home battery charging kits indicating a possibility of unrestricted home charging in the future and thus a universal hub would still be cost effective. The current software applications used by the different organizations for the riders to access the battery services may be used individually for the universal hub until an integrated software application is developed.

3.1.3. Economic feasibility

In economic feasibility, the total infrastructure capital, operation and maintenance costs, and sales from the existing swap stations were considered. A standard charging and swapping hub with capacity of up to 36 batteries synonymous with the universal hub requires over USD 5,000 as capital costs, operation and maintenance costs of up to USD1,500. A fully charged battery in Uganda costs $1.6 (Zembo), $2.3 (SPIRO) and $2.7 (Redvers) all estimated to run for a distance between 70 – 175 km. In the UK, riders have to wait and charge the battery on the motorcycle either at a cost or free depending on the charging point. The business model for the above companies in Uganda is pay per use by providing battery-as-a-service (BaaS) through a network of battery-swap stations.

The existing busy individualized swap stations serve an average of 30 riders and 2 swaps a day. This is projected to increase in the future as adoption rates increase. Considering this demand and with a minimum cost of a fully charged battery at $1.6, it is economically viable to operate a swap station considering the operation costs and sales. To break even, a

minimum of 22 riders each making 2 swaps daily are required. Therefore, with Universal Hub, it is expected the sales will be higher, making it financially feasible as more motorcycle riders will be served. With the collaboration from the different parties coupled with government support towards transport decarbonization, a universal hub is feasible. To minimize costs, this study recommends locating a universal battery swapping hub at the existing fuel stations. Fuel stations may further stimulate the acceptability and adoption of electric motorcycles with ICE motorcycle riders acknowledging the availability of swapping services during fueling. This strategy should be adopted by the UK mobility organisations that have plans for establishing swap stations. The location of swap stations at existing petrol stations is further supported in a feasibility study conducted in Thailand by Chutima and Tiewmapobsuk (2021). Alternatively, shopping malls and markets are other feasible locations for battery swapping and charging that were economically feasible without subsidies in a study conducted by Wibisono, Nugrahadi and Sutopo (2022).

3.2. Electric vehicle user attitudes towards battery charging and swapping

3.2.1. Importance

User attitudes are crucial for the success of any scheme, including battery swapping initiatives, for several reasons:

- **Adoption and Usage**: Positive attitudes towards a scheme increase the likelihood of adoption and regular use. If users perceive battery swapping as convenient and beneficial, they are more likely to use it.
- **Feedback and Improvement**: Understanding user attitudes helps identify areas for improvement. Feedback from users can guide adjustments to make the scheme more user-friendly and effective.
- **Trust and Reliability**: Positive attitudes build trust in the scheme. If users trust that battery swapping stations are reliable and accessible, they will be more inclined to rely on them.
- **Marketing and Communication**: Knowing user attitudes allows for better-targeted marketing and communication strategies. Highlighting the aspects that users' value most can attract more customers.
- **Sustainability and Growth**: A scheme that aligns with user attitudes is more likely to be sustainable and grow over time. Satisfied users can become advocates, spreading positive word-of-mouth and encouraging others to participate.
- **Policy and Support**: Positive user attitudes can influence policymakers and stakeholders to support and invest in the scheme, ensuring its long-term viability.

By understanding and addressing user attitudes, you can design a battery swapping initiative that meets the needs and expectations of electric vehicle users, leading to greater success and impact. UK sample (598) consisted of North East (6%), North West (9%), Yorkshire and the Humber (9%), East Midlands (9%), West Midlands (10%), East of England (6%), London (11%), South East (14%), South West (9%), Wales (4%), and Scotland (14%). Uganda sample (90) was from Kampala city. The UK sample consists of equal share of male and female (49%:51%). Kampala sample is male dominated (electric motorcycle riders). 77% of the respondents in the UK sample belong to age group of 25-54 years old. 96% of the respondents from Kampala belongs to 25-44 age group. Figures 2 and 3 show the attitudes of electric vehicle users in the UK and Uganda. These figures should read with Table 1 that has the list of attitudinal statements.

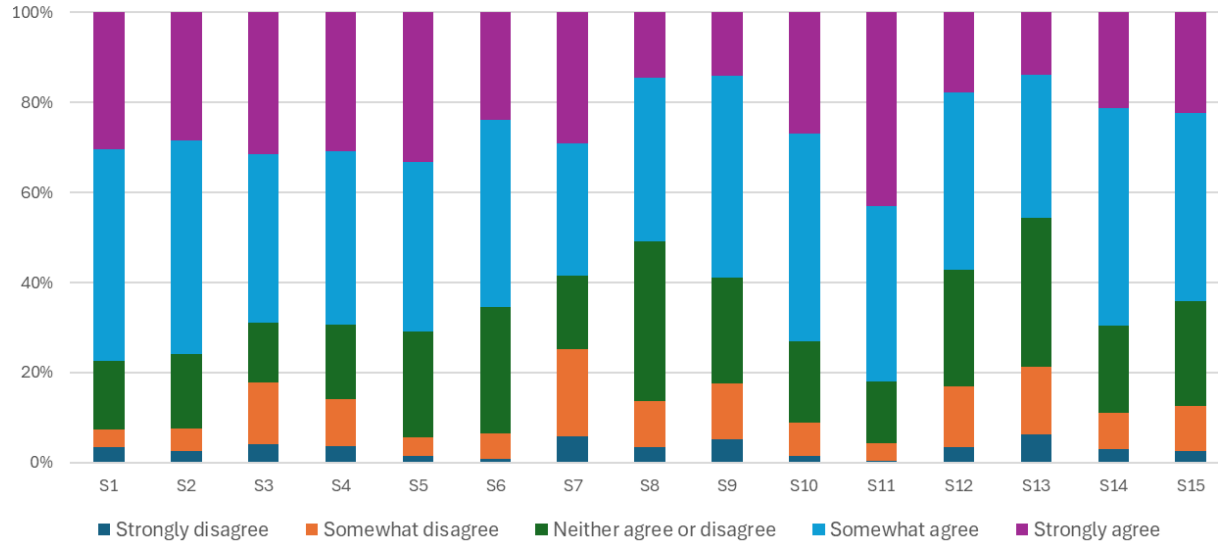

Figure 2 Electric vehicle user attitudes to battery charging and swapping (UK)

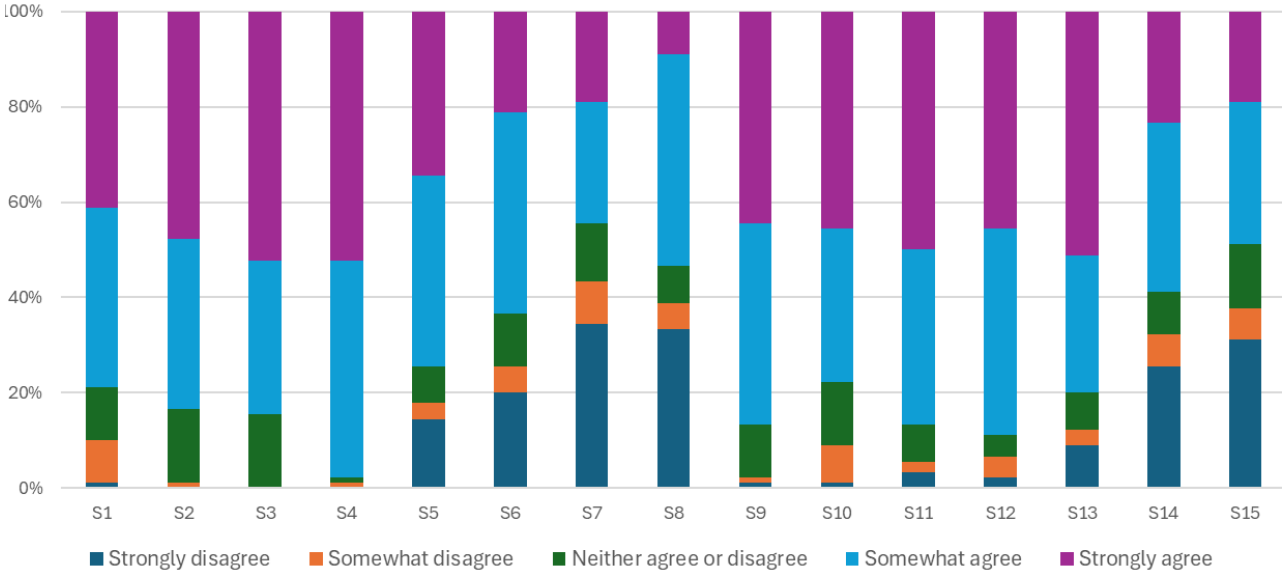

Figure 3 Electric vehicle user attitudes to battery charging and swapping (Uganda)

Table 1 Attitudinal statements

S1	Battery swapping is useful when there is insufficient charging infrastructure in our cities
S2	Battery swapping is useful when there is a deficiency of depot based fast charging
S3	Battery swapping is useful as charging in public locations takes a long time
S4	Battery swapping is useful to reduce Range Anxiety
S5	Insufficient availability of battery swapping stations limits the practicality of battery switching to reduce range anxiety and increase the driving range
S6	Holding a sufficient inventory of fully charged batteries for swapping results in additional expenses, increasing the overall costs of operations
S7	I am happy with my current charging options and therefore battery swapping may not be useful.
S8	Increased electric mobility leads to a surge in electricity demand, which can be challenging for countries that intend to phase out nuclear energy and shift towards renewable energy sources.
S9	Renewable energy sources alone may not satisfy the growing need for electricity, and those peak loading periods are unlikely to provide access to affordable electricity
S10	The current power network system may not be adequate to charge a commercial fleet; hence, upgrading the grid demands investment
S11	With different electric vehicle makers using different battery chemistries and sizes, creating a universal battery swap system remains difficult
S12	Battery swapping potential would increase the electric vehicle uptake
S13	People prefer to buy electric vehicles if battery swapping facility is available in general
S14	As the landscape of electric vehicles continues to evolve, battery swapping could play a crucial role in shaping the future of transportation
S15	I am not sure I may find right batteries to swap at the battery swapping locations.

In the UK, battery swapping is still in its early stages of the discussion, with electric vehicle users beginning to recognise its potential benefits. Figure 2 highlights the perceptions of UK users, who generally show less agreement on the advantages of battery swapping compared to their Ugandan counterparts. In Uganda, where battery swapping is widely implemented, user perceptions are more aligned with the practical benefits of this technology. Figures 2 and 3 illustrate similar trends, but Ugandan users express stronger agreement on several points: ***the usefulness of battery swapping due to lengthy public charging times*** (S3), ***its role in reducing range anxiety*** (S4), ***the limitations of renewable energy sources in meeting growing electricity demands during peak periods*** (S9), and ***the preference for purchasing electric vehicles if battery swapping facilities are available*** (S13). This comparison underscores the impact of real-world experience on user perceptions in both countries. It is seen that the majority of electric vehicle users (65%) in the UK feels that ***they may not find right batteries to swap at the battery swapping locations*** (S15), but this is less of a concern for the users in Uganda (55%).

3.2.2. Analysing Attitudinal Statements using Principal Component Analysis

The PCA results have identified 4 components in the UK dataset to represent electric vehicle users' perceptions on battery charging and swapping, as shown in Table 2.

Table 2 Output from the Principal Component Analysis- Attitudes towards Battery Charging and Swapping

Statement	CL
Component 1 (Positive attitudes and perceptions towards BS) (α =0.494)	
S1: Battery swapping is useful when there is insufficient charging infrastructure in our cities	0.880
S2: Battery swapping is useful when there is a deficiency of depot based fast charging	0.836
S3: Battery swapping is useful as charging in public locations takes a long time	0.648
S4: Battery swapping is useful to reduce Range Anxiety	0.607
S7: I am happy with my current charging options and therefore battery swapping may not be useful.	-0.437
Component 2 (Perceptions related to uptake of electric vehicles and how BS will play a role) (α =0.839)	
S12: Battery swapping potential would increase the electric vehicle uptake	0.869
S13: People prefer to buy electric vehicles if battery swapping facility is available in general	0.781
S14: Battery swapping could play a crucial role in shaping the future of transportation	0.698
Component 3 (perceptions about the energy grid and consequence of using electric vehicles) (α =0.649)	
S8: Increased electric mobility leads to a surge in electricity demand	0.783
S9: Peak loading periods are unlikely to provide access to affordable electricity	0.841
S10: The current power network system may not be adequate to charge a commercial fleet	0.575
Component 4 (Uncertainties related to BS) (α =0.565)	
S5: Insufficient availability of battery swapping stations limits the practicality leading to range anxiety	0.663
S6: Holding a sufficient inventory of batteries will increase the overall costs of operations	0.626
S11: With different battery sizes, creating a universal battery swap system remains difficult	0.727
S15: I am not sure I may find right batteries to swap at the battery swapping locations.	0.621
KMO: 0.847; α = Cronbach Alpha; KMO=Kaiser-Meyer Olkin; BS: Battery Swapping	

These components are labelled as "***Positive attitudes and perceptions towards BS*** "***Perceptions related to uptake of electric vehicles and how BS will play a role***", "***perceptions about the energy grid and consequence of using electric vehicles***" and "***Uncertainties related to BS***". Given the dataset from Uganda is small (90) the PCA analysis is not conducted. But this will be the next stage of the project in addition to two journal publications with attention to stakeholder and user perspectives.

4. Conclusion and Recommendations

4.1 Conclusions

This study explored the feasibility of a universal battery charging hub for electric motorcycles in Uganda and UK. In the UK, riders rely on home, work and public charging unlike in Uganda where majority of riders swap their batteries. Some of the current individualized BSS in Uganda are not cost effective and sustainable. Uganda has higher adoption rates of the electric motorcycles since it is one of the main modes of passenger public transport unlike the UK where it is mainly used for goods delivery but with more electrification targets. As a result, there is a fast-growing transition from conventional Internal Combustion Engine (ICE) to electric motorcycles in both countries and thus this study is timely given the need to harmonize the efforts and solve some of the challenges to facilitate the affordability, acceptability and adoption of electric motorcycles.

Electric motorcycle technology is growing and evolving where substantial changes are expected regarding battery swapping and charging services in the adoption and thus a universal hub will be an option. The universal hub will provide insights into the development of standards and interoperability so that batteries can be swapped and exchanged between motorcycle brands to minimize costs. The concept of a universal battery swapping and charging hub is feasible financially, technically and will have potential market given the increasing energy transition in the motorcycle industry. However, for effectiveness and with space constraints, the hub may be designed to serve up to two and three brands in urban and rural areas

respectively. This concept was welcomed by the key stakeholders in the industry due to accessibility and cost effectiveness advantages. However, it was pointed out that this may work possibly under a franchise model despite some reservations for future battery interoperability by some retailers.

4.2 Recommendations

Electric motorcycle organizations should start working together to solve some of their challenges regarding battery swapping and charging. In both countries, a key step in this direction is to develop some partnerships with existing fuel station organizations for a business sharing model since the location of most fuel stations is strategic and ideal for universal battery swapping services. In the UK, universal charging and swapping facilities at existing petrol stations, shopping malls and public spaces are recommended with increased use and adoption of electric motorcycles.

As the adoption of electric mobility takes shape, it is expected that the mode of operation will equally change including battery charging and swapping. The competition is likely to distort the market share and thus organizations should prepare and plan for future possibilities. In the UK, the electric motorcycle riders charge their bikes from home/public places, and this might be the case in Uganda soon for some of the riders especially non – commercial riders with limited number of trips. Therefore, organizations in Uganda should provide riders with several options for battery charging and swapping other than the current pay per use model and possibly provide for home charging as well. The charging and swapping infrastructure required to facilitate the adoption, acceptability and accessibility of electric mobility requires a concerted effort from all the key stakeholders including guidance from government; otherwise, the uncoordinated individual investments may not be sustainable with such unpredicted growing industry. Therefore, we recommend governments in both countries to develop standards and policies to guide the transition to electric mobility. There is need for battery standardization and interoperability as a sustainable approach towards accelerating the shift from non – renewable to renewable energy specifically with electric motorcycles that are used as modes of public transport in developing countries. It is important to note that companies like Honda, Yamaha, Kawasaki and Suzuki have made progress towards this direction where in 2019 they signed a consortium towards developing standards for battery swapping.

With increasing adoption rates for electric motorcycles, the frequency for battery swaps is likely to be higher than the capacity and this situation will be exacerbated by insufficient charging and swapping infrastructure in Uganda. In the UK, home, work and public charging will present limitations with increasing adoption rates. A possible solution to this future problem is the universal battery charging hub recommended in both countries, but also more research is needed towards developing high-capacity batteries that can sustain long distances without recharging. Alternatively, mechanisms for recharging the batteries during operation need to be explored as well. In Uganda, the pay per use model is dominant unlike in the UK where a monthly subscription model is being introduced. As the market grows and with increasing competition, it is recommended that retailers will require to explore the use of other payment models for battery swapping services as this may serve as a marketing strategy and increase the effectiveness of battery swapping services.

Acknowledgement

The authors acknowledge with gratitude the continuing support and finances in conducting this research provided by Future Transport Visions Group (FTVG) funded by Rees Jeffreys Road Fund. Specifically, the authors are grateful to Dr Ransford A. Acheampong for the guidance and support of this research project.

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