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Social acceptance and sustainability assessment of light electric vehicles in Ghana

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Abstract

The demand for transportation in Ghana has seen an increase in recent times with a non-corresponding increase in transport infrastructure. An opportunity is created to introduce sustainable modes of transport such as light electric vehicles. The researchers use a mixed methods approach to evaluate the factors that would increase the social acceptance of such devices in Ghana. The researchers evaluate the sustainability of such devices by means of a criteria catalogue. It was found that factors such as cost, noise and range ranked high for respondents whiles environmental considerations ranked low for a mobility switch. Results of the sustainability assessment are as well presented in a graphical manner.

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1. Introduction

The demand of reliable transportation solutions is increasing in Ghana because of the urbanization and population growth experienced in the country in recent decades (World Bank, 2021). This increase of demand showed the challenges and problems of the infrastructure conditions in Ghana clearly with an increase in vehicles 6.7 million in 1960 to 30.8 million in 2022 on non-expanded infrastructure as showed by Ayetor et.al (2022). Unexpanded and improved transport facilities means congestion, road safety challenges and high emissions particularly in urban centres such as the capital city, Accra (Ayetor et.al, 2022). The current challenge for mobility presents an opportunity for the introduction of sustainable mobility into the local environment. The MoNaL project seeks to achieve this with a pilot project on the campus of the academic partner Don Bosco Solar and Renewable Energy Centre. Following the deployment of vehicles, a test regime is required to confirm the suitability of devices. Further to that, it is necessary to identity what factors contribute to the social acceptance such light electric vehicles in the local environment. Finally, a catalogue of criteria need to be selected and assessed in the local environment to prove the sustainability of the

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products introduced. The product clinic, essentially a workshop based on a specific product, held on the Don Bosco campus set out to answer the following research questions:

I. What factors influence the social acceptance of light electric vehicles and their sharing systems in Ghana?
II. How can the sustainable offer of light electric vehicles used in Ghana be assessed by means of a criteria catalogue?

2. Literature Review: an overview of the Assessment of Light Electric Vehicles on Social Acceptance and Sustainability

Transportation in its current form remains unsustainable. The use of fossil-fueld vehicles to power mobility leads to high GHG emissions. The focus is to leverage on modes such as walking, public transport, or the use of micro-mobility devices such as Light electric vehicles (LEVs). LEVs such as electric mopeds and electric cargo bicycles are gaining prominence and use in most western societies and slowing being incorporated into transitioning economies (Adjei et. al, 2022). Their promise of being able to substitute short trips is crucial to emissions reduction (Ewert et. al, 2020). In better context, between 17%-49% of trips made and 6%-30% of distances covered by private trips can be substituted by LEVs (Ewert et. al, 2020). A sustainable mobility turnaround will only be successful if the focus is also on avoiding car travel and shifting to other modes of transport (Ewert et. al, 2020). A substantial part of increasing the sustainability reach of LEVs is to deploy them in a sharing system (Mensah, 2021). Sharing systems aid in the decrease in greenhouse gases emissions and decrease in exploitation of natural resources to produce raw materials due to the effect of needing less devices for larger populations and even more so when powered by renewable energy sources (Belk, 2014). A study on bike sharing impact and implementation outlined benefits and some importance of bike sharing system such as reduction in travel time, improvement in the health of the population, offering other choices of transport and reduction in cost of transport (Ricci, 2015). These benefits are currently primarily targeted at males and the younger generation and those that have more disposable income (Ricci, 2015). Most studies on sharing systems have been targeted at developed countries with low focus on developing and transition economies (Cheng, 2016). The track test and product clinic in Ghana sets out to fill the gap and provide insight into the feasibility of electromobility usage and its sharing system in Ghana using social acceptance and technology acceptance models as a theoretical framework to find factors that would impact the adoption of such devices in the local environment.

A key part of introducing technology in a sector is to ensure the use of trials and a participatory process for the use and potential adaptation of the technology to the local setting (Mirvis et. al, 1991). Hence it is necessary to test LEVs in Ghana across different terrain to provide data on the performance of devices and as well provide a first look for users. There is no literature known to the authors at this time of tests for LEVs in Sub-Saharan conditions. Whiles track tests tell a part of the story when it comes to assessment in the local environment, a different mode is required to assess the overall product sustainability. Goedkoop et.al (2020) provide a basis for the assessment of products on social impact. Further research on the topic of sustainability criteria have been conducted usually with either an ecological focus or economical. For a complete picture, it is necessary to adapt existing literature to evaluate sustainability across the spectra of ecological, social and economic criteria.

3. Methodology

To achieve the objectives of the track testing and product clinic, is a mixed approach which includes focus group discussions and track testing in various terrain is used. A mixed methods approach allows the use of qualitative and quantitative questions and hence is well-suited to the research questions (Wu, 2012). Social acceptance being key to the discussions are easily incorporated using such an approach. Using the theoretical framework of Schäfer et.al, the social acceptance of LEVs were assessed as part of the overall sustainability assessment using the criteria catalogue. The phenomenon of acceptance can be seen practically on the basis of three dimensions: Acceptance subject, acceptance object and acceptance context (Schäfer and Keppler, 2013). Acceptance therefore infers that someone (acceptance subject) accepts something (object of acceptance) within the respective or initial conditions (context of acceptance) (Schäfer and Keppler, 2013). The overall sustainability assessment was derived using the framework of Goedkoop et.al (2020). To evaluate the sustainability performance qualitatively and quantitatively, a multi-criteria evaluation based on a selection of key figures and indicators is required. For this, a set of criteria has been identified and replenished by appropriate metrics and potential data sources. For the purposes of this research a simplified reference scale was developed and converted to a three-stage evaluation as shown in Table 1.

Table 1. Scoring system for Sustainability Assessment's criteria catalogue

Score	Explanation
+1	Beyond generally acceptable situation
0	Generally acceptable situation
-1	Unacceptable situation

This system excludes any past or future improvement efforts, as for this a longer period of time is necessary to observe changes or evaluate past processes. To evaluate the overall sustainability performance of the system, the total number of each achieved evaluation will be counted and an average will be provided by dividing the total score sum by the number of evaluated criteria. If the result exceeds zero, the system can be evaluated as overall acceptable. If it remains below zero, further improvement will be necessary. The required data for the three-stage evaluation were collected using different methods and data sources, such as the aforementioned focus group survey, interviews or manufacturer information. An overview about the criteria catalogue is provided in the section results. An essential part of the product clinic procedure is the focus group survey that includes the questionnaire. The questionnaire is divided into 4 kinds. Social, economic, ecological and cross-cutting questions that are not specified to a specific field but answer to two or more selected criteria. The questionnaire was developed with the survey tool https://www.umfrageonline.com. The questionnaire is contained in the Appendix of this report. The structure of the focus group discussion which comprised groups of 10-25 people over 3 sets of groups.

Light electric vehicles (e-moped, two-wheeler e-cargo bike, and three-wheeler e-cargo bike) installed on the campus of Don Bosco were tested on selected tracks as part of the product clinic (elaborated above). Different standard motorcycle track tests were performed to determine their performance in the local terrain based on the work of Capitani et al. (2006), the tests used for the assessment are displayed in Fig. 1. Standard track tests were outlined on sandy/grassy, paved, and graveled roads. Following three continuous revolutions on the test tracks, drivers were asked qualitative questions on manoeuvrability and handling, stability, steering, and brake traction. A summary of recommendations and comments are presented in the results and discussions.

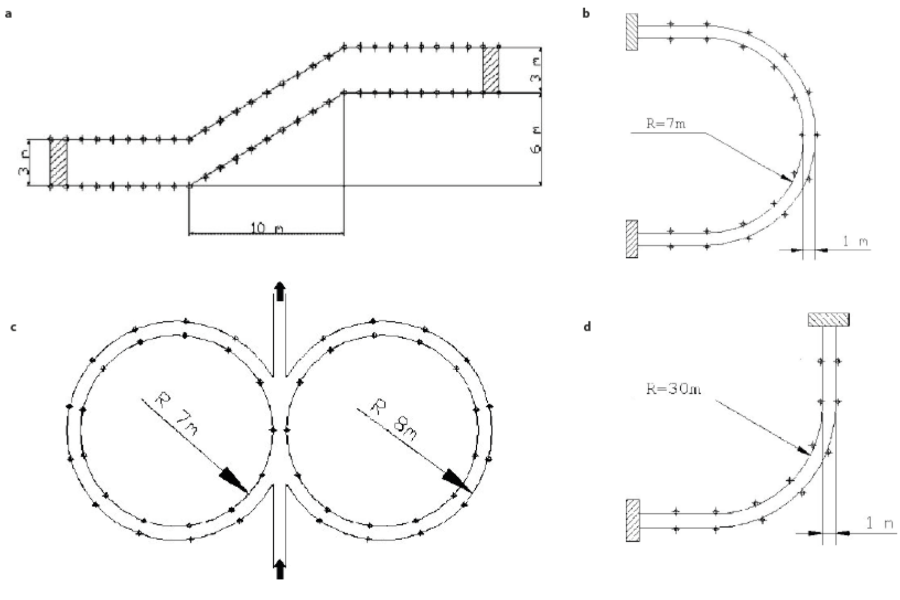

Fig. 1 Track Tests: (a) ISO Lane Change (b) R30 turn (c) 'Figure-8' (d) Constant Radius J-turn

4. Result and discussions

4.1 Factors influencing social acceptance of LEVs

Drivers for the light electric vehicles after the track tests answered qualitative questions on manoeuvrability and handling, stability, steering, and brake traction with the aim of identifying areas of deficiency or parts requiring adaptation to the local environment. A summary of deficiencies and recommendations are elaborated Table 2.

Table 2: Summary from track tests of LEVs on local terrain

Product	Findings/Comments/Recommendations for Improvement to the local environment
E-Moped	• Bigger vehicle tires with additional grooves for better traction. • Vehicle should have higher clearance from the ground would be better for the rough and uneven local terrain. • Vehicle is heavy especially in the back leading to curvature during sharp turns. • Speed is continuous when the throttle is released
Two-Wheeler e-cargo bike	• Difficulty in sharp turns, poor performance on gravel particularly in terms of stability. • Lights should be connected to main batteries instead of the use of replaceable AA batteries. • Placement of electronics and batteries in loading bay inconvenient. • Loading bar should have a cover for security and protection from elements such as rain. • Reflective materials should be placed on various areas of the vehicle to ensure visibility for improved safety.
Three-Wheeler e-cargo bike	• Difficulty in sharp turns, poor performance on gravel particularly in terms of stability. • Lights should be connected to main batteries instead of the use of replaceable AA batteries. • Placement of electronics and batteries in loading bay inconvenient. • Loading bar should have a cover for security and protection from elements such as rain. • Reflective materials should be placed on various areas of the vehicle to ensure visibility for improved safety.

4.2 Factors influencing social acceptance of LEVs

In evaluating factors that influence social acceptance of Light Electric Vehicles (LEVs) in Ghana. Respondents were made to rank factors deemed very important to them when using a sharing system and e-mopeds. Respondents had e-mopeds as well as e-bicycles on site and hence could familiarize themselves with the use of both devices. The factors for influencing the adoption of e-mopeds are therefore similar if not the same for the adoption of e-bicycles. The factors influencing the social acceptance of e-mopeds and sharing systems are elaborated in Table 3 and Table 4 respectively.The Kendall's Coefficient of Concordance was also used in analyzing factors important to the purchase and or use of an e-moped as mentioned above. The Kendall's Coefficient (W) was found to be 0.013 and significant at 1% level. The null hypothesis (i.e., Ho: No agreement among respondents ranking) was rejected in favor of the alternate hypothesis (i.e., Ha: There is agreement among respondents ranking) in the factors considered important when purchasing or using an e-moped. The Kendall's 'W' implies that there was 13% agreement among the respondent rankings. Because of incomplete data, 50 responses were used in this analysis.

Table 3: Ranking of factors important to respondents in the purchase and use of e-moped.

Factors	Mean Score	Rank
Acquisition Cost	5.31	1st
Low Noise	5.32	2nd
Possible distance	5.34	3rd

Weight Capacity	5.37	4th
Safety	5.38	5th
Repairability	5.46	6th
Power	5.53	7th
Environmental sustainability	5.57	8th
Maintenance Cost	5.77	9th
Design	5.95	10th
Diagnostics		
Number of Observation	50	
Kendall's W	0.013	
Degree of Freedom	9	
Chi-square	5.806	
Asymptotic Significant	0.000	

The ranking of factors for the social acceptance of sharing systems for LEVs as well was done using a Likert scale from 1-5 (1= very important, 2= important, 3= neutral, 4= not important, and 5= not very important). The Kendall's Coefficient of Concordance was used to analyze agreement in the ranking of these factors by respondents. The Kendall's Coefficient (W) was found to be 0.20 and significant at 1% level. The null hypothesis (i.e., Ho: No agreement among respondents ranking) was rejected in favor of the alternate hypothesis (i.e., Ha: There is agreement among respondents ranking) in the factors considered important in using the sharing system. The Kendall's 'W' implies that there was 20% agreement among the respondent rankings. Because of incomplete data, 49 responses were used in this analysis.

Table 4: Ranking of factors important to respondents in using the sharing system.

Factors	Mean Score	Rank
Location	2.89	1st
Easy Usage	2.94	2nd
Availability	2.95	3rd
Price	2.97	4th
Variety	3.26	5th
Diagnostics		
Number of Observation	49	
Kendall's W	0.20	
Degree of Freedom	4	
Chi-square	3.867	
Asymptotic Significant	0.000	

The results elaborated above offer concrete insights into the social acceptance of LEVs and their sharing systems in societies such as Ghana and other transitioning economies. The results confirm or agree with earlier work done by Adjei et. al, where conventional motorbikes were used instead of LEVs due to their unavailability in the country at the time [3]. It is clear that environmental sustainability is not the driving factor for a switch to a more sustainable transport mode for the given society. An entry strategy for future suppliers or service providers would need to focus on the core needs or purposes for transport as opposed to an inference to planet protection or climate change. Cost appears to be the main factor and this is reflective of the current economic conditions in the country. Further factors such as distance, weight/load capacity reflect the need of these devices to their specific use cases: short distance travel and the transport of people and materials.

4.3 Factors influencing social acceptance of LEVs

The results from surveys and interviews were used to populate a criteria catalogue designed in the conceptual planning of the MoNaL project to assess and provide a larger overview of the sustainability of the product system installed on the campus of Don Bosco. The criteria catalogue is given in Table 5. Each indicator is attributed to a category – either ecological, economical, or social – and, barring two exceptions, to one or many SDGs. This hierarchical structure allows for a structured visualization.

Table 5: Indicators for acceptance of LEV, grouped by Indicator category

Indicator Category	No.	Criterion Name	Indicator	SDG	Data Source	Result	Score
Ecological	1	End-of-life-responsibility	EoL management performed in formal and using standardized method	12; 13	Desktop Research/expert interviews	Informal recycling is the norm in Ghana with few formal recycling firms in operation	-1
	2	Air quality	NOX, CO, VOC, SO2 transport emissions per passenger km	3; 11; 12	LCA Analysis	No Tank-to-Wheel emissions and there, thus no additional air pollution in cities	+1
	3	GHG-Emissions	Measured in CO2-eq./pkm (passenger-kilometre) for passenger transport, CO2-eq./tkm (tonne-kilometre) for freight transport and CO2-eq./kWh for electricity generation. GHG-emissions mainly include CO2, CH4 and N2O.	3; 11; 12; 13	LCA Analysis, literature comparison	E-Cargo bikes: 184 g CO2-eq./tkm (PV-Powered); 520 g CO2-eq./tkm (powered by Ghanian grid mix) E-Mopeds: 16 g CO2-eq./pkm (PV-Powered); 27 g CO2-eq./pkm (powered by Ghanian grid mix), when batteries are swapped at the facilities; 41 g CO2-eq./pkm (PV-Powered); 51 g CO2-eq./pkm (powered by Ghanian grid mix), when batteries are swapped by Diesel transporters Mini-Grid: 55 g CO2-eq./kWh	+1

	4	Noise pollution	$\frac{\text{Inhabitants in area with noise polluttion} > 65\text{dB in m}^2}{\text{total study area in m}^2}$	3	Objective rating	No noise from E-Vehicles	+1
	5	Space occupancy	Defined by space used up by charging station and stationary devices compared to vehicles	11	Survey Questionnaire	Space occupied by devices and charging station less than occupied by conventional vehicles	+1
	6	Use of renewable Energy	Literature review	7; 12	Literature review/pilot site scenario	Currently 100% renewable energy sourced	+1
	7	Life span of the scooter	Life span provided in years or km/ tkm/ pkm (for vehicles), differentiation of the lifespan of individual components when components are exchanged over life span of the product	12	LCA Analysis	E-Cargo bikes: 20 years (Batteries 4 years, Tyres: 6 years, electronics 10 years, Frame: 20 years); 6.750 tkm E-mopeds: 65.000 pkm: 50.000 km (Battery: 40.000 km, Vehicle: 50.000 km) Mini-Grid 25 years (PV-modules, cables, construction: 25 years, Batteries: 10 years, Solar Charger, Inverter and electronics: 7 years).	+1
Economic	8	Affordability	Comparison to the price of local alternative means of transportation	10	Uber Technologies Inc. 2022; World Taximeter 2022	GHS 26-47 for a Uber/Taxi per ride for a distance of 10km	0
	9	Local employment	$\frac{Number\ of\ employees\ hired}{Total\ Number\ of\ employees}$	1;8	-	-	Not applicable
	10	Convenience	How convenient is it for you? Survey, scale from 1-5.	10	PC-Questionnaire & Group Discussion	4/5	+1
	11	Profitablity	Break-even analysis, revenue / cost	8	Profitability Analysis	5.9 Years with GHS 30 per ride for a distance of 10km	+1
	12	Policy framework	The existence of a system in place to ensure that decisions regarding mobility solutions are agreed by city authorities and decisions are in line with city development plans	9; 11	Desktop Research	No Policy/legal framework on e-mobility available in Ghana	-1
Social	13	Gender and social equality	The existence of a policy that guarantees equal rights for women	5; 10	PC-Group Discussion	Female Participants felt safer in using shared vehicles than in public transport	+1

14	Accessbility	$\frac{Number\ of\ charging\ points}{Number\ of\ Mopeds}$	10	Pilot site inspection	4 vehicles, 1 charging point	+1
15	Safety	$\frac{\text{Number of fatal and non} - \text{fatal accidents}}{\text{person kilometer}}$	3	PC-Questionnaire	No safety incidents recorded	+1
16	Society Health	CO2 eq., SO2 eq., PO4 eq. per passenger km (GWP, AP, EP) LCA	3	LCA Analysis	-	-
17	Effectiveness and Comfort	Number of Bikes/Mopeds accessible by residents walking 10 min	n/a	Site Inspection	Within site, charging stations available withing 10 minutes of walking	+1
18	Usability of the sharing app	Objective rating	n/a	Focus Group discussion	3/50	0

As the visualization of choice, a sunburst chart was used, which is also known as Ring or multi-level pie chart. They are given in Fig. 2, with segmentation by criterion category and SDG contribution. The outer ring elements (leaves) are colored according to the indicator score with the inner ring elements being colored according to the average score of their children.

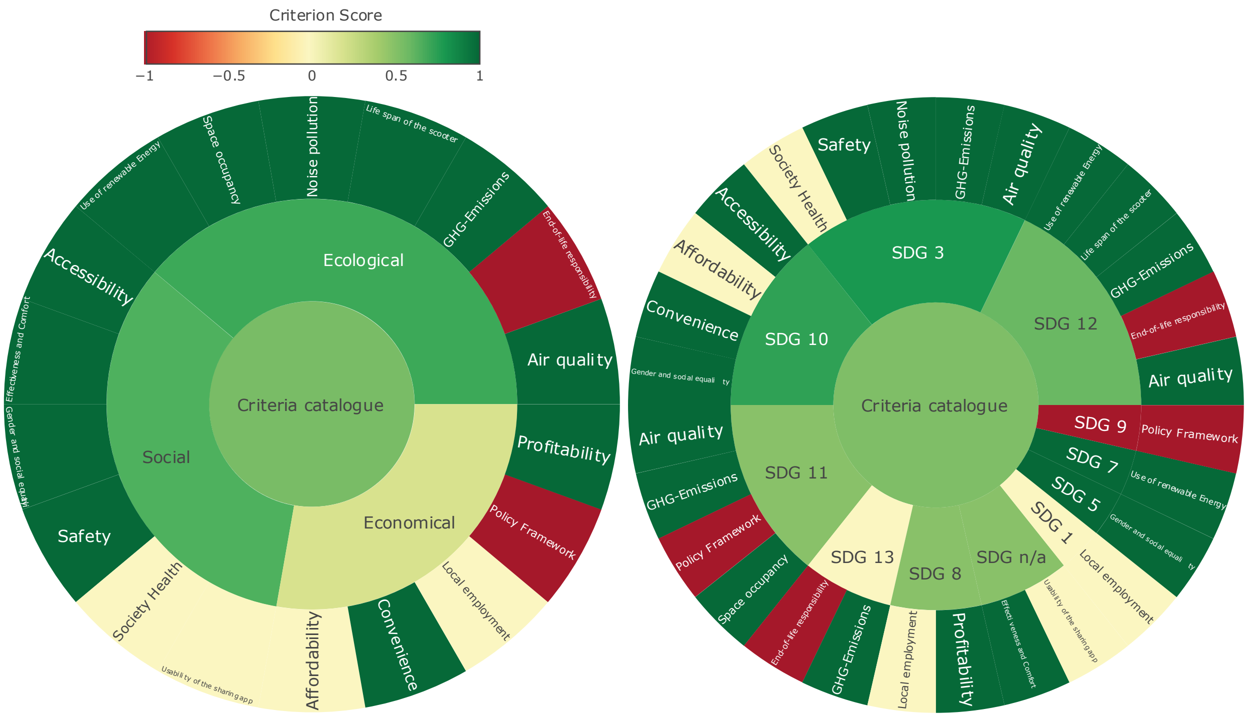

Fig. 2: Sunburst chart visualization of the criteria catalogue data, segmented by category (top) and by SDG contribution (bottom)

5. Conclusions

It is clear that environmental sustainability is not the driving factor for a switch to a more sustainable transport mode for the given society from its 8th rank in factors affecting social acceptance. An entry strategy for future suppliers would need to focus on the core needs or purposes for transport as opposed to an inference to planet protection or climate change. Cost appears to be the main factor, and this is reflective of the current economic conditions in the country. On sharing systems, location of pick-up points, easy usage of software applications, availability, price (cost), and variety of devices were ranked as significant to potential users. With the aid of criteria catalogue, it is possible to prove the sustainability of the product system across economic, ecological and social dimensions. With these insights, it is possible to device entry strategies to transitioning economies such as Ghana for light electric vehicles and their sharing systems.

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