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**Taking a sustainability turn?
Stakeholder perceptions on electrification
of motorcycle taxis in Nairobi, Kenya**

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Statement of authenticity

This thesis contains no material which has been accepted for the award of any other degree or diploma in any institution and to the best of my knowledge and belief, the research contains no material previously published or written by another person, except where due reference has been made in the text of the thesis.

A handwritten signature in black ink, appearing to read "Emilie Martin".

Emilie Martin

Nairobi, 29th April 2020

Abstract

In Kenya, motorcycle taxis known as boda bodas have dramatically increased in numbers over the last two decades, with the amount of registered motorcycles multiplying by 11.4 between 2007 and 2017. The result of this surging phenomenon, also observable in other Sub-Saharan African countries, is their increasing contribution to transport carbon emissions and pollutants, combined with social externalities of traffic accidents and criminality. However, while showing some unsustainable environmental and social patterns, this transport mode is also recognized to cater for mobility needs of urban and rural populations in a context of flawed collective transport and poor road conditions, as well as opportunities for self-employment. In Nairobi, motorcycle taxis remain a minor option, far from walking and minibuses, but have shown one of the quickest modal progressions in the same period.

To address the issue of this mode's sustainability in Nairobi, the thesis explores how a transition to electric motorcycles, a strategy currently implemented in some East-African cities and in the process of being conceptualised by a couple of organisations in Nairobi, may contribute to a betterment strategy.

Based on a number of key features identified in electrification literature that shape the sustainability of electric motorcycles, data collected is analysed through the triple lens of environmental, economic and social dimensions of sustainability. A diversity of perceptions of expected sustainability impacts is catered for via a survey conducted with motorcycle taxis drivers as an entry point to the research subject, deepened in a second stage through semi-structured interviews of electric and urban mobility experts. A matrix combining perceived impacts (opportunities, risks) and feasibility (drivers, barriers) is applied to capture a complete picture of stakeholders' views.

Results of both methodologies indicate that stakeholders predominantly identify potentials for benefits, more substantial than the anticipated risks. A hierarchy of perceived sustainability dimensions emerge, led by economic gains, followed by environmental benefits and lastly by more uncertain social effects. This study identifies a theoretical reversal from a low-carbon strategy with co-benefits to a socio-economic project with environmental co-benefits, likely deriving from the focus on economic development in Kenya and the taxi component of boda bodas. While economic gains for drivers prevail in the perceptions of stakeholders, with secondary economic benefits regarding the manufacturing industry and job opportunities, environmental benefits are still identified by experts in the form of climate change mitigation and reduced air pollution, partly stemming from the first sustainability variable of cleanliness of the electricity mix. Options to mitigate the risk of battery end-of-life mismanagement, that is the second environmental variable, are discussed and will depend upon modalities of projects implementation. Finally, social aspects lag behind and mainly revolve around road safety, as a potential risk and benefit, with little attention given to impacts on self-regulation and opportunities for multimodality. Potential rebound effects, including an undesired modal shift, will be a further decisive criterion to assess the sustainability outcome. In addition to the sustainability assessment, the thesis identifies a list of facilitators and barriers to electric mobility take-up.

To operationalise the assessment, the research finally suggests a set of policy recommendations aiming to improve the sustainability footprint of a transition to electric motorcycle taxis. It recommends further investigating this subject that bears potentials to transform informal transportation in Sub-Saharan Africa and to renew debates on informal transport, through longitudinal research studies.

Keywords: electric motorcycles, electric two-wheelers, motorcycle taxis, informal transport, sustainable transport, low-carbon transport, Sub-Saharan Africa

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Table of Contents

| | |
|--|-----------|
| Abstract | ii |
| Acknowledgments | iii |
| Table of Contents | iv |
| List of Figures and Tables..... | v |
| List of Abbreviations..... | vi |
| Section 1 - Introduction | 1 |
| 1.1. Problem statement | 1 |
| 1.2. Research aim | 2 |
| 1.3. Research question..... | 2 |
| 1.4. Methodology and structure | 4 |
| Section 2 - Literature review..... | 7 |
| 2.1. Motorcycles taxis in Sub-Saharan Africa..... | 7 |
| 2.2. Development of electric two-wheelers, including electric motorcycles | 11 |
| 2.3. The sustainability question of electric motorcycles..... | 15 |
| 2.4. Conclusion | 19 |
| Section 3 - Local context..... | 20 |
| 3.1. Emergence of electric motorcycle taxis in East-Africa..... | 20 |
| 3.2. Kenyan landscape: motorcycle taxis, electric mobility and electricity | 21 |
| 3.3. Nairobi urban mobility system..... | 25 |
| Section 4 - Survey of boda boda drivers | 29 |
| 4.1. Survey methodology | 29 |
| 4.2. Results..... | 31 |
| 4.3. Interpretation | 36 |
| Section 5 - Stakeholders interviews..... | 38 |
| 5.1. Methodology | 38 |
| 5.2. Results | 39 |
| 5.2.1. First part: semi-structured interviews | 39 |
| 5.2.2. Second part: questionnaires..... | 44 |
| 5.2.3. Combined results from the interviews and questionnaires | 47 |
| 5.3. Limitations | 58 |
| Section 6 – Discussion and recommendations | 59 |
| 6.1. Summarised findings | 59 |
| 6.2. Interpretation | 60 |
| 6.3. Policy recommendations..... | 61 |
| Section 7 – Conclusion | 65 |
| List of References..... | 67 |
| List of Figures (sources)..... | 73 |
| Annex 1 – Questionnaire administrated to boda boda drivers..... | 75 |
| Annex 2 – Sustainability Assessment | 81 |
| Annex 3 – Questionnaire administrated to experts | 87 |
| Annex 4 – List of experts interviewed | 90 |

List of Figures and Tables

Figures

- Figure 1:** Research framework: Sustainability Assessment (SA) of electric motorcycles in Nairobi
- Figure 2:** Three-pronged review of academic literature
- Figure 3:** Annual new vehicles registrations between 1968 and 2017
- Figure 4:** Registration of motorcycles, 2005-2017 and forecasts up to 2030
- Figure 5:** Electric mobility in Kenya: policies, projects and recommendations
- Figure 6:** Evolution of modal split in Nairobi between 2004 and 2013
- Figure 7:** Drivers survey: locations of questionnaire administration
- Figure 8:** Boda boda drivers waiting at an unpaved stage localized at the Taj Mall Roundabout, in the industrial area of Embakasi
- Figure 9:** Paved stage with a shed under the Northern Bypass in the high-income residential area of Runda
- Figure 10:** Data on drivers' gender, age, education (in %)
- Figure 11:** Drivers knowledge of electric motorcycles (in %)
- Figure 12:** Drivers perceptions of opportunities related to electric motorcycles (in %)
- Figure 13:** Drivers perceptions of O&M costs of electric motorcycles (in %)
- Figure 14:** Drivers' perceptions of risks related to electric motorcycles (in %)
- Figure 15:** Identified and interviewed expert stakeholders
- Figure 16:** Occurrences of sustainability codes from the semi-structured interviews
- Figure 17:** Impacts: opportunities as rated on average by experts
- Figure 18:** Impacts: risks as rated on average by experts
- Figure 19:** Feasibility: facilitators as rated on average by experts
- Figure 20:** Feasibility: barriers as rated on average by experts
- Figure 21:** Experts positions on an impact and activity scale

Tables

- Table 1:** Push and pull factors explaining the emergence of motorcycle taxis in SSA
- Table 2:** Scope of the E2W category
- Table 3:** Factors determining sustainability of electric motorcycles or two-wheelers
- Table 4:** Three-pronged urban mobility components
- Table 5:** Two electric motorcycles projects in Kigali and Kampala
- Table 6:** National regulatory framework for the operation of bodas
- Table 7:** Sources assessing the modal share of boda bodas in Nairobi
- Table 8:** Typology of projects revolving around electrification of motorcycle taxis in Nairobi

List of Abbreviations

| | |
|---------|--|
| AC | Alternating current |
| ADB | Asian Development Bank |
| BAK | Boda Boda Safety Association of Kenya |
| BEVs | Battery Electric Vehicles |
| BOTTAX | Kenya Boda Boda, Tuk Tuk and Tax workers Union |
| CBD | Central Business District |
| CC | Cubic Centimetres |
| CO2 | Carbon dioxide |
| DC | Direct current |
| E2Ws | Electric two-wheelers |
| EMs | Electric motorcycles |
| EoL | End of Life |
| EPRA | Energy and Petroleum Regulatory Authority of Kenya |
| EVs | Electric Vehicles |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH |
| GHG | Greenhouse Gas |
| ICE | Internal Combustion Engine |
| JICA | Japan International Cooperation Agency |
| ITDP | Institute for Transportation and Development Policy |
| KES | Kenyan Shilling |
| KPLC | Kenya Power and Lighting Company |
| KNBS | Kenya National Bureau of Statistics |
| kWh | Kilowatt-hour |
| LCT | Low-Carbon Transport |
| Li-ion | Lithium-ion |
| MoTIHUD | Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works |
| NCC | Nairobi City County |
| NEMA | National Environment Management Authority |
| NTSA | National Transport and Safety Authority |
| NGO | Non-Governmental Organisation |
| O&M | Operation & Maintenance |
| OEM | Original Equipment Manufacturer |
| PHEV | Plug-in Hybrid Electric Vehicle |
| SACCO | Savings and Credit Cooperative Organisation |
| SSA | Sub-Saharan Africa |
| STA | Sustainable Transport Africa |
| TCO | Total Cost of Ownership |
| UN | United Nations |
| UNEP | UN Environment Programme |
| USD | United States Dollar |
| WEEE | Waste Electrical and Electronic Equipment |

Section 1 - Introduction

1.1. Problem statement

In Kenya, motorcycle taxis known as “boda bodas” have experienced a strong rise over the last two decades. While these taxi services emerged in the 1960s at the Ugandan-Kenyan border, initially as bicycles and later as motorcycles, the real surge started in the middle of the 2000 decade. Annual new registrations of motorcycles were multiplied by 11.4 between 2007 and 2017, far before the second fastest growing vehicle type of station wagons (passenger cars) that were multiplied by 2.3 in the same period (calculations based on Ogot et al 2018, p.41). This growth is expected to be sustained with a further multiplication by 2.8 between 2017 and 2030 (calculation based on EPRA and UNEP 2020, p.9). Far from being a unique Kenyan phenomenon, this increase took place within a regional movement in many Sub-Saharan African countries where motorcycles are mostly used as taxi services rather than for private purposes (Kumar 2011, p.1). In Nairobi, the city under scrutiny in this study, the modal share of two-wheelers – a category encompassing boda bodas – rose from a mere 1.1% in 2004 to 5.4% in 2013. It remains a minor mode but has shown one of the strongest increases of 4.3 percentage points, while the walking and minibus modal shares decreased respectively by 7.4 and 0.5 percentage points in the same period (NCC 2014b, pp.7-12).

As a consequence of this surge, boda bodas increasingly contribute to transport carbon emissions. A research led by Nairobi University for the energy regulatory body EPRA (EPRA and UNEP 2020, p.11) indicated that nation-wide, boda bodas started emitting more carbon dioxide (CO₂) than passenger cars in 2014 owing to their higher numbers. Additionally, they emit other harmful pollutants, contributing to worsening air pollution in cities (*ibid*, p.12). A series of significant societal issues add up to these environmental negative externalities. Boda bodas are strongly criticised for their high rate of road accidents as well as associated with urban criminality (NTSA 2019, n.p.; NCRC 2019, pp.3-4). At the same time, boda bodas, like motorcycle taxis systems in other Sub-Saharan African countries, are recognized to cater for accessibility needs in a context of flawed collective transportation, as well as to provide for self-employment opportunities (Kiminyei and Gachanja 2018). Public discourses precariously oscillate between both perspectives. Besides, this transport mode is neither included in urban planning in Sub-Saharan Africa nor much researched at academic level yet (Ehebrecht et al 2018, p.242; Evans et al 2018, p.2).

To address the mode’s weak points, transformative projects have been initiated in sub-Saharan African countries. One of the emerging strategies is to transition motorcycle taxis to electric-powered vehicles, with the aim to curb emissions contributing to climate change and air pollution. Electric vehicles are almost non-existent on the continent (Black et al 2018), but initiatives have emerged over the last one to two years. In East-Africa, several electric motorcycles projects have been initiated by private companies in Kigali (Rwanda) and Kampala (Uganda). In Nairobi, fledgling companies have emerged, operating a small fleet of electric car taxis, retrofitting safari vehicles to electric vehicles or developing charging stations for passenger cars. Regarding the specific segment of electric motorcycles in Nairobi, various pilot projects are at conception phase, led by start-ups, a waste recycling center, and a consortium of stakeholders including the national ministry of transport MoTIHUD and the UN Environment Programme (UNEP).

1.2. Research aim

This research seeks to understand the extent to which electrification of boda bodas bears a transformative potential of this mode in the specific context of Nairobi, understood in terms of multidimensional sustainability effects. In other terms, it will investigate whether and how this transition may reshape features and patterns of current boda bodas operations, possibly to address current flaws of the mode. In fact, electrification may prove as a betterment strategy but may also entail risks, both needing to be assessed in short and long-term perspectives.

1.3. Research question

The main research question is the following: how may a transition to electric mobility contribute to a sustainability strategy for boda bodas in Nairobi?

Sustainability is here understood in its typical three-pronged approach combining environmental, economic and social characteristics that the research will use as a supporting reading grid. To answer the question, the research will investigate stakeholders' perceptions on the transformative impacts of electrification. This study does not intend to objectively quantify effects such as the amount of emissions that could be reduced by shifting to electric motorcycles, but rather to uncover effects as subjectively perceived and anticipated by key stakeholders.

Further subordinate questions complete the research scope:

- What are the technical, financial and governance characteristics of nascent projects to electrify motorcycles in Nairobi?
- Besides impacts on the boda boda ecosystem, are there any beneficial or harmful side effects on other dimensions of the economy, society or environment in Nairobi and more generally in Kenya?
- Besides the impact dimension, what are the key factors influencing feasibility of this transition, namely key drivers and barriers?
- How can this transition contribute to academic research on motorcycle taxis as an informal transport mode in Sub-Saharan Africa as well as on electrification processes currently emerging in various geographies? What type of similarities and dissimilarities may be identified between this localized case of Nairobi and these two broader research fields?

This study subject is responding to a number of research gaps pointed out in academic studies.

Electric two-wheelers in general and electric motorcycles to a stronger extent are still little studied, especially when it comes to their sustainability impact (Bakker 2018, p.97). Furthermore, most studies focus on electric two-wheelers in Asian countries as the bulk of electric vehicles (EVs) development took place in this geographical area (Weiss et al 2015, p.349; Eccarius and Lu 2020, p.7; Fu 2013, Gota 2018, p.27). This contrasts to an almost absence of EVs in Africa (Black et al 2018, p.1). As electric vehicles start emerging in Sub-Saharan Africa, the need to uncover specific features of electrification in this geography will prove critical to avoid replicating findings from external environments. As an illustration of divergences, motorcycles are mainly used for private purposes in Asian countries but as taxi services in

Sub-Saharan Africa (Eccarius and Lu 2020, p.7; Kumar 2011, p.1). In addition, climatic, geographical and socio-economic conditions vary, pleading for spatially differentiated analyses. As Eccarius and Lu (2020, pp.13-14) frame it: “a more detailed consideration of fleets in developing countries in Africa and South America could provide additional insights into EM potential”. There is therefore a need to conduct localized research bundling informal transport services in African countries and electric mobility. A further interest in unpacking characteristics of electric mobility for African informal transport modes stems from high expectations recently raised. A distinguished conference paper by Black et al (2018) speaks from a theoretical leapfrogging opportunity, identifying numerous advantages that this transition could induce. Adding to this gap in the electrification literature, comes the relative recentness of studies on motorcycle taxis in Sub-Saharan taxis, less intensively studied compared to collective informal transport modes in the form of buses and minibuses.

The targeted vehicles are motorcycles, understood as high-capacity motorised two-wheelers, used as a commercial transport mode (Sietchiping et al 2012, p.186) also referred to as taxi-like services (Cervero 2000, p.14), within the boundaries of the Nairobi Metropolitan region. According to EPRA (EPRA and UNEP 2020, pp.16-17), the majority of boda bodas in Kenya have a capacity of 126 to 150 cubic centimetres (CC). Excluded from the scope of the data collection are motorised three- and four-wheelers, non-motorised two-wheelers and lighter-weight electric vehicles such as electric bicycles.

1.4. Methodology and structure

A research framework to analyse sustainability impacts of electric motorcycles is developed and structured in two successive phases, a preparatory and a data collection one, containing each two components. Throughout the research, response elements to the research question are collected to elaborate a Sustainability Assessment, updated at each step of the process as represented in Figure 1.

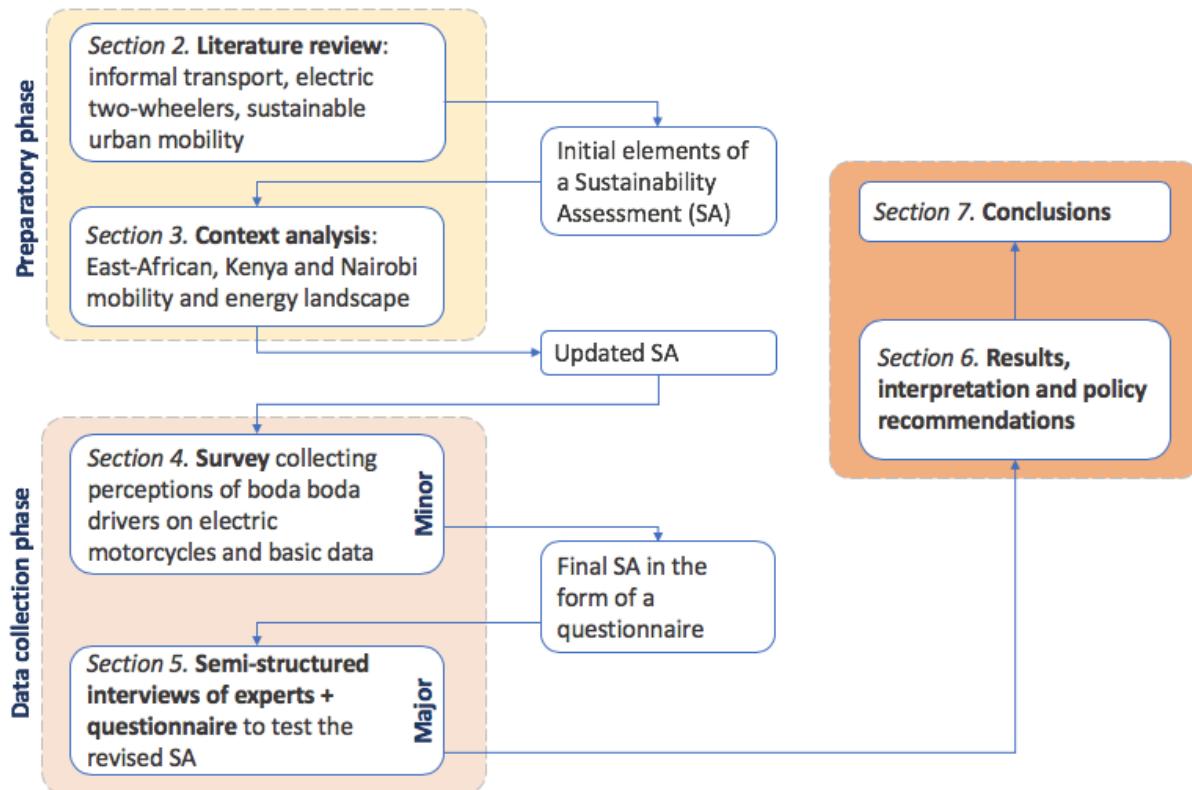


Figure 1. Research framework: Sustainability Assessment (SA) of electric motorcycles in Nairobi

In a preliminary research phase, description of the theoretical framework is operated via a review of relevant academic literature in Section 2. This is followed by an analysis of the local context in Section 3 using legal texts, press articles and grey literature.

In a second phase consisting in primary data collection, a sequential mixed-method strategy is applied as it allows for a diversity of angles to study the topic, whose results progressively build up on each other (Creswell 2013, p.14). To answer the question of perceptions, different target groups considered as vital components or knowledgeable of the boda mobility ecosystem are selected.

General perceptions of boda boda drivers on electric motorcycles are quantitatively collected in Section 4, together with basic numeric data on boda patterns and characteristics. This survey is used as an entry point into the subject and considered as a minor component. In Section 5, analysis is qualitatively deepened via semi-structured interviews with individuals considered as experts, that constitute the main part of data collection. Experts are also asked to complete a questionnaire built on the progressively updated Sustainability Assessment (SA) where they rate a large list of impact and feasibility factors, so as to allow comparison between spontaneously emerging themes and the SA.

Results of both methodologies are separately presented in respective sections 4 and 5, but finally summarised and interpreted in Section 6. This results in a set of policy recommendations as this research is application-led, ultimately aspiring to translate a research question into practical recommendations.

1.4.1. Literature review

Relevant studies in the fields of transport policy, transport geography, energy policy and African studies were identified in two phases, during an initial overview research in July 2019 and a more extensive identification of sources in November 2019. Following keywords were employed on web search engines (Google Scholar, Science Direct, Academia, ResearchGate) and university library portals: ““electric motorcycles”, “electric motorbikes”, “electric two-wheelers”, “motorcycle taxis”, “motorbike taxis”, “motorcycles Africa”, “informal transport Africa”, “paratransit Africa”. Articles having a sole engineering perspective were removed from the selection. The dates of publication of selected studies on two-wheeler electrification ranged between 2013 and 2019, with the bulk of literature stemming from the last 2 years. Literature on informal transport precede these, with a seminal study published in 2000 for instance, albeit a couple of studies focusing on motorcycle taxis are recent, also dating back the last 2 years. Reviewing the theoretical framework, especially studies on impacts of electric two-wheelers, enabled to lay the foundations for the sustainability assessment.

1.4.2. Analysis of the local context

The local context was studied based on two interconnecting layers of scope and topic. The geographical scope was explored from the broadest to narrowest dimension, starting with the East-African region where relevant motorcycle electrification projects have been initiated, zooming into Kenya and finally focusing on Nairobi. Various components pertaining to the subject of electric mobility were examined, namely trends and figures of motorcycle taxis, their legal and financial regulation, electricity and electronic waste. Uncovering these aspects was done through the examination of legal texts, press articles and reports released by national or international organisations.

1.4.3. Primary data collection

Perceptions of stakeholders is here understood in a broad meaning, going beyond a simple focus on the consumer or user that is commonly opted for in works analysing electrification uptake (Rezvani et al 2015 pp.124-125). Instead, this research follows Byrne and Polonsky (2001) approach, assessing the role and perceptions of different groups of essential stakeholders. Here, stakeholders are grouped into two categories: the boda boda drivers in the first place, deemed as central for the emergence of electric mobility and for understanding impacts on current boda boda patterns, and secondly, identified experts. Such experts are selected based on their knowledge and involvement in electric mobility or in the urban mobility landscape of Nairobi. Successively investigating perceptions of both groups aims to compare and contrast views.

Studying these two groups' perspectives is done based on a matrix combining a primary dimension of anticipated impacts, and a secondary one of perceived feasibility. Both impact and feasibility aspects are expressed in positive or negative terms, resulting in four categories: “opportunities” and “risks” as positive and negative expressions of anticipated impacts, and “facilitators” and “barriers” as positive and negative expressions of perceived feasibility. These constitute the four pillars of the sustainability assessment whose

final outcome is the questionnaire submitted to experts following the semi-structured interviews (Annexes 2 and 3).

The mixed method adopted begins with a minor quantitative component, followed by a major qualitative component. This part describes their main characteristics; further details on both methodologies will be provided in respective sections.

Survey of boda boda drivers

The quantitative cross-sectional survey with boda boda drivers in Section 4 was conceptualized as a first approach to the subject, to collect the drivers' perceptions on a transition to electric motorcycles as well as basic numeric data on boda boda operations. This second aim intends to partially fill an identified knowledge gap on patterns and features of motorcycle taxis in Nairobi (author's best knowledge, Ehebrecht et al 2018). Comparing results with literature review on motorcycle taxis in Sub-Saharan Africa allows identifying similarities or dissimilarities with boda bodas in Nairobi.

Semi-structured interviews of experts

The angle of perceptions that was chosen for this research then needs a deeper, thicker approach that is realized in section 5 via a qualitative approach, considered as the major component of the data collection. Not only permitting to go deeper into diverse views and thoughts that are the core research question, qualitative approach is also particularly adapted for recent topics having been little researched, allowing for exploratory research (Creswell 2013, p.19). This qualitative phase principally consists of semi-structured interviews with individuals considered as experts. These experts were asked about their knowledge of and involvement in electric motorcycles projects, connection with other stakeholders, positive and negative perceptions on anticipated consequences and feasibility. Following the semi-structured interview, they were asked to fill a questionnaire resulting from the Sustainability Assessment, namely, to rate a broad list of impact and feasibility factors in terms of significance. This questionnaire did not serve quantitative purposes but was thought as a means to allow for critical comparison between the preceding interviews and their answers to the questionnaire.

Section 2 - Literature review

The subject of this study lies at the intersection between three areas of research, as depicted in Figure 2. Upcoming subsections will successively explore each of them.

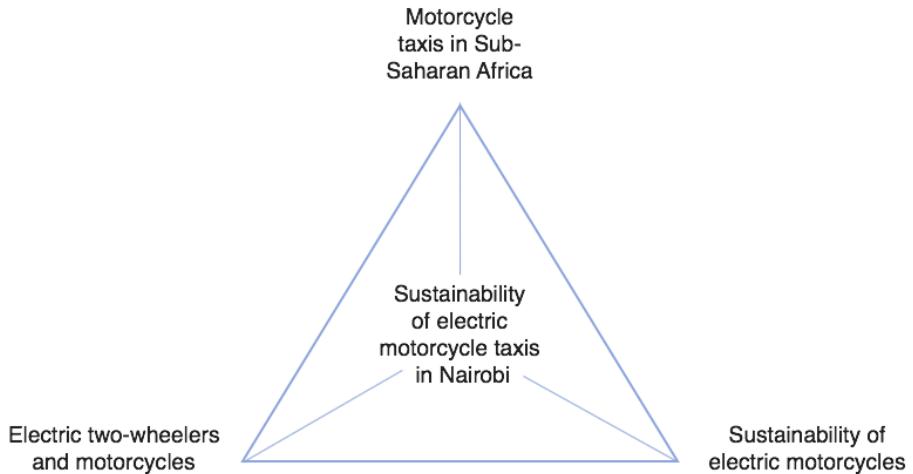


Figure 2: Three-pronged review of academic literature

2.1. Motorcycles taxis in Sub-Saharan Africa

Motorcycles used for private or commercial purposes have significantly increased since the 1990s in several countries of the Global South. This growth took place mostly in Asian countries including Vietnam, India, China, Thailand, Malaysia, Indonesia, Taiwan and Sri Lanka, but also in some Latin American countries such as Brazil as well as in Sub-Saharan Africa (Sheng et al 2016, p.74; Eccarius and Lu 2020, p.3; Ehebrecht et al 2018, p.243).

This study focuses on motorcycles used for “taxi-like” services (Cervero 2000, p.14), also named “for-hire motorcycles” (*ibid*, p. 17). Such motorcycle taxis are also considered as a “commercial” transport mode (Sietchiping et al 2012, p.186) or a “commercial public” mode (Kumar 2011, p.1; Ehebrecht et al 2018, p.253). Privately used motorcycles fall out of the scope of this subsection.

Growth of motorcycle taxis in African cities

In his seminal study exploring informal transport modes at a global scale, Cervero (2000, pp. 17,21) stated as early as 2000 that motorcycle taxis were “the most rapidly growing form of informal transport services” (p.17, 21) in several regions of the world.

This growth phenomenon has also been observed in Sub-Saharan Africa (SSA), both in urban and rural geographies. Ehebrecht et al (2018, p.251) identify a “massive” increase, Kumar (2011, pp.15-16) an “exponential” and an “unplanned” one, which spreads from single SSA cities or countries to an increasing number of places. According to Sietchiping et al (2012, p.187), motorcycle taxis have become “an integral

part of [sic] urban mobility equation in most SSA cities". In a study on Douala, Lagos and Kampala, Kumar (2011, p.11) states that motorcycles in SSA are nearly only used in their taxi component, unlike Asian countries where a share of motorcycles is owned and driven for private use.

Motorcycle taxis first arose in Nigeria in the 1970s, followed by Niger, Cameroon, Benin and Rwanda in the 1980s and then Cameroon, Chad, Kenya, Togo, Uganda in the 1990s. Since the beginning of the 21st century, they have spread in urban environments and to further countries: Angola, Ethiopia, Ghana, Ivory Coast, Malawi, Mozambique, Sierra Leone, Tanzania and South Africa (Diaz Olvera et al 2016, p.2; Ehebrecht et al 2018, p.243). While a general surge on the continent may be observed, Black et al (2018, p.1) note heterogeneous developments in terms of usage and numbers, for instance, low numbers in South Africa or Ghana versus significantly high ones in Nigeria or Angola.

Research shows that this emergence of motorcycle taxis took place within the second wave of urban mobility transformations in SSA. The first movement saw a collapse of formal public transport by bus in the 1990s, resulting from a couple of factors: insufficient sources of revenues for incumbent public transport companies during the post-decolonization phase, mismanagement and international structural adjustment programs (Kumar 2011, p.6-7). This led first to the emergence of informal minibuses and shared taxis to fill the gap in collective transport provision, later followed by motorcycle taxis.

Scholars have identified numerous variables explaining the increasing appeal of motorcycle taxis as listed in Table 1, linked to poor quality of exogenous variables ("push") and endogenous motorcycle advantages ("pull"). These factors vary from country to country, rural to urban cases and may not be found in all geographies.

Table 1: Push and pull factors explaining the emergence of motorcycle taxis in SSA

| Push factors | Pull factors |
|---|--|
| Low quality and quantity of public transport | <i>For users</i> |
| Insufficient secondary and orbital road network | Affordability |
| Poor road conditions | Door-to-door |
| Increasing congestion | Ability to weave in traffic |
| Urban sprawl | Accessibility to rough terrains |
| Low private ownership of motorised vehicles | Transportation of goods |
| Low density | |
| Lack of alternatives | <i>For drivers</i> |
| | Employment opportunities |
| | Access to second-hand cheaper vehicles |
| | Cheap or adulterated fuel |
| | Access to credit, increased purchase power |
| | Little regulation or lack of enforcement |
| | Political patronage |

(Author's representation based on Kumar 2011, p.21; Ehebrecht et al 2018, pp.243-244; Sietchiping et al 2012 pp.184-186; Wahab and Jiang 2019, p.23)

Motorcycle taxis through the “informal transport” lens

Scholars commonly examine motorcycle taxis in the Global South via two concepts: “informal transport” or “paratransit”.

Cervero (2000, p.3) conceptualized the notion of “informal transport” as transport services operated without “to some degree, official and proper credentials” or “without official endorsement” (Cervero and Golub 2007, p.446). This regulatory perspective impregnated UN Habitat’s understanding of the phenomenon, qualifying informal transport as “privately owned vehicles whose operators often lack necessary permits or do not meet requirements for vehicle size, insurance coverage or driver standards” (United Nations Human Settlements Programme 2013, p.15). While this definition sets a duality between informal and formal transport, it does not imply that informal transport operators disrespect all set regulations (Cervero 2000, pp.43-44, 52). In addition, despite sharing some common characteristics and trends, informal transport is not a uniform, homogenous category. Rather, characteristics vary, depending on transport modes and geographies.

Motorcycle taxis are occasionally characterised as “paratransit” modes (Bakker 2018, p.103; Nugroho and Zusman 2018, p.342). This notion was developed by Behrens et al (2016, p.1) as “a flexible mode of public passenger transportation that does not follow fixed schedules, typically in the form of small- to medium-sized buses”. The common denominator here is not the legality of the transport service but its flexibility. However, several publications on paratransit focus on *collective* paratransit or *public transport* paratransit, namely buses, excluding for-hire services (for instance Behrens et al 2016, p.7; Klopp and Cavoli 2017, p.95).

These two concepts are still commonly used as references, yet recent publications have introduced new approaches to grasp the realities of the phenomenon. In a study on two- and three-wheeler taxis in Dar es Salaam, Heinrichs et al (2017, p.134) reject the divide between the formal and the informal, introducing the notions of “institutional or urban bricolage” and “co-creation” that aim to reflect how stakeholders jointly negotiate norms and rules.

Recentness of research on motorcycle taxis in SSA

As aforementioned, Cervero observed as early as 2000 the rise of motorcycle taxis as the most rapid among all informal transport modes (pp.17,21) and identified some basic characteristics. Yet, knowledge on the features of this specific mode is scarce (Kumar 2011, p.3). Basic data is often lacking at the local level, such as the precise number of motorcycles in cities (Dar es Salaam for Heinrichs et al 2017, p.140; Kampala for Evans et al 2018, p.3; Lomé for Diaz Olvera et al 2016, p.167). Studies have mostly covered isolated cases. Observing the contrast between their growing significance in SSA countries and a lack of attention in planning and research, Evans et al (2018, p.2) goes further by qualifying this as “a collective blind spot”.

Recognizing an existing knowledge gap, Ehebrecht et al published in 2018 a study on motorcycle taxis in SSA which provides an overview of existing studies and looks for similarities and dissimilarities across cases in terms of demand and supply. They note the persistence of large research gaps, especially in organisation, regulation and spatial characteristics.

When it comes to this under-researched spatial dimension, recent explorations by Evans et al (2018) and Ibrahim and Bize (2018) attach more importance to the geographical and anthropological analysis of

motorcycle taxis movements. In studies conducted in Kampala and Nairobi, they explore how the constitution of waiting stands and solidarity bonds represent a form of urban infrastructure.

Main features of motorcycle taxis in SSA

Initial characterization

Cervero (2000, p.15) identified four main characteristics of motorcycle taxis: flexible routes and schedules, limited seating capacity, main role as feeder services, limited geographical coverage at neighbourhood level. Motorcycle taxis tend to wait at stands or points, often localized at intersections between major roads and narrower streets, where they return after a trip (also in Cervero and Golub 2007, p.450).

Evolution of their role in urban systems

This role of motorcycle taxis as feeders, describing services done for the first or last mile part of the trip in conjunction with mass transit services, has been confirmed by other studies. Ehebrecht et al (2018, p.247) and Heinrichs et al (2017, p.140) add two further roles: first, trips on routes not covered by public transport services, second, trips made by motorcycles to weave in traffic and avoid congestion. This last phenomenon is increasing in the context of worsening congestion in SSA cities.

The relationship between motorcycle taxis and other urban transport modes is a critical question. While complementary between modes may be noted when motorcycle taxis are used as feeder services, and targeted when implementing mass transit solutions (Ehebrecht et al 2018, p.254), other studies raised concerns that motorcycles compete with public transport rather than completing it (Cervero 2000, p.23 for the case of Ho Chi Minh City; Suatmadi et al 2019, p.9).

Similarities and dissimilarities in SSA

Ehebrecht et al (2018, pp.246, 248) identify a couple of similar features, such as young male drivers - aged between 20 and 30 years -, and perceived benefits in terms of accessibility, flexibility, speed, employment in related activities such as maintenance. The negative impacts of motorcycle taxis are increasingly being discussed across countries, touching upon safety and environmental issues. Accidents are one of the most frequently mentioned problems of the mode, arising from a combination of insufficient or nonexistent driving training, higher risks as they weave through congested traffic and drive at high speeds. According to Evans et al (2018, p.2), the numbers of deaths incurred has been occasionally compared with the HIV health crisis. Air pollution is also a key concern as motorcycles pollute disproportionately higher than cars (case of Douala, Gota 2018, p.251). Linked with these negative externalities as well as their rural origin, motorcycle drivers have a poor image, often seen as "aggressive" and associated with criminality (Sietchiping et al 2012, p.186).

The list of dissimilarities is long, ranging from the spatial range of average trips (e.g. a majority of trips of circa one to three kilometers in Accra versus five to fifteen kilometers in Aba, Nigeria), to ownership patterns, and public regulatory approaches (Ehebrecht et al 2018, pp.246, 249, 253). Affordability of motorcycle taxis services is debated: while it is a recurrently cited benefit, for instance by Sietchiping et al (2012, p.186), Kumar (2011, p.1) indicates that they are more expensive than bus services. Behrens et al (2016, p.49) mention that, in 2014, the average motorcycle taxi fares in Nairobi were 2.5 higher than minibus services in off-peak hours, and 1.3 higher in peak hours.

Regulation and self-regulation

Motorcycle taxis were considered by Cervero (2000, p.23) as “the most difficult form of informal transport to regulate”. From a top-down perspective, lacking regulation or lacking enforcement of regulation on driving documents, helmets or reflecting jackets is a recurrent observation, though varying across countries (Kumar 2011, p.16; Ehebrecht et al 2018, p.254). Sietchiping et al (2012, p.186) shed light on the failure of some repressing approaches, such as bans to enter city centres.

From a bottom-up perspective, self-regulation stemming from motorcycle taxi drivers has been observed in some locations, closely linked to their spatial organisation. In their study on two- and three-wheelers in Dar es Salaam, Heinrichs et al (2017, pp.141, 146) examine emerging processes of self-regulation and institutionalization at waiting points called stands. They identify “rather advanced forms and levels of organization”, structured around a collection of savings, issuance of small loans, internal functioning rules, occasionally fare setting. Institutional bricolage takes place when public agencies accompany projects carried by these self-regulated organisations, for instance when implementing driving training programs. These findings align closely with those of Ibrahim and Bize (2018), observing solidarity bonds taking place at a motorcycle taxi stand in Nairobi.

Research on motorcycle taxis in Kenya

To the exception of this latter study on motorcycle stands in Nairobi, academic research on motorcycle taxis in Kenya has solely focussed on rural areas or medium-sized cities (Ehebrecht et al 2018, p.252). Studies analyse digitalisation, safety, organisation and socio-economic impacts.

2.2. Development of electric two-wheelers, including electric motorcycles

Following the exploration of the rise in motorcycle numbers in the previous subsection, this subsection investigates a further dimension of the research question: the shift of powered two-wheelers from internal combustion to electric propulsion. Identified literature touches upon either electric motorcycles or the broader category of electric two-wheelers (E2Ws).

Outline of the global emergence of electric two-wheelers

According to the International Energy Agency (2019, p.6), electric two-wheelers reached 260 million worldwide at the end of 2018, a much higher figure than the 5.1 million electric cars and 460,000 electric buses.

Similar to the growth of conventional motorcycles, the development of E2Ws started in Asia. The process in which e-bikes became popular in China is well-documented (Bakker 2018, pp.99-100; Kerdlap and Gheewala 2016, p.1400; Black et al 2018, p.1; Weiss et al 2015, pp.351-352; Eccarius and Lu 2020, p.12; Mou et al 2013, p.9). While the production of e-bikes started as early as the 1980s, it was the bans or restrictions on gasoline-powered motorcycles enacted by several Chinese cities in the 1990s and 2000s, combined with lax regulation on the use of e-bikes, that contributed to an exponential growth of e-bikes in the 1990s. Further factors include a decrease in e-bikes prices, increase of congestion in urban centres and

increase of fuel prices (Weiss et al 2015, pp.351-352). China is still deemed to be the world-leading country for E2Ws in terms of use - 200 to 230 million E2Ws and 7% of transport modal share in 2015 - and sales (Bakker 2018, p.99; Black et al 2018, p.1). Even though commonly labelled e-bikes, doubts are raised on the category they belong to; Eccarius and Lu (2020, p.12) qualify “a large proportion of [them as] motorcycles with “decorative” pedals”. In addition, Macao and Taiwan have been particularly supportive of the development of e-motorcycles through various policy instruments (Mou et al 2013, p.9, Ching 2013, p.3, Eccarius and Lu 2020, p.2).

Other Asian countries have not experienced such a strong increase, due to the absence of the aforementioned factors combined with challenging weather conditions and negative perceptions linked to low-quality imported EVs (Weiss et al 2015, p. 352). However, timid growth and development of policy support measures can currently be observed as an answer to critical air pollution issues (Black et al 2018, pp.1-2). EVs are still at a nascent phase in India (Dhar et al 2016, p.140) but their uptake is supported by recent policy regulation, including funding schemes (WRI India and IIT Madras 2019, p.72). Thailand accounts for circa 380,000 electric two-wheelers (own calculation from Kerdlap and Gheewala 2016, p.1400, no specification on the types of two-wheelers). Electric two-wheelers in the form of e-bikes exist in Vietnam but are very limited in numbers, used mostly by students (Bakker 2018, p.100; Jones et al 2013, p.2).

After Asia, Europe comes second in terms of use and sales of electric two-wheelers - mostly e-bikes - in the Netherlands, Germany and Denmark, followed by Japan and the USA (Bakker 2018, p.99; Weiss et al 2015, pp.351, 355; Eccarius and Lu 2020, p.2). In Africa, “electric vehicles are almost non-existent” (Black et al 2018, p.1), a phenomenon that will be detailed in the following subsections.

Electric two-wheelers: a broad and fluctuating category

As this brief outline shows, E2W is a broad category comprising a wide array of vehicles ranging from bicycles, alternatively called e-bikes, medium-sized vehicles such as e-mopeds and e-scooters (here understood as “electric seated scooter”, not as “motorized kick-scooter”, Yanocha and Allan 2019, p.13) and last but not least to large motorcycles. Yet, these vehicles have different characteristics, in terms of speed, power, weight, presence of pedals, public perceptions etc.

Large electric motorcycles are differentiated from lighter-weight vehicles by Weiss et al (2015, p.349) as having speeds higher than 45 kilometers/hours and a motor power over 4 kW. This category corresponds best to the Kenyan situation where a power of 6 to 7.5 kW is expected to match current ICE motorcycles, whose majority currently has a capacity of 126 to 150 cubic centimetres (CC) (EPRA and UNEP 2020, p.12).

In fact, the definition of the E2Ws category varies by studies, as shown in Table 2. Electric motorcycles are included in most defined boundaries for E2Ws, except for two publications by Bakker (2018, p.97) and the Asian Development Bank (2009, p.vi).

Table 2: Scope of the E2Ws category

| Category | Sources | Vehicle types included in E2W |
|------------------------------|--|---|
| Electric two-wheelers (E2Ws) | Black et al (2018, p.4), Sheng et al (2016, p.74), Fu (2013, p.3) Weiss et al (2015, p.349) | Electric bicycles, (seated) scooters and <i>motorcycles</i> |
| | Bakker (2018, p.97), Asian Development Bank 2009, p.vi | Electric bicycles, scooters/mopeds and <i>motorcycles</i> Pedelets, e-mopeds, e-scooters (i.e. not large e-motorcycles) |
| | Yanocha and Allan (2019, p.14) | Electric seated scooters and <i>motorcycles</i> (i.e. not e-bikes considered as micromobility) |

A further caveat when comparing E2Ws types lies in heterogeneous national definitions together with lacking and opaque information. Eccarius and Lu (2020, pp.4, 13) estimate that up to 60% of e-bicycles in China surpass speed and weight thresholds, possibly qualifying them as light motorcycles.

In addition, research on the E2Ws category focuses mostly on e-bikes. This may stem from the predominant use and sales of these vehicles in China, higher than those of large electric motorcycles (Weiss et al 2015, p.349; Eccarius and Lu 2020, p.7; Fu 2013; Gota 2018, p.27). Therefore, even if electric motorcycles belong to the E2Ws category, specific caution must be exercised when reviewing literature.

Finally, some studies solely focus on electric motorcycles, not requiring such caution (e.g. Eccarius and Lu 2020; Sheng et al 2016; Mou et al 2013; Ching 2013; Wahab and Jiang 2019; Kerdlap and Gheewala 2016).

Technical characteristics of electric motorcycles

Electric motorcycles may be defined as powered by electricity stored in a rechargeable battery. Most of them are battery electric vehicles (BEVs), meaning they are solely powered by the battery, while a very few are plug-in hybrid vehicles (PHEV) combining a conventional engine with an electric motor and a battery (Ching 2013, p.1; Eccarius and Lu 2020, p.4). Composition of batteries, charging options and locations vary.

Batteries may be lead-acid or lithium-ion (Li-ion), the latter defined by different subcategories with distinct features. A preference for Li-ion batteries was found in a couple of studies, stemming from “high energy density, long cycle life and high charging and discharging rate capability” (Dhar et al 2016, p.143), despite being more expensive than lead-acid ones (Kerdlap and Gheewala, p.1410). In addition, research shows that Li-ion battery prices are decreasing (*ibid*; Black et al 2018, p.2).

Longo et al (2016) identify three options for charging EVs: conductive charging that may be done at home or public areas (AC or DC), inductive charging namely wireless charging, and finally battery swapping. Swapping involves the exchange of a depleted battery against a charged one at designed places, implying different business models as the battery is owned by the company and leased to the user. Since the battery is the most valuable component in a motorcycle, leasing it rather purchasing may have a significant impact for the driver.

Building a charging infrastructure is not a systematic prerequisite. An advantage often cited for electric motorcycles lies in their lighter weight batteries: they may be removed and charged at conventional electrical sockets at home - for instance at night -, or in office buildings. However, this requires a stable electric grid, and access to it. Batteries may also be swapped at dedicated stations (Eccarius and Lu 2020, p. 11), in this case requiring a dedicated infrastructure. Charging locations depends on the selected option and may range from charging at home, at office locations (parking spaces or detachable batteries), swapping at fuel stations, shops etc.

State of academic research on electric motorcycles

Electrification of motorcycles is a research field showing knowledge gaps on several levels. A first gap originates from a focus on electric passenger cars, although these do not represent the majority of electric vehicles. In fact, the terminology "electric vehicles" is sometimes used in publications to study solely light-duty vehicles (e.g. Rezvani et al 2015). This may have implications on perceptions as electric cars and motorcycles have different characteristics, such as the capacity to have a detachable battery. Moreover, within the E2Ws category, electric motorcycles are less analysed than e-bikes, as previously explained. Identified publications on electric motorcycles study environmental aspects (Kerdlap and Gheewala 2016; Sheng et al 2016; Mou et al 2013), factors influencing consumer purchase or use decisions (Eccarius and Lu 2020; Wahab and Jiang 2019) or costs dimension (Ching 2013).

Emergence of electric motorcycles in Sub-Saharan Africa

As stated by Black et al (2018, p.1), "current levels of motorization are still exceptionally low and electric vehicles are almost non-existent" in SSA. In this conference paper, the authors argue in favour of the development of electric motorcycles as a "leapfrogging" strategy (*ibid*, p.2) which could reduce carbon emissions and air pollution, while developing a manufacturing industry with lower entry barriers than cars manufacturing. Besides this article, researchers have started investigating perceptions and impacts of electric mobility and potential uptake in African cities. In a study on Tamale, Ghana, Wahab and Jiang (2019) examine purchasing factors for a switch of motorcycle taxis to electric vehicles. In a master thesis, Czeh (2019) looks at potentials for electrification of three-wheelers in Dar es Salaam, Tanzania.

Electric motorcycle taxis have been recently tested in East-African countries and some of them have moved to a commercialization phase. However, these developments are too recent to have been critically analysed in academic literature. They will therefore be described in Section 3 within the local context.

2.3. The sustainability question of electric motorcycles

Gasoline-powered motorcycles and sustainability

The relationship between conventional motorcycles and sustainable urban mobility is a complex one. Studies oscillate between the recognition of motorcycle use as a benefit for accessibility, flexibility, affordability, employment when used as taxi services and feeder role on one side, and significant negative externalities including air pollution, emissions, traffic accidents, detrimental impacts over other transport modes and association with crime on the other side (Gota 2018, pp.7-10; Koossalapeerom et al 2019, p.619; Bakker 2018, pp.97, 102-104; Eccarius and Lu 2020, p.1; Sietchiping et al 2012, pp.185-186).

As Gota (2018, p.5) expressed it, “two-and-three-wheelers pose some of the most serious unresolved questions within the context of sustainable urban mobility”. This complexity is reinforced by a lack of data and knowledge as this mode is “by and large, ignored in sustainable transport research, as well as in policy discussions and climate change literature” (Bakker 2018, p.98). In addition, many Southern cities do not consider them in urban planning (Evans et al 2018, p.2; Sietchiping et al 2012, p.186). Some cities have banned motorcycle taxis in specific urban areas, a strategy often failing (*ibid*). The Institute for Transport and Development Policy (ITDP) has recommended replacing them through modes deemed more sustainable, namely public transport, walking and cycling (Gota 2018, p.14).

And yet, some scholars highlight the potential for this transport mode provided it undergoes reforms, especially in their taxi component. Gota (*ibid*, p.23) suggests promoting stronger integration with other modes, reduction of emissions via electrification, retrofit or fuel emission standards so that they can be turned “into a valuable addition to urban sustainable mobility concepts”. Sietchiping et al (2012, p.185) and Evans et al (2018, p.2) underline how motorcycle taxis address Sub-Saharan specific contexts and needs, arguing that benefits override shortcomings.

Can motorcycles electrification contribute to a transformation of this transport mode towards sustainability? The next subsection investigates sustainability factors and impacts of electric motorcycles, or the broader category of E2Ws, used in urban environments.

Multidimensional sustainability of electric motorcycles

Among academic literature on E2Ws, environment is the most documented sustainability dimension, far ahead of economic and social ones. The article by Weiss et al (2015) stands as an exception, investigating the three dimensions.

Two complementary answers can be found in literature to the sustainability question of electric motorcycles. First, studies list potential sustainability impacts, positive or negative; secondly, they identify factors shaping the degree of sustainability.

Identification of sustainability impacts

Environment

The opportunity to reduce fuel consumption, hence emissions of greenhouse gas (GHG), as well as other air pollutants is identified in numerous studies (Bakker et al 2019, p.1; Suatmadi et al 2019, p.228; Bakker 2018, p.10; Black et al 2018, p.1; Wahab and Jiang 2019, pp.22-23; Eccarius and Lu 2020, p.1; Jones et al 2013, p.2). Electrification would tackle one of the most unsustainable characteristics of conventional motorbikes that is a disproportionate emitter of GHG and other pollutants (Gota 2018, p.21). Assessment of the exact degree in the reduction of GHG emissions varies from case to case, for instance from 50% if conventional motorcycles are replaced by electric scooters (ADB 2009, p.vi; Koossalapeerom et al 2019 p.619), to 66% in a case in Macao (Mou et al 2013, p.9). Case specificity is reinforced by the fact that transition may involve a change in the type of vehicle, for instance in China e-bikes having replaced ICE motorcycles.

Given these identified benefits, electrification of motorcycle fleets emerges in the list of measures recommended to address climate change in the transport sector. ADB (2017, p.54) identified two-wheelers electrification as one of the two measures with the strongest mitigation potential for the transport sector in Vietnam. Dhar et al 2016 (p.144) estimate that nearly all two-wheelers in India need to become electric to stay within a 2-degree scenario. The fact that electrification is occasionally cited as a decarbonization benefit without underlying data to support the case (e.g. Suatmadi et al 2019, p.228, Bakker et al 2019 p.1) also reveals its mainstreamness.

Still, there are nuances: electrification may result in a double shift: from emissions at use phase (fuel) to production phase (electricity generation), and from urban areas to remote ones (Kerdlap and Gheewala 2016, p.1399, Dhar et al 2016, p.145). This will be further explored in the upcoming subsection on sustainability factors.

Electrification of two-wheelers may therefore be framed within two decarbonization-related transport concepts: low-carbon transport (LCT) and the Avoid-Shift-Improve paradigm.

LCT measures are defined by Bakker et al (2019, pp.1-2) as “transport sector developments that emit less GHG emissions than in a business-as-usual (BAU) scenario”. These authors identify electrification of two- and three-wheelers as one of ten recommended LCT measures. Two-wheelers electrification can also be found in the Avoid-Shift-Improve concept, as part of the “Improve” dimension, namely “improving vehicle energy and carbon efficiency of each mode” (*ibid*, p.4; Gota et al 2018, p.378). Gota et al (*ibid*) praise electric vehicles “as a representative example of deep emission reduction pathways” and recommend stepping up two-wheeler electrification.

Further environmental benefits are identified in literature, such as the reduction of air pollutants in cities and associated health hazards (Dhar et al 2016, p.148; Kerdlap and Gheewala 2016, p.1399; Gota 2018, p.21; Bakker 2018, p.102; Jones et al 2013, p.2; ADB 2009, p.vi; Weiss et al 2015, p.354), as well as reduced noise levels, especially in cities that have a significant modal share for motorcycles (Sheng et al 2016, p.73). However, environmental risks are also identified, mainly issues linked with sourcing and disposal of batteries. Such risks depend on sourcing of raw materials, types of batteries, the existence of efficient battery production, recycling chains, end-of-life (EoL) management (Brown et al 2010, p.3801; Kerdlap and

Gheewala 2016, p.1403). Lithium-ion batteries are seen as more environmentally sustainable than lead-acid ones (Weiss et al 2015, p.358; Gota 2018, p.29). These risks are qualified by Dhar et al (2016, p.140) as “co-costs”. Recycling of Waste Electrical and Electronic Equipment (WEEE) proved to be a significant issue in China (Weiss et al 2015, p.354).

Economic

Economic aspects are mentioned in publications on two-wheelers electrification. However, they mostly appear as possible co-benefits, not as an entry point into the subject.

Energy security via reduction of fuel imports is mentioned by Bakker (2018, p.102). Black et al (2018, pp.2,3) identify the opportunity to create a national manufacturing industry of electric motorcycles on the African continent. Studies also discuss total cost of ownership (TCO). Several consider this cost to be lower as a consequence of lower operation and maintenance (O&M) costs, even with higher upfront investment costs (Kerdlap and Gheewala 2016, p.1399; Black et al 2018, p.2; Ching 2013, pp.3, 5). However, Weiss et al 2015 (p.356) seem less conclusive on a lower TCO.

Job creation was mentioned in Brown et al (2010, pp. 3803, 3805): introducing a new type of vehicle creates new employment opportunities and requires training professionals on vehicle use, maintenance, and repairs, as well as on safe charging or swapping of batteries. No mention of potential job destructions in activities related to conventional motorcycles, such as mechanics, repair shops, spare parts dealers, fuel stations, were found.

Social

Social aspects are rarely mentioned, the most frequently discussed one being safety. Electric motorcycles are considered riskier when driven at low speeds as the engine does not produce sound and may be less easily detected by other vehicle drivers (Weiss et al 2015, p.357; Eccarius and Lu 2020, p.11; Gota 2018, p.28). However, this could be mitigated through added sound and does not seem to be a concern at higher speeds (Eccarius and Lu 2020, p.11). Other potential social elements, such as an impact on the image of motorcycle taxi drivers, organisational aspects of informal transport, were not found. A reasonable assumption lies in the fact that EVs are mostly privately owned in Asian and European contexts, possibly leading to few or no social changes incurred by electrification.

One further dimension is not officially labelled as socio-economic, yet one could classify it so as it includes a strong accessibility component: the constitution of an integrated transport network. Eccarius and Lu (2020, p.1) and Gota (2018, p.28) both consider that electric two-wheelers can participate in the creation of a more sustainable urban system if planned in integration with other transport modes. This could be the case for instance if charging or swapping stations were strategically located at connections with mass transit.

Identification of main sustainability variables

The previous subsection identified expected multidimensional impacts of electric two-wheelers. This subsection dives deeper in listing variables that are deemed to have the strongest impact on the degree of sustainability. As shown in Table 3, the most commonly identified ones are: the share of renewable sources in electricity generation, possible dynamics of modal shift and the production and disposal of batteries.

Table 3. Factors determining sustainability of electric motorcycles or two-wheelers

| | Electricity mix | Modal shift | Batteries | Others |
|--|-----------------|-------------|-----------|--|
| Weiss et al 2015, pp.354, 358-359 | ✓ | ✓ | ✓ | Emissions treatment at power plants |
| Kerdlap and Gheewala 2016, pp. 1388, 1405 | ✓ | | ✓ | Speeds, i.e. higher electricity consumption at higher speeds |
| Gota 2018, pp.27, 29 | | ✓ | ✓ | |
| Bakker 2018, p.99 | | ✓ | | |
| Black et al 2018, p.2 | ✓ | | | |
| Dhar et al 2016, p.147 | ✓ | | | |

The environmental primacy is found here again: the share of renewables in the electricity mix and batteries are seen as the most critical sustainability variables (Weiss et al 2015, p.358). However, regarding the former, some scholars claim that E2Ws would have a better environmental footprint than ICE motorcycles even in the case of coal-powered electricity generation (Gota et al 2018, p.378). The question of batteries partly depends whether they are lead-acid or lithium-ion, on EoL management and on recycling, as discussed above.

Modal shift may be triggered by electric modes if they are considered more attractive or convenient. This aspect may lean in either negative or positive directions. In the positive outcome scenario, E2Ws may replace conventional motorcycles or even cars, using less road space in this last case. They may also provide complementary services to public transport, acting as feeder modes. In the negative outcome scenario, they may substitute public transport or non-motorised transport for E2Ws. Gota (2018, p.28) identified such a case in two Chinese cities. More generally, this aspect shows that two-wheelers electrification is not only a technological project but may have more systemic impacts as identified by Bakker (2018, pp.98-99): “E2W thereby change urban mobility ecosystems or regimes, including the vehicle fleet composition, mobility options and urban planning”.

2.4. Conclusion

Analysis of literature has shown several research gaps: on electric motorcycles, on motorcycles used as taxi services and on African contexts. This study aims to bring forward the debate by investigating the specific case of motorcycle taxis electrification in Nairobi. To do so, it will apply the approach recommended by Weiss et al (2015, p.359) namely, to investigate the sustainability of motorcycle taxis in Nairobi as a case-by-case assessment, looking at specific economic, social and environmental impacts.

Perceived effects will be analysed against the three-pronged dimensions of sustainable transport, using Litman (2007, pp.11,14) classification as a basis, adapted with specific focuses generated for the Kenyan context. Simultaneously, the study will keep a specific focus on findings identified in electrification literature, namely the key significance of batteries, electricity mix and modal shift. Table 4 summarises this approach, emphasising aspects specific to SSA or to electrification in bold. Anticipated effects will be scrutinised in a holistic approach in line with the definition of sustainable transport suggested by the international structure Slocat in 2012 as reported by Bakker et al (2014, p.345):

“Sustainable transport enables access to goods and services that support equitable development while limiting short- and long-term adverse consequences for environmental, social and economic services and systems.”

Table 4: Three-pronged urban mobility components

| Environmental | Economic | Social |
|--|---|--|
| Climate change | Congestion | Safety |
| Air, noise and water pollution | Supply costs (infrastructure, vehicles) | Accessibility, including for persons with reduced mobility |
| Energy consumption, Electricity mix | Demand costs (users) Employment | Affordability Liveability |
| Impacts and depletion of natural resources | Costs of accidents and depletion of resources | Connectivity of modes Regulation of informal modes |
| Battery sourcing and management | | Modal split and shift |

(Adapted from Litman 2007, pp.11,14, with author's additions)

Section 3 - Local context

This section starts by reviewing developments of electric motorcycle taxis in East-African countries, as they may inspire or influence Kenyan stakeholders. It then zooms into the Kenyan national level, investigating developments and policies on motorcycle taxis, electric mobility and energy. It finally describes Nairobi's urban mobility system. To do so, it combines analysis of relevant laws and regulations with newspaper articles and reports.

3.1. Emergence of electric motorcycle taxis in East-Africa

As aforementioned and to the author's best knowledge, academic literature of motorcycles electrification in SSA is insubstantial if non-existent, to the exception of Black et al (2018) and Wahab and Jiang (2019). Therefore, available information stems mostly from press articles. These must be analysed with particular care, given limited press freedom in some of these countries and a possible lack of critical distance with information spread by involved companies.

Table 5 focusses on two commercial initiatives that have been launched in capital cities of two close countries to Kenya: Kigali (Rwanda) and Kampala (Uganda). Both projects use lithium-ion batteries, as well as swapping and leasing of batteries, and claim to ensure substantial economic gains for drivers. They both have been started by companies led by foreigners.

Table 5: Two electric motorcycles projects in Kigali and Kampala

| Features | Ampersand | Bodawerk |
|--|--|--|
| Location | ◆ Kigali, Rwanda | ◆ Kampala, Uganda |
| Development phase | ◆ Commercial launch of 20 electric motorcycles in May 2019, following a testing phase of prototypes in 2018 | ◆ Commercial pilot planned for end 2019 starting in February 2020 with 100 conversions, following development of prototypes in 2019 |
| Projections | ◆ 500 motorcycles in 2020, further expansion in East-Africa | ◆ Unknown |
| Vehicles & batteries | | |
| Retrofit or new | ◆ New vehicles | ◆ Retrofit (conversion) of vehicles |
| Type of battery | ◆ Lithium-ion | ◆ Lithium-ion |
| Provenance of parts (chassis, motors, batteries) | ◆ Tailor-made motorcycles adapted to the context of Kigali (prototyping phase), built from ICE motorcycles parts, with a battery pack of their own design ◆ Combination of local and imported parts | ◆ Retrofit of ICE motorcycles currently being used (Bajaj Boxer 100 CC, i.e. 90% of Kampala motorcycle fleet), or purchase of converted models ◆ Manufacturing of batteries out of components sourced out from dead laptops, combined with imported cells |
| Infrastructure | | |
| Charging options | ◆ 2 swapping stations, made of recycled shipping containers | ◆ Swapping stations |
| Time to charge | ◆ 2 minutes to swap | ◆ Unknown |

| | | |
|------------------------------------|---|---|
| Distance per charge | ◆ Diverging information, 60 to 75 kilometers per charged battery | ◆ 70 km per charged battery, i.e. 2 batteries needed per day to cover an average of 100 km |
| Business model | | |
| Model | ◆ Motorcycles leased or purchased (about 1,500 USD) ◆ Batteries owned and maintained by the company and rented out to drivers. | ◆ Free-of-charge retrofit ◆ Sale of converted motorcycle without battery (circa 800 USD) ◆ Subscription plus daily fee of batteries (unlimited swaps), owned by the company |
| Battery fees | ◆ Pay-as-you-go model for batteries, i.e. depending on use | ◆ Subscription plus a daily fee of circa 3 USD |
| Claimed economic gains for drivers | ◆ Electrically charging costing circa 50% less than using fuel | ◆ Reduced charging costs by circa 50% plus lower maintenance costs |
| Further elements | | |
| Recycling | ◆ Unknown | ◆ Recycling former laptop cells to build motorcycle batteries ◆ No information on reuse |
| Noise to avoid safety risks | ◆ Additional sound/music via electric speakers | |

Sources: Ndegeya (2019, n.p.), Kuhudzai (2019a n.p., 2019b n.p.), Szentpetery-Kessler (2019, n.p.), Peters (2020, n.d.), Elmendorp (2019, n.p.), Kimberly (2020, n.p.)

This list is not exhaustive: further projects shifting motorcycle taxis from fuel to electricity are taking place in Kampala (start-up Zembo), Nigeria (start-up Max.ng) (Olayinka 2019, n.p.). Electrification projects also tackle other transport modes, such as public buses in Uganda or passenger cars in Kigali (Ndegeya 2019, n.p.). Initiatives taking place in Kenya and Nairobi will be described in upcoming subsections.

3.2. Kenyan landscape: motorcycle taxis, electric mobility and electricity

This subsection addresses a number of aspects that all play a role in the topic of electric bodas and need to be described before proceeding to data collection.

Surge in the numbers of motorcycles

The term “boda boda” originates from taxi services provided at the Ugandan-Kenyan border in the 1960s, initially using bicycles and later motorcycles, said to derive from the “border border” expression (Kumar 2011, p.8, Evans et al 2018, p.2). Boda bodas started spreading in Kenya from the 1990s onwards, but the real increase can be traced back to 2007 when the VAT rate of 16% was removed for motorcycles under 250 CC (Kiminyei and Gachanja 2018, n.p.).

The rise of motorcycles has been significant since then, identified as the most rapidly increasing vehicle in Kenya. Annual new registrations have been multiplied by 11.4 between 2007 and 2017 from 16,293 to 186,434, as depicted in Figure 3 (Ogot et al 2018, p.5). Yet, this spread did not happen uniformly across regions and cities. Boda bodas are more present in small to medium-sized cities such as Kakamega, Malindi, Kericho, Embu, Kitui and Kisumu (Salon and Gulyani 2019, p.9).

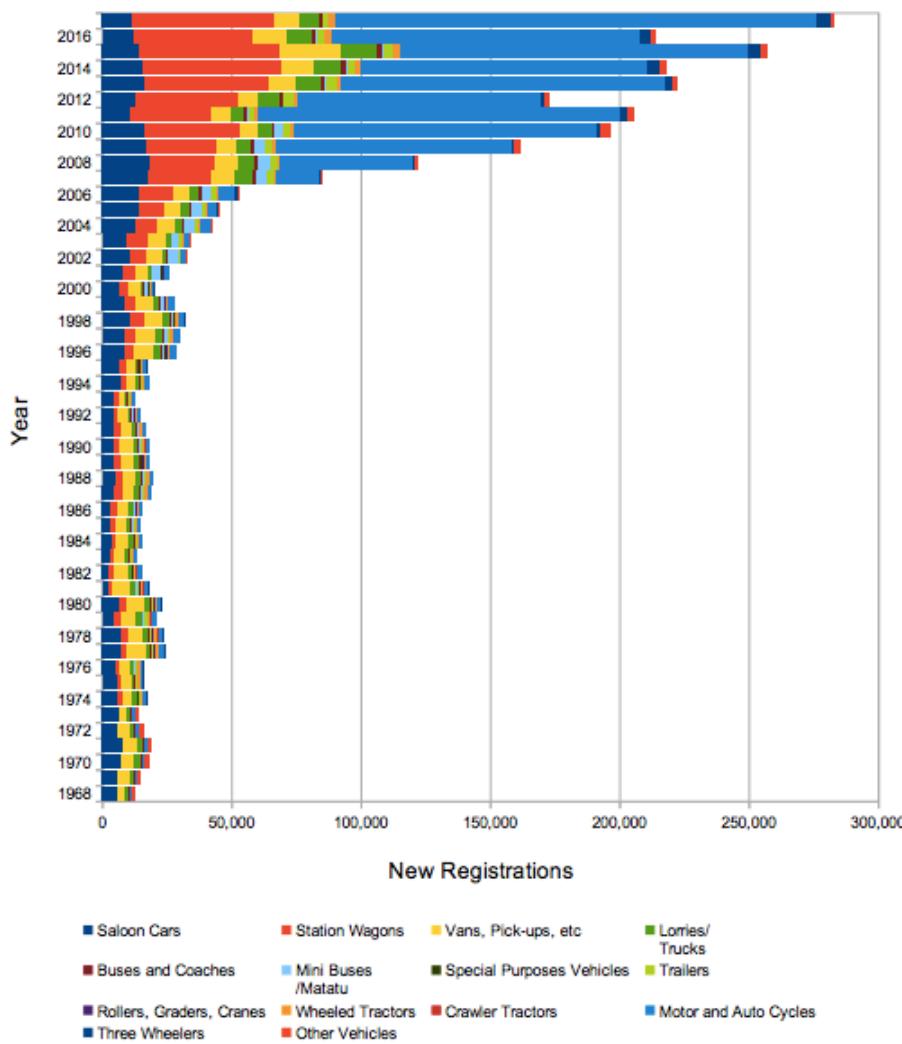


Figure 3: Annual new vehicles registrations between 1968 and 2017 (Ogot et al 2018, p.5)

Forecasts consider that this strong increase tendency will persist over time, as pictured in Figure 4.

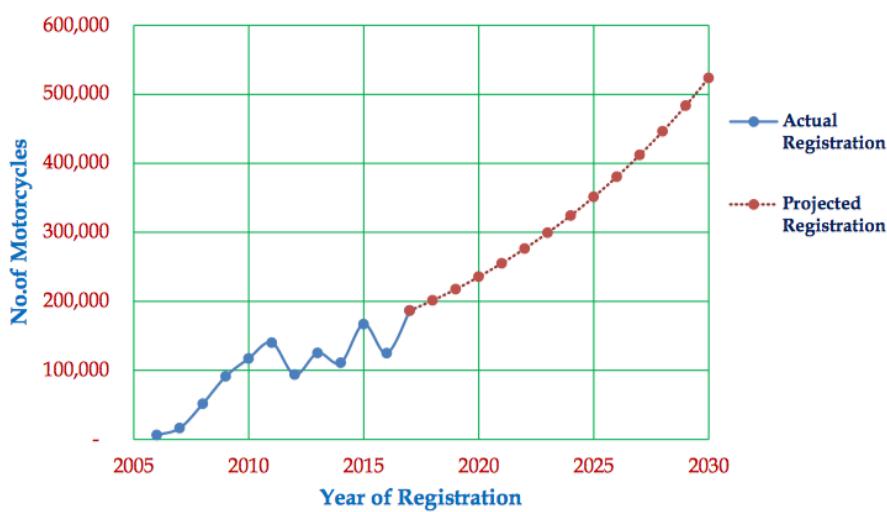


Figure 4: Registration of motorcycles, 2005-2017 and forecasts up to 2030 (EPRA and UNEP 2020, p.9)

Several sets of data collected by Nairobi University's professors for the German development agency GIZ or for the Energy and Petroleum Regulatory Authority (EPRA) and UNEP draw a picture of motorcycles in Kenya. According to Ogot et al (2018, p.9), the majority of motorcycles are aged 6 to 10 years, with an average of 9 years. Nearly all motorcycles registered (95.29%) have a capacity ranging from 51 to 150 CC, with 41.28% of them in the 126-150 CC category (EPRA and UNEP 2020, p.13). 98.5% of them use gasoline, only 1.40% of them diesel (ibid, p.18), none are battery-electric powered.

Narratives around boda bodas often align with academic literature's findings on motorcycle taxis, namely an unstable balance between the recognition of benefits and of significant negative externalities (e.g. Kiminyei and Gachanja 2018; Rajé et al 2018 p.102; Energy Regulatory Commission 2015, p.34).

The first externalities are environmental ones. Data collected for EPRA and UNEP (2020, pp.11, 18) show that two- and three-wheelers – 98% being motorcycles - emit more CO₂ emissions than passenger cars since 2014 because of their higher quantities. In addition, they disproportionately emit other pollutants such as hydrocarbons, carbon monoxide and nitrous oxides (ibid, p.12).

A further analogy with literature lies in the connection made with road accidents and criminality. According to the National Transport and Safety Authority (NTSA 2019, n.p.), 724 motorcycle drivers and 345 passengers died in 2019, representing increases of 23% and 40% since 2018. These categories have the lowest safety records after pedestrians (1,382 deaths). Boda drivers have been identified as perpetrators of crimes, thefts, assaults including rapes, but also as victims of violent behaviours including murders (NCRC 2019, pp.3-4). The sector is almost completely male-dominated (97.4% of drivers) and young (68.2% aged 18 to 33 years).

National regulation of boda bodas

The safety issue may be traced back to the regulatory framework that, although existing, is deemed not to be implemented. Table 6 describes the formal regulatory framework framing the operation of motorcycle taxis in Kenya.

Table 6: National regulatory framework for the operation of boda bodas

| | |
|-------------------------|---|
| Market entry | ◆ Driving (or provisional) license issued by NTSA. No operating licence required |
| Conditions of operation | ◆ 2 yellow helmets and 2 reflective vests, both indicating the registration number and the latter the name of the Savings and Credit Cooperative Organisation (SACCO) or group ◆ Only 1 person carried at a time; carriage of passengers <i>or</i> freight (specific requirements for the load dimensions allowed) ◆ Hours and areas of operations designed by NTSA having consulted the County |
| Insurance | ◆ Third party public service vehicle (PSV) insurance |
| Organisation | ◆ Participation to a corporate group or a SACCO of no less than 100 bodas |
| Pricing | ◆ Not regulated |

(Author's representation based on the National Transport and Safety Authority Act 2015, Articles 4, 5, 8, 9, 14)

There is currently no exhaustive database of boda drivers in Kenya, and the abovementioned regulation is commonly admitted not to be implemented (NCRC 2019, p.10). Discourses and narratives link poor safety records with a lack of driving training – some drivers operating without license - and disrespect for traffic rules. A national task force to bring “sanity” was established in November 2018 but its conclusions were only produced in February 2020 with a report - unpublished -, outlining more focus on driving training and more stringent controls by the NTSA (Muraya 2018, n.p.; Mwere 2020, n.p.).

Financial regulation also has a significant impact on bodas. An excise tax of motorcycle assembly initially envisaged in 2015 was removed in 2016 following the pressure of motorcycle manufacturers (Kiminyei and Gachanja 2018, n.p.). As a consequence, the number of newly registered motorcycles rose by 56% between 2016 and 2017 (own calculation from Ogot et al 2018, p.41).

Electric mobility policies and projects in the making

Figure 5 presents different facets of electric mobility in Kenya: national policies, projects, recommendations and initial impact assessments.

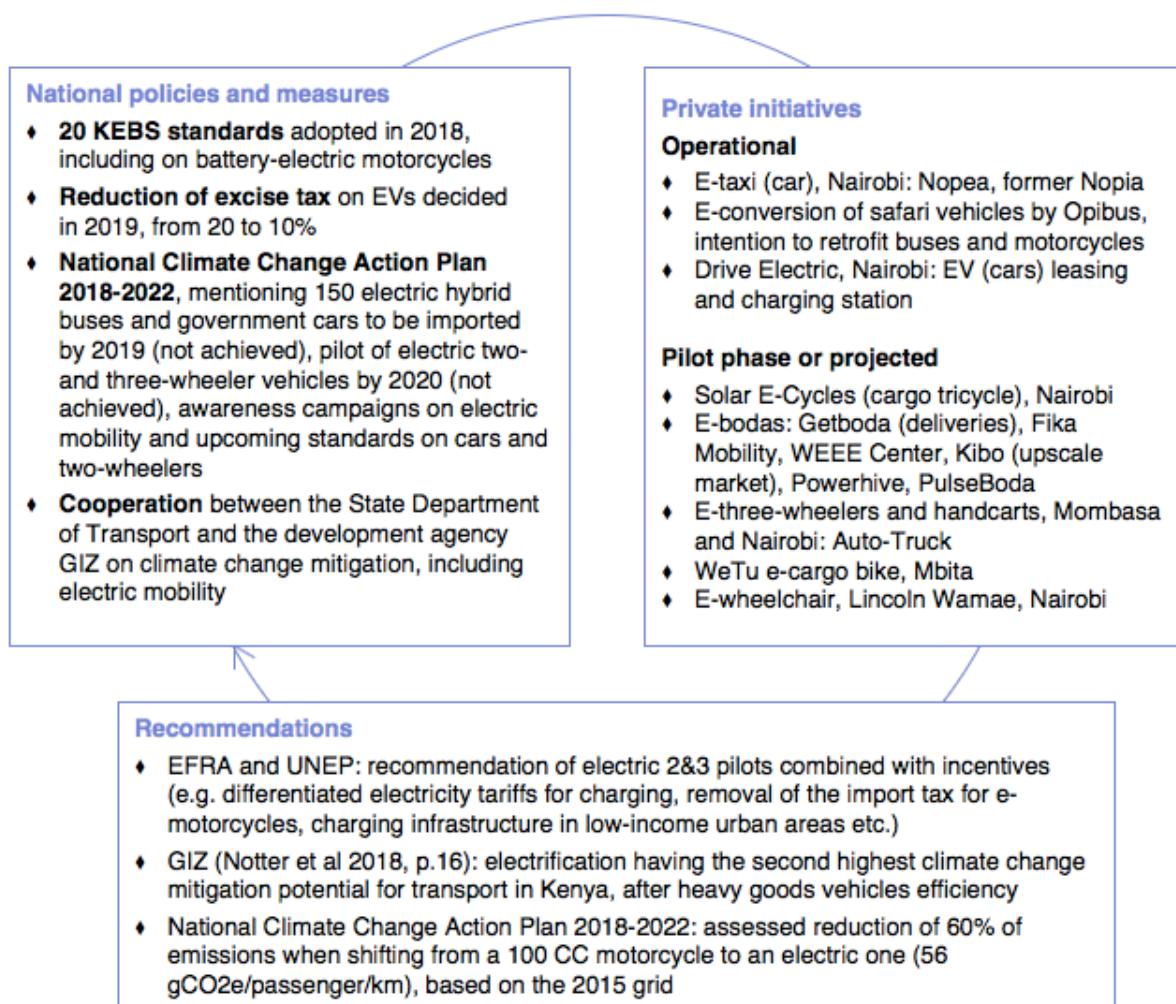


Figure 5: Electric mobility in Kenya: policies, projects and recommendations

(author's representation based on EPRA and UNEP 2020, pp. viii, 63; Government of Kenya 2018a, pp.62,66 and 2018b, pp.96,101; Notter et al 2018, p.16; Mbugua 2019, n.p.; Otuki 2019, n.p.; The Kenya Gazette 2018, p. 3753; Wachira 2019, n.p.)

Strengths and weaknesses of Kenya's electricity generation and distribution

Electricity generated in Kenya is characterised by a particularly high share of sources qualified as renewable at 86% as of 2018 (KNBS 2019a, p.19). The renewable share was generated by 46% geothermal sources, 36% hydroelectricity, 3% wind and 1% solar, the 14% non-renewable part coming from thermal sources. Net-metering enabling solar or wind energy producers to feed-in less than 1 megawatt is recently possible (Energy Act 2019, Article 162). Furthermore, plants currently face a situation of installed over-capacity, which raises interest of public authorities to increase demand for electricity. The high renewable share can partly explain the focus on electric mobility as a climate change mitigation strategy, together with economic interests to reduce increasing expenses of fuel imports (KNBS 2019a, p. 147).

Distribution of electricity, however, remains a challenge in some parts of the territory. Kenyan urban areas are more connected than rural ones, yet connection to the electric grid amounts to 81% in urban areas, leaving 7% using off-grid solutions and 12% without electricity (IEA, IRENA, UNSD, WB and WHO 2019, p.25). It seems arduous to have exhaustive and up-to-date information on access to electricity in Nairobi's informal settlements, but data collected by Corburn et al in 2012 (p.36) showed that in one major settlement, Mathare, only 9% of residents had a formal connection.

In addition, electricity prices are locally considered high, a situation partially due to overcapacity which incurs financial compensation to the plant operators (Kamau 2019, n.p.). Electricity was billed at 0.22 USD per kWh in 2016 in Kenya, that is 0.6 and 0.7 USD more expensive than its Tanzanian and Ugandan neighbours, but 0.21 USD less than in Rwanda (Trimble et al 2016, p.28). On the other hand, several taxes are applied to fuel in Kenya, leading to a gasoline price of 113 USD-cents/litre (GIZ 2019, p.2).

State of Waste Electrical and Electronic Equipment (WEEE)

In Kenya, WEEE management is at a nascent phase characterised by a few formal initiatives, while the bulk of this waste is handled by informal actors. In addition, awareness on this issue is considered insufficient, as well as the regulatory framework (Otieno and Omwenga 2015, p.663-664).

[**3.3. Nairobi urban mobility system**](#)

Main characteristics

Kenya's capital city Nairobi is a fast-growing city, whose population was officially estimated at circa 4.4 million in 2019 (KNBS 2019b, p.7). The Nairobi Metropolitan region encompasses 5 counties, including Nairobi City County (NCC), and a total population of circa 10.4 million inhabitants.

Nairobi is still marked by its colonial past and remains a "divided city", characterised by income-based segregation (Klopp and Cavoli 2017, p.97). High-income and low-density residential areas contrast with informal settlements that are said to house 50% of Nairobi's population on only 5% of the total residential area (Karanja and Makau 2009, p.10).

Residential outskirts are quickly expanding while employment remains concentrated in the city center (Cira et al 2016, pp.85-86). In addition, the road network is radial, shaped like a star linking 8 to 9 main corridors. Orbital and secondary roads are lacking. In fact, a majority of residential roads are unpaved, quickly turning

into mud (JICA 2018, pp.106, 151). Congestion has therefore arisen from a combination of the following factors: urban sprawl, increased private motorisation rates and a deficient road network. The World Bank calculated an average speed at circa 14 km/h, incurring costs ranging between 0.8 and 4 million USD per workday (Cira et al 2016, pp. 82, 92), down to 7.6 to 8.3 km/hr during peak hours according to Salon and Gulyani (2019, p.3).

While the majority of Nairobians still walk (39.7% of modal share in 2013, see Figure 6 below), sidewalks are non-existent or of poor quality, characterised by potholes and discontinuity. The bulk of collective transport is operated by informal minibuses and buses called matatus (28.5%) and a smaller share of semi-formal buses (12.2%). Passenger cars, taxis and trucks come third with 13.5%.

The last two decades have seen the share of walking and minibuses slightly decreasing, while two-wheeler modes - an aggregated category comprising bodas and bicycles - have increased. Caution must be exercised as the most recent official data dates back to 2013. Although official data identify a decrease of 1.8 percentage points for the aggregated category of private cars, taxis and trucks, others note an increase of private motorisation since 2004, following the removal of car import restrictions (Cira et al 2016, p.88, Klopp 2012, p.3). Increased private motorisation is already observable, especially in high-income areas that partially forbid access by matatus. Uber entered the market in 2015, likely to have triggered new dynamics (JICA 2018, p.119).

Forecasts follow similar tendencies, that are a further decrease of walking and buses combined with a further rise of private modes up to 21.6% of modal share in 2030 (NCC 2014b, p.7-33).

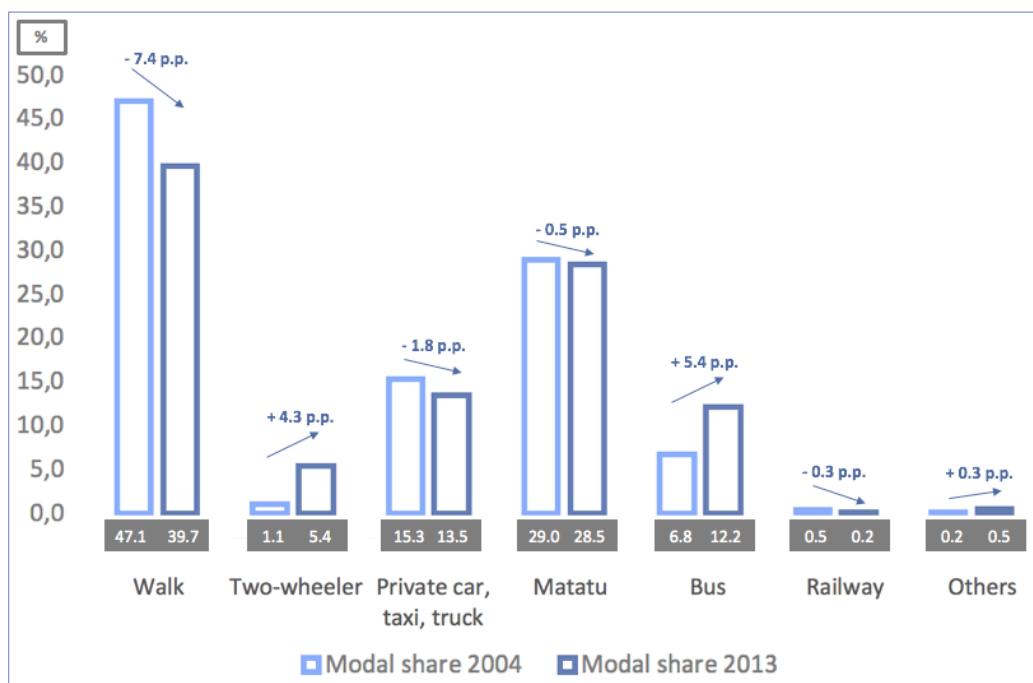


Figure 6: Evolution of modal split in Nairobi between 2004 and 2013 (% of person trips; p.p.: percentage points) (author's representation and calculation based on NCC 2014b, p.7-12)

Focus on data related to boda bodas

Studies presented in Table 7 capture the modal share and evolution of motorcycles in Nairobi on a granular level. They similarly show a tendency increase, while still remaining a minor mode within the modal split. Since these data mostly date back to a few years, caution must be taken as well.

Table 7: Sources assessing the modal share of boda bodas in Nairobi

| Source | Methodology | Findings |
|--|--|--|
| 2014 Integrated urban Development Master Plan, part I, part II, part III | Person Trip Survey | <ul style="list-style-type: none"> ◆ Both the number of trips and the modal share of two-wheelers, i.e. bodas but also bicycles, increased between 2004 and 2013 (+ 310,000 person trips and +4.3 percentage points). ◆ Two-wheelers had in 2013 a modal share of 6.6% for “work” trips, 5.8% for “home” trips, 4.6% for “others” and 4.1% for “school”. |
| | Cordon Line Traffic Volume: 14 points at Nairobi's limits | <ul style="list-style-type: none"> ◆ Motorcycles represented 4.9% of vehicles counted in 2013. Yet they were the vehicles showing the strongest increase since 2004, multiplied by 9.9. |
| | Screen Line Traffic Volume: 15 points within Nairobi | <ul style="list-style-type: none"> ◆ The survey also showed that bodas were increasing the most rapidly, multiplied by 9.4. Like the former survey, this method counted motorcycles specifically, not aggregated with other vehicles. |
| Academic studies | 22 points within Nairobi | <ul style="list-style-type: none"> ◆ Delaunay (2019a) finds out an aggregated share for bodas and taxis of 6%, in a study conducted in 2019. |

In addition, 2013 data show bodas as a phenomenon particularly taking place at the outskirts of Nairobi, with higher shares in peripheral areas such as Dagoreti (8.3%) and Kasarani (8%), followed by the industrial area of Embakasi (6.4%) (NCC 2014c, appendix 3-23).

The number of motorcycles was expected to rise “rapidly [...] in the near future” (NCC 2014a, p.5-8). However, no isolated forecast can be indicated for boda bodas, as they were surprisingly aggregated within the “walk” category for forecasts (NCC 2014c, Appendix 4-3).

Planning documents show two critical gaps around boda bodas. First, they indicate no data on the number of motorcycles registered in Nairobi County. There exists no other source of information providing this figure to the author’s knowledge. This lack of public knowledge is not specific to bodas: the NTSA knows neither the number nor the routes of matatus operating in Nairobi (JICA 2018, p.2-17).

Secondly, documents reveal the absence of formal planning for this mode. Aforementioned NCC planning documents do not mention nor plan for boda stands. The only reference found to these stands was in the County Integrated Development Plan 2018-2022 (NCC 2018, p.144), according to which stands areas should have been designed in 2018. However, it specifies neither the location nor the number of these areas.

Last but not least, no mention of electric mobility was found in NCC planning documents. Projects on electric motorcycles in Nairobi exist, as aforementioned, but are still at the conception phase.

Local regulation of boda bodas

Boda regulation in Nairobi over the last two years has been marked by top-down attempts to partially restrict them. In 2018, the County forbade bodas from entering the Central Business District (CBD) on the grounds of petty criminality (Omulo 2019, n.p.). However, many boda drivers infringed this ban which is said to provide bribery opportunities for corrupt police officers. As a result of this failed approach, some of - in the thousands - impounded motorcycles were first occasionally released, before the City County announced in September 2019 to allow access to the CBD through six specific stands and designated corridors (Kinyanjui 2019 n.p.; Omulo 2019, n.p.). Yet, these stands and corridors have still not been implemented as of April 2020. The Boda Boda Safety Association of Kenya (BAK) tried during this period to appear as a constructive partner, engaged in endeavours to improve safety and reduce criminality. Some proposals BAK made in the press, such as registration numbers printed on safety vests (Ambani 2018), were already enshrined in the abovementioned 2015 NTSA Regulation.

Future developments are uncertain as some of the County's functions, including transport, have been exceptionally transferred to the national government on 25th February 2020 (State House 2020, n.p.), resulting from a governance crisis linked with the imprisonment of Nairobi's current governor Mike Sonko.

Besides the CBD's particular case, the boda sector in Nairobi is characterised by fluid forms of self-regulation taking place at stands where boda drivers wait for customers. These stands are also called "stages" or "shimos". In a study on one shimo, Ibrahim and Bize (2018, p.80) show how these unplanned infrastructures – formed sometimes by a concrete shed but more often by the mere fact that drivers wait together at locations of high transport demand – enable bonds of solidarity between drivers. They present various degrees of organisational structures, from a simple congregation of drivers to formalised entities organising loans and savings, motorbike leases, internal rules including membership conditions, representative elections and meetings (*ibid*, p.82-84). These places and their solidarity bonds would be jeopardised by the rise of ride-hailing applications, which do not need such geographically located waiting spaces. While Ibrahim and Bize's study provides useful information, a more exhaustive analysis comparing different stages and studying the involvement of public authorities (Counties, politicians etc.) at a broader level is lacking.

Section 4 - Survey of boda boda drivers

4.1. Survey methodology

Aim

The cross-sectional survey followed a twofold purpose. First, it sought to study boda boda drivers' knowledge on and perceptions of electric motorcycles at the time of survey. This included opinions over possible benefits and risks. This population was selected as individuals playing a key role in the adoption of EVs and whose current operational patterns and livelihoods could be specifically impacted by this transition. Secondly, the survey intended to collect basic data on boda bodas' characteristics and patterns in Nairobi that is currently missing. Such data, among others spatial and institutional organisation, daily distances or access to electricity, is valuable when looking at feasibility of a transition to electric motorcycle taxis and to interpret the results of expert interviews of upcoming Section 5.

Instrument

The quantitative fieldwork consisted of a questionnaire containing a majority of closed-ended questions (35) and a minority of open-ended ones (5) (Annex 1). Closed-ended questions were used to collect figures on spatial features, ranges, organisational and financial aspects. With regards to drivers' perceptions of electric motorcycles, open-ended questions were used to capture these since a list of preselected options could have influenced answers. Answers to these open-ended questions were then categorised for purposes of quantitative analysis. In-person surveys were preferred over online tools such as social media, as the latter could not guarantee that respondents were real boda boda drivers.

Data collection

In the absence of a publicly available figure on the population size of boda boda drivers in Nairobi as shown in Section 3, purposive heterogeneous sampling was applied in order to account for different realities of drivers in Nairobi. Four locations were selected for their heterogeneous socio-economic and spatial conditions as depicted in Figure 7.

The near vicinity of CBD was selected for its central location, concentration of employment and as a place of tension between the implementation of the CBD access ban and drivers' attempts to ferry commuters to or from their workplace. Second, Embakasi is Nairobi's industrial area, concentrating jobs in the vicinity of the airport while encompassing some low- and middle-income residential areas. Third, Gachie is a formerly rural area at the periphery of Nairobi City County, officially belonging to Kiambu County that is part of the Nairobi Metropolitan region. This area is marked by increasing urbanisation and significant traffic linked to commuting trips, and displays some visual patterns of an informal settlement (for instance high density, informal street vending activities, absence of street numbering, low-quality building materials etc.). Finally, the bordering area between the two areas of Runda and Gigiri was selected as characterised by high incomes, the presence of international organisations (UN, foreign embassies), a ban of matatus in the area but allowed at the periphery, ferrying notably Kenyan nationals employed by expatriates.

Interviews typically started at a pre-identified stand, generally at an intersection between major roads or between a major artery and a residential area. Then, walking through the neighbourhood and randomly interviewing waiting boda boda drivers was meant to engage with a diversity of situations such as drivers being members of a waiting stand or not, drivers waiting near a matatu stop or not etc.

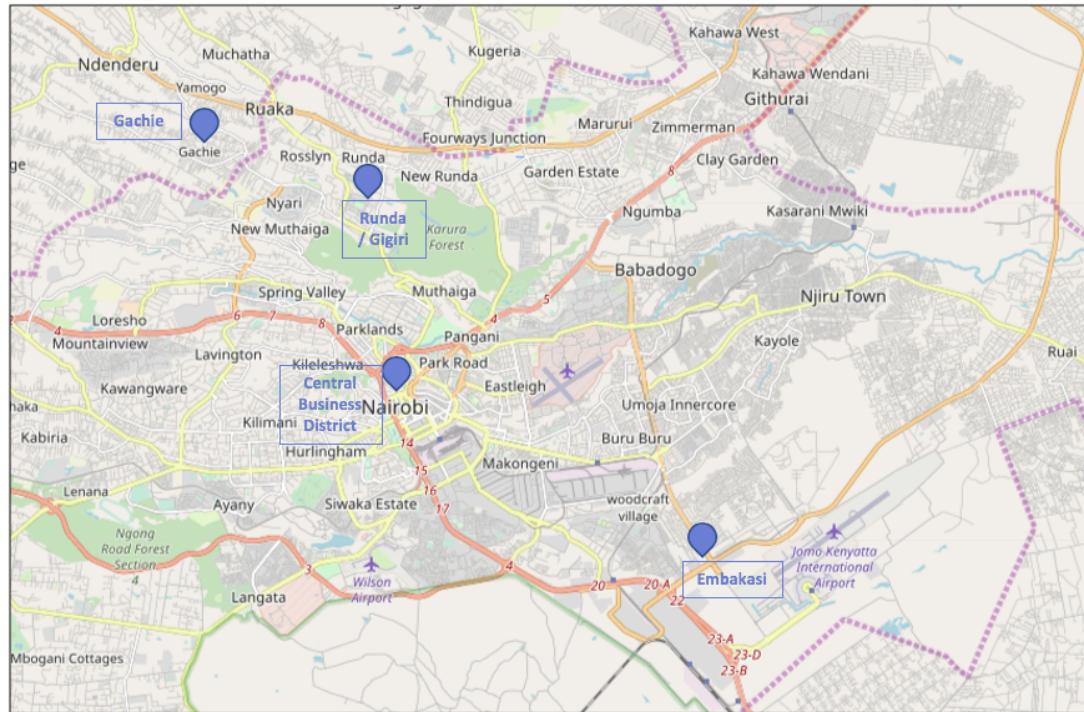


Figure 7: Drivers survey: locations of questionnaire administration (based on Open Street Map)

Questionnaires were administered on the afternoon of Monday, 16th December 2019, and during the days of Tuesday 17th and Thursday 19th December. To increase the number of boda bodas drivers that could be surveyed, three undergraduate students from Nairobi University's department of urban and regional planning were recruited to distribute the questionnaire, along with the thesis author. This strategy is a common one in Nairobi, due to the difficulty of accessing target groups (e.g. Cap 2014, p.29, Delaunay 2019b, p.3). To ensure consistency in the questionnaire administration, a guidance document was explained and discussed during a preparatory meeting on the morning of 16th December. Surveys were jointly conducted by the thesis author and the students on collection days in the four locations. An interim meeting took place between the two collection days on 18th December to address possible questions.

Respondents

A total of 83 drivers were interviewed. In order to reduce reluctance to answer and potential bias in answers, respondents were informed that collected information would remain anonymous and confidential. No approached driver refused to answer the entire survey, but 15 drivers in the CBD vicinity and 1 in Gachie refused to provide information on age and education level, fearing confidentiality issues despite anonymity having been mentioned. Administrating the survey in English was not an issue except for one driver with limited English fluency. Figures given by two drivers were excluded from the analysis due to coherency issues and interviewee anxiety due to nearby police officers.



Figure 8: Boda boda drivers waiting at an unpaved stage localized at the Taj Mall Roundabout, in the industrial area of Embakasi (Martin, 2019). The stage does not have a protecting shed and is located in the vicinity of a matatu stage currently under construction by a Chinese company, and a fuel station.



Figure 9: Paved stage with a shed under the Northern Bypass in the high-income residential area of Runda (Martin, 2019). The semi-formalisation of the stage is financially supported by the Runda Residents Association Boda. The stage is located next to a matatu informal stop on the bypass; queuing rules are indicated on the pole at the center of the stage.

4.2. Results

Basic data

Figure 10 shows basic personal data on gender, age and education. All interviewees were male. The most represented age group was 30-34 years (23%), closely followed by 25-29 years (22%). The majority (58%) had a secondary degree. 10 drivers could be identified as living in informal settlements (Githogoro, Mathare, Kawangware, Kayole), 14 in the low-income settlement of Gachie and 29 in Pipeline Estate, a low-cost tenement housing area with limited infrastructure service provision.

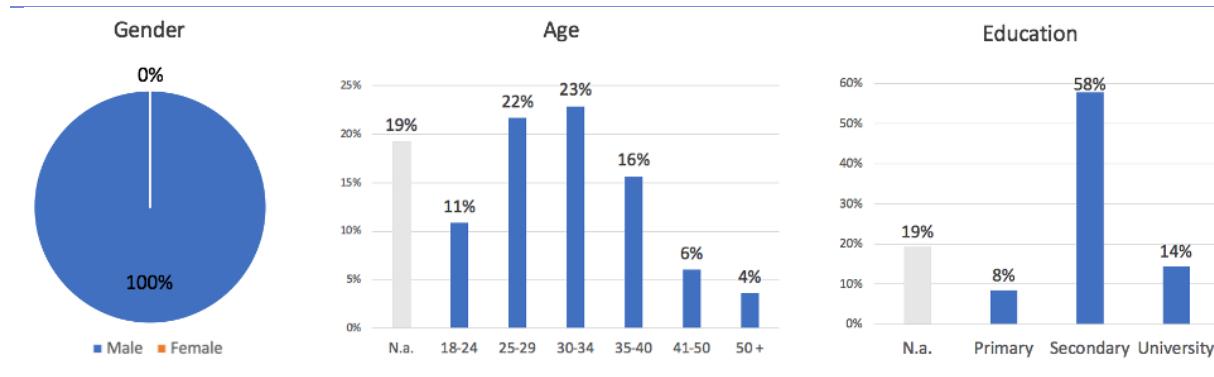


Figure 10: Data on drivers' gender, age, education (in %)

The vast majority of interviewees (81%) owned their motorcycles, the remaining 19% rented them. With respect to motorcycle brands, a few models were most prominent, primarily the Bajaj Boxer X150 (25%), followed by Honda 125 (15%) and 2 TVS models (11% for TVS Start 125 and 6% for TVS HLX 150). At the time of the survey, the mean age of motorcycles as declared by drivers was 3 years. Drivers were expecting a very long lifespan of their motorcycles: 10 years and more for 30 drivers, 6 to 9 years for 22 drivers and a theoretically limitless duration depending on maintenance for 9 drivers. In addition, durability and robustness of the vehicle ranked as the highest criteria when buying a motorcycle (mentioned 19 times), before low fuel consumption (13 times), low purchase price (8 times) and availability of spare parts (6 times).

Perceptions of electric motorcycles

Figure 11 shows that only a minority of drivers (37%) had heard of electric motorcycles. Amongst them, the information has mostly spread through acquaintances (34%). Online tools including personal internet searches (25%) or social media (6%) were significant sources of information as well. Despite the limited penetration of EVs in Nairobi at the time of the survey, 9% of drivers claimed to have seen lightweight electric two-wheelers but could not provide further information on their names.

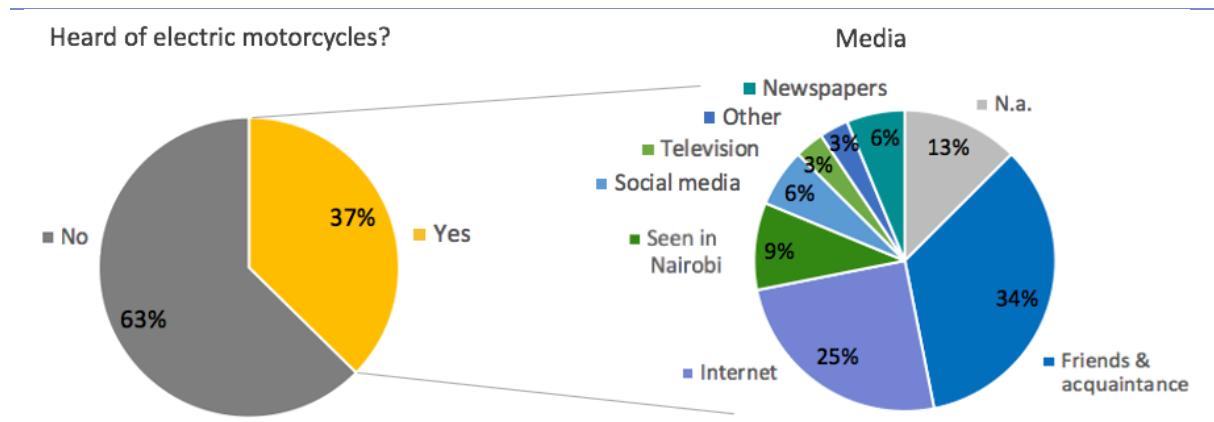


Figure 11: Drivers knowledge of electric motorcycles (in %)

Drivers were then asked about opportunities and risks that electric motorcycles could lead to. The majority of them had no opinion on possible impacts, respectively 58% on opportunities and 69% on risks. This comes close to the 63% of them who had not heard of such vehicles.

Among the 41% of drivers who had an opinion on impacts, most of them (35% of all interviewees) considered that electric motorcycles would bring improvements. These benefits were dominantly seen as economic gains, namely savings in fuel and oil. Other benefits identified were assumed higher efficiency of the vehicles and higher stability of electricity prices. Environmental benefits were identified by only 2 drivers, mentioning reduced emissions and noise levels. No social impact was spontaneously identified.

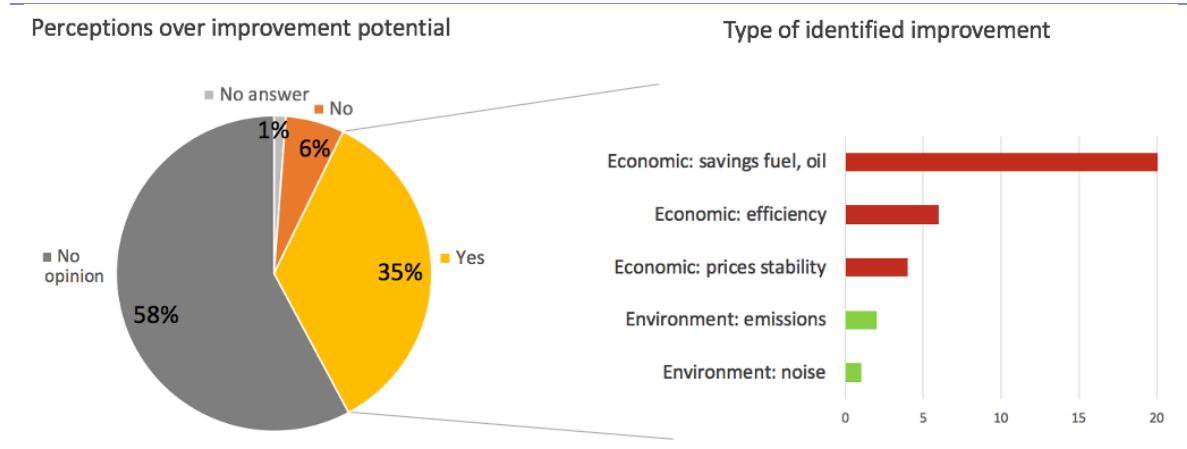


Figure 12: Drivers perceptions of opportunities related to electric motorcycles (in %)

Similarly, among the 41% who had an opinion on O&M costs of electric motorcycles, the majority (31% of all interviewees) thought that these vehicles would be cheaper to operate. Only 10% considered that they would be more expensive to operate and maintain.

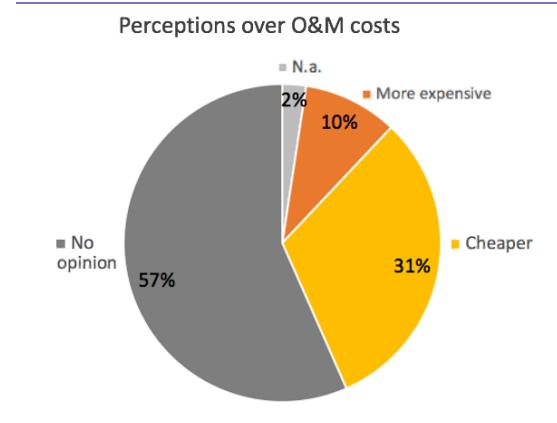


Figure 13: Drivers perceptions of O&M costs of electric motorcycles (in %)

When coming to possible detrimental impacts, 25% of drivers cited risks as shown in Figure 14. In fact, fewer drivers identified risks compared with the 35% who anticipated benefits. These risks mostly relate to technical and feasibility aspects such as lack of access to electricity or electricity shortages (6 drivers), lack of power or speed of the vehicles (6), range anxiety (5), charging inconvenience (4), feasibility (3), availability of spare parts (1) and lack of trained technicians (1). Only 2 drivers identified possible socio-economic detrimental impacts in the form of loss of market shares for gasoline-powered motorcycles.

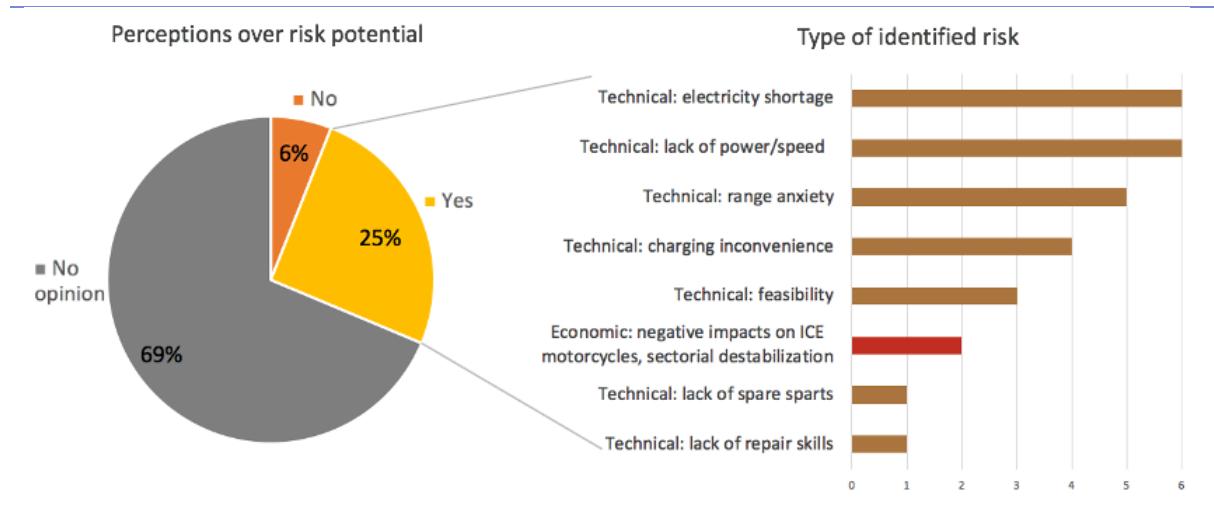


Figure 14: Drivers' perceptions of risks related to electric motorcycles (in %)

Other data on characteristics and patterns

Stage and spatial patterns

With respect to spatial patterns, all drivers but those undertaking freight deliveries (98%) stated that they wait at a stand, most commonly called a "stage", and most of them (88%) return to this place after transporting a client. The number of drivers waiting at a stage ranged from 4 to 60 (self-assessed by the driver). The largest stages in terms of number of drivers were found in the vicinity of the CBD.

When asked about the places they mostly drive to, the analysis of locations indicated by the drivers reveals that the majority of them (57%) transport customers between the stage and the nearby neighbourhood, within a few kilometers range. A further 25% of drivers undertake mostly drives within the neighbourhood but with some more distant destinations. This was especially the case in the industrial area Embakasi with occasional drives to places 10 to 12 kilometers away from the stage. Third, a much smaller share of drivers (7%) principally drive outside the neighbourhood with drives reaching up to 15 kilometers, also mostly from Embakasi. Finally, 11% of the answers could not be classified because of unclarity or lack of regular pattern. Particular caution must be exercised with this data as it relies on the drivers' personal assessment on places and frequencies. 41% of drivers stated to undertake 10 daily trips and more, followed by 33% reporting 15 trips and more.

The median daily distance, based on drivers' self-assessments, amounts to 90 kilometers. Half of the drivers approximated a driving range of 67.5 to 100 kilometers (interquartile range). However, this data must again be taken with specific care as the dataset includes a significant number of outliers such as 200 or 250 kilometers. A figure of 500 kilometers was deemed incoherent and excluded from the dataset.

Contrasting to the dominant feature of neighbourhood coverage, up to 39% of drivers reported to occasionally use their motorcycle to drive to further locations outside of Nairobi, mostly for personal purposes such as visiting relatives. Most of them (9 drivers) do so in a limited range outside Nairobi up to 100 km, but 6 of them indicated destinations located further than 200 km away from Nairobi.

93% of motorcycles are parked at home at night, 2% in their residential areas paying a fee, 2% at petrol stations and 1% at a car park. 96% of interviewees claimed to have access to electricity at home through

the official provider, Kenya Power. Since previous research on the local context (Section 3) shows limited formal access to electricity in informal settlements in Nairobi, and as at least 10 interviewees were living in such settlements, a bias in this survey answer seems likely.

Self-regulation

To measure the degree of regulation and institutionalisation, drivers were asked questions on membership in an association formed at stage level and in a SACCO, as well as services provided by these formal or informal organisations. Regarding the stage, 58% of drivers asserted to belong to an association. Such association was understood in very simple terms such as the existence of a stage book (Ibrahim and Bize 2018, p.83) or of written rules, not necessarily involving a declared association with status.

60% of drivers mentioned the existence of mutual services organised even without a formalised group or association in place. Services provided – in the existence or absence of an association - were mostly financial ones, 37 drivers mentioning saving schemes and 22 small loans. Other services were related to the daily functioning of the stage, 29 mentioning internal rules and 3 conflict resolution.

A small majority of drivers (54%) indicated to be part of a SACCO, meaning that a significant number of them (42%) were not respecting this requirement as per national regulation. SACCO services most commonly identified were design of internal rules (cited by 19 drivers), representation of drivers' interests (13 drivers), provision of loans (11 drivers) and design of fares (11 drivers).

Finally, only 34% of drivers indicated to use one or several ride-hailing applications. These were often criticised for the associated fees.

Incomes and expenses

The median daily revenues, as declared by drivers, amounts to 1,660 KES -circa 15.6 USD-, with an interquartile range from 1,037 to 2,000 KES -9.7 to 18.8 USD-. Fuel expenses represent a significant part of these revenues, subtracting a median 350 KES per day -3.3 USD- (interquartile range from 300 to 437 KES -2.8 to 4.1 USD-). Further expenses were gearbox oil, used once to twice a month, maintenance and repairs. Fuel stations seem an important component of the boda ecosystem: providing fuel, but also gearbox oil.

Safety

92% of drivers claimed to have a driver's license, 5% admitted to not having one and 4% did not answer. When it came to driving training, 77% claimed to have been trained (8% not trained and 14% without answer). This raises significant doubts on the veracity since 15% would have a license without being trained. More generally, the safety dimension seems prone to a "shame bias", drivers being reluctant to admit breaches of minimal legal requirements such as driving licenses. Similarly, 65% of them claimed not to have been involved in an accident. This contrasts with the analysis of the local context undertook in Section 3 and one driver in Runda declaring: "I can't count how many I've had. We do a dangerous business". In addition, drivers were not wearing safety vests showing their registration number as per regulation. These vests had been donated to them by various entities such as sport betting companies, a neighbourhood association, local shops, a church, politicians.

4.3. Interpretation

Limitations

Limitations to the results can be identified. First, as the survey did not use a non-probability sampling technique in the absence of information on the population size, one cannot generalise these results to the entire population of boda boda drivers in Nairobi. Rather, these results give indications and assumptions. These seem reasonable since based on heterogeneous locations and including random elements such as walking within neighbourhoods to identify drivers.

Second, one limitation stems from the structure of the stages. As drivers were constituting groups of close individuals, it cannot be excluded that individual answers influenced other answers. Very homogenous answers could indeed be identified for instance in a stage in Embakasi on questions of daily ranges or knowledge on electric motorcycles. However, this may also be related to the fact that drivers spend significant time waiting together and may share information, beliefs and recommendations on motorcycle brands and repairs at the stage.

Third, one may assume the existence of a bias for questions on safety and access to electricity, as answers diverge strongly with the analysis of the local context (Section 3). This may be hypothesised as a “shame bias”, involving reluctance to admit illegal behaviours (absence of a driving license) or limited financial resources (no formal electricity access).

Discussion

Both similarities and dissimilarities may be identified between these survey results and existing literature on motorcycle taxis in SSA. Similarly, drivers are mostly young and male. They congregate at a waiting place, where they depart and return in order to ferry passengers, confirming the centrality of the stage. Such centrality may prove a key feature when designing a charging infrastructure, for instance swapping stations. Similar to the literature, a majority of drivers seem to undertake trips in the neighbourhood; however, 36% of them undertake occasional or regular trips that do not seem to qualify as first and last-mile services, for instance when reaching 10 to 15 kilometers. Further studies seem therefore necessary to uncover purposes and distances of trips undertaken by boda bodas in Nairobi.

When it comes to the question of electrification, only a minority of drivers had heard of electric motorcycles and had an opinion on their possible consequences. Yet, the fact that 39 drivers had heard about them is the notable piece of information, since electric motorcycles do not exist in Nairobi yet. Entities currently operating other EVs such as Nopea, E-Solar Cycles or Opibus only have a few vehicles, hence limited visibility. Information seems to be spread rather through physical or digital networks of drivers as well as via personal internet searches. Furthermore, several drivers who expressed an opinion on possible beneficial or harmful effects had specific knowledge, pointing out classical barriers to the adoption of EVs and raising technical questions in a detailed manner. Following the administration of the survey, drivers, in many instances, asked for further information on existing projects, requested to see pictures of prototypes or even asked to be involved in pilot tests. While one should not romanticise and exaggerate the drivers' technical knowledge, this survey casts some doubts on the classical picture of boda boda drivers seen as rural and illiterate.

Benefits were more frequently perceived than risks (35% of drivers citing opportunities versus 25% risks). Their perceptions, when existing, were almost exclusively revolving around economic impacts. Immediate effects have primacy, primarily as the opportunity to remove fuel costs, but also risks understood in terms of feasibility, put simply: will the vehicles work? Longer-term effects, as well as environmental and social effects, did not appear as a major concern. This may reveal a lack of environmental awareness, as well as the mere recentness of the information, not allowing for deeper considerations. These avenues for reflection will be further explored and compared after the expert interviews in section 6.

Last but not least, feasibility was discussed mainly as a challenge, concentrated on technical barriers with regards to the battery, the charging infrastructure, the reliability of the grid as well as maintenance-related aspects of repair skills and spare parts. Nevertheless, the fact that opportunities were more frequently identified than risks may be a substantial facilitating factor for uptake, presuming a positive attitude of the target population of boda boda drivers towards electrification.

In addition, basic data collected through the survey give some hints on feasibility characteristics that are valuable to consider when implementing electrification projects, bearing in mind the aforementioned inability to generalise takeaways to the whole population in the absence of information on the population size. Some boda boda features appear as advantages for electrification, such as the trips mostly taking place in the neighbourhood and going back to the stage, that would fit well with the installation of charging or swapping stations at the stage. In contrast to passenger cars requiring a much broader network of charging points owing to the higher number of possibly far-stretching destinations, the short distances and linking to the stage as an anchor point for boda bodas is of advantage, allowing to start with a few localized projects. However, the spatial dimension is also a challenge for those drivers occasionally using their motorcycles to drive to further rural distances in case of a swapping system, where the battery may only be exchanged at the station. This would require arrangements such as swapping stations installed in satellite cities around Nairobi or provision for a few higher capacity batteries. Another asset when envisaging stations installed at stages is the existing solidarity bonds at some stages, organised around the provision of common services. Projects could specifically identify stages particularly advanced in formalisation.

Connection to the grid remains a weak point, not existent at most of the stands identified in the survey. Yet, charging at home, for instance at night, does not appear to be a solid option. While the vast majority of drivers claimed to have access to electricity at home, doubts on the veracity of these assertions are strong. Charging at an external place to the drivers' residence, as chosen in the two East-African projects identified in Section 3 using a swapping system, therefore offers benefits, including controlled charged conditions.

Section 5 - Stakeholders interviews

5.1. Methodology

Qualitative interviews using an expert sampling method formed the core part of this study's data collection. Identifying and analysing key stakeholders' views appeared critical to answer the research question of perceptions on the sustainability of e-bodas. So-called key "expert stakeholders" were selected on the basis of two alternative criteria: their involvement in electric mobility in Kenya and Nairobi or in transition projects to electric motorcycles, or their in-depth knowledge of the political economy of urban mobility in Nairobi. A first mapping was undertaken in December 2019, completed by further recommendations using snowball sampling.

Among these expert stakeholders identified, 18 were interviewed between 14th January 2020 and 2nd March 2020 (Figure 15, Annex 4). Duration ranged from 40 minutes to 2 hours, but most of them lasted for 1 hour. Stakeholders agreed to be recorded except for one, where written notes were taken directly. Two interviews were led over the phone, resulting in written notes as well. All personal names and the identity of two start-ups and one donor agency have been anonymised to protect confidentiality and enable open speech.

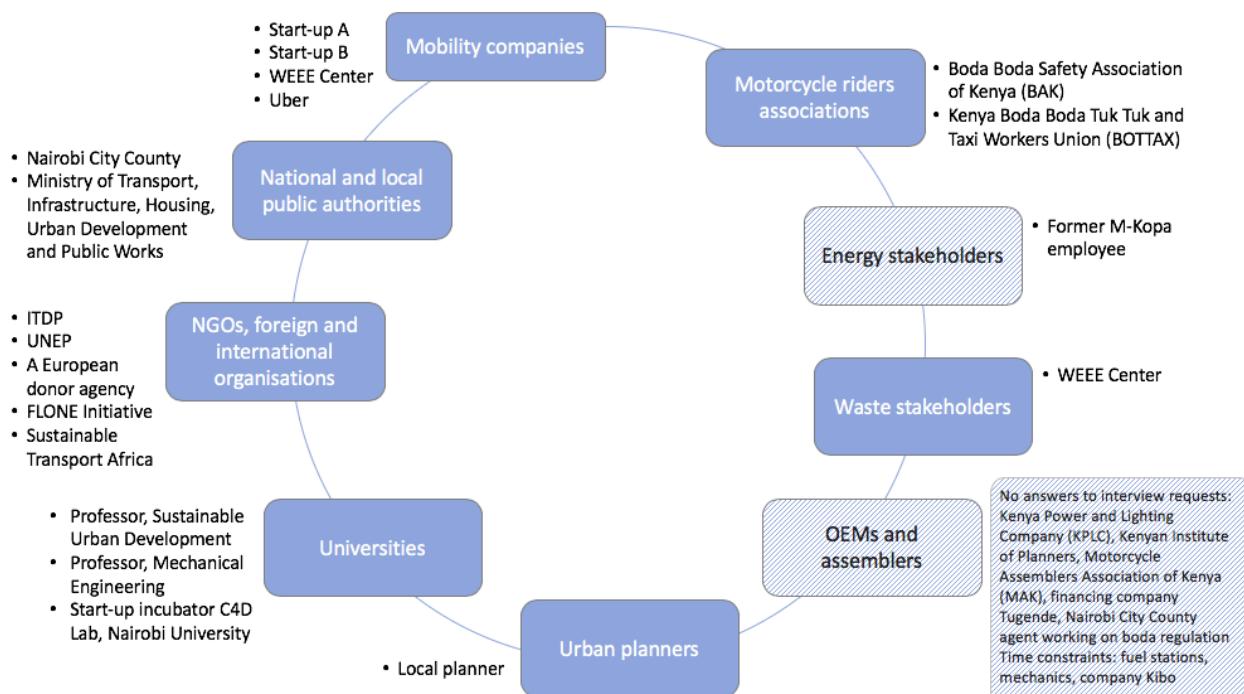


Figure 15: Identified and interviewed expert stakeholders

Among those who could not be interviewed, in the absence of answers to requests or because of time constraints, were notably Kenya Power and Lighting Company (KPLC) and the Motorcycle Assemblers Association of Kenya (MAK). A further and deeper analysis would need to include the two stakeholders and

a broader range of actors, including ministries of Industry, Environment and Energy, the Energy and Petroleum Regulatory Authority (EPRA), fuel stations, and original equipment manufacturers (OEMs).

Interviews were structured in two successive parts applying different methodologies. First, semi-structured interviews were conducted, organised around questions on their knowledge of boda electrification, their involvement in corresponding projects, their views on positive and negative possible impacts and feasibility elements. Interviewees were given significant leeway in leading the discussion. This part aimed to identify topics that would spontaneously emerge. Secondly, interviewees were asked to fill out a questionnaire in which they rated possible impacts (opportunities, risks) and feasibility aspects (facilitators, barriers) of boda boda electrification on a scale from 0 to 4 on their degree of importance (Annex 3). This questionnaire was the result of the Sustainability Assessment emerging from the study of literature, local context and results of the drivers' survey (Annex 2). The purpose of this second part was to confront interviewees with a broader list of characteristics of electric mobility based on this assessment and to allow for a comparative analysis with the spontaneous topics that had previously emerged.

Results were analysed using the software ATLAS.ti 8.4.4. Qualitative analysis led to the identification of 48 codes, following a deductive coding technique based on the sustainability dimensions identified during the literature review phase, enriched with additional codes that emerged during interviews. These codes were then grouped into six main themes, one related to current boda patterns ("Existing"), three to sustainability perceptions of electric bodas ("Environment", "Economic" and "Social") and two to perceptions and electrification projects ("Qualification" and "Implementation").

5.2. Results

5.2.1. First part: semi-structured interviews

Interviews were crucial to better understand current and future stakeholders' plans, in the limit of interviewees' willingness to divulge information on their projects in a private competitive environment. Business model options or locations of charging stations are for instance sensitive topics. Table 8 summarises these projects.

Typology of motorcycles electrification projects in Nairobi

Table 8 lists a variety of projects currently led or conceived to transition to electric motorcycle taxis in Nairobi, as identified through the interviews of experts.

Table 8: Typology of projects revolving around electrification of motorcycle taxis in Nairobi

| Stakeholders | Project typology | Characteristics | Location |
|---|--|---|--|
| Cooperation of UNEP, Sustainable Transport Africa, Nairobi University's Mechanical Engineering Department, KPLC | Pilot and research projects, expected around spring 2020 | <ul style="list-style-type: none"> ◆ Testing vehicles imported from China (here named Vehicle Strategy A) to collect data and later sensitise boda drivers, with a total of 50 bikes (Li-ion batteries), distributed between 2 pilots in Nairobi and Kisumu ◆ Range of circa 80 km ◆ No infrastructure solution selected yet (charging home or elsewhere e.g. boda stage, swapping stations) | Nairobi University and Ruakara (KPLC location) |
| Start-up A | Start of a pilot in Nairobi around spring or summer 2020, following a first one of 30 motorcycles in Kisumu County | <ul style="list-style-type: none"> ◆ Initial mix of new ICE motorcycle parts bought from local assemblers e.g. chassis, combined with imported parts, e.g. Li-ion battery (Vehicle Strategy B); aiming to design their own chassis, produced in Kenya in a second phase ◆ Aimed range of circa 80 km ◆ No business model determined yet ◆ No infrastructure solution selected yet, upcoming testing of charging or swapping stations, e.g. at fuel stations, boda stages, kiosks ◆ Not set yet if passengers or deliveries | Area in Nairobi not yet determined |
| Start-up B | Exploratory phase of the boda market | <ul style="list-style-type: none"> ◆ No set strategy for vehicle, infrastructure and business models, but likely to be battery leasing and swapping stations | Not yet determined |
| E-waste center WEEE | Pilot project with 1 or 2 motorcycles starting in May 2020 | <ul style="list-style-type: none"> ◆ Retrofit of ICE motorcycles currently used by boda drivers (Vehicle Strategy C) to put an electric powertrain ◆ No range specified yet ◆ Li-ion battery pack made of reused components disassembled from dead laptops and reassembled at the center ◆ Business model to be tested, initially based on purchase of the battery, retrofit for a cost and charging at home | Utarwala (Nairobi) |
| Flone initiative, for UNEP | Gender-focused research on bodas and electrification | <ul style="list-style-type: none"> ◆ Research on the role of women in current boda patterns and upcoming electrification projects | Nairobi as a whole |

Strategies are more advanced on the vehicle segment, compared with the infrastructure and business model ones. Three main vehicle strategies are identified: category A (imported new battery electric vehicle), B (mix of new parts bought from local assemblers of conventional motorcycles, from Indian brands for instance, and imported parts such as batteries) and C (conversion of vehicles being used by boda drivers, combined with recycling of e-waste).

Regarding infrastructure, various technologies (charging or swapping) and locations (home or residential areas, fuel stations, boda stages, malls, new locations etc.) are still under consideration and will be tested at a later stage. The same applies to business models, namely payment models which may be based on the battery utilisation (“pay-as-you-go”) or on a daily fee allowing unlimited use of batteries via a swapping system.

Projects are carried out either by foreigners (start-ups A and B) or Kenyan nationals (WEEE center, Kenyan partners within the UNEP-led group).

General narratives around electric bodas

Most interviewees used particularly strong positive adjectives when talking about boda electrification projects, such as “great”, “excited”, “amazing”, “important”, “really interesting”, “definitively worth considering”, “huge”, “motivating”, qualificatives that were often repeated. Qualification of such projects ranged from the identification of an “opportunity” to a more superlative qualification of “a godsend” (UNEP interviewee). Only a few dampened this enthusiasm, for instance ITDP considered that benefits are “not a given” but depend on implementation and accompanying policies. Stakeholders’ positions will be further explained and detailed in subsection 5.2.3.

Such predominantly positive evaluations can be linked with narratives of change, innovation and disruption. This technological transition was seen as a “novelty” but also as a “game changer”, a term spontaneously used by two distinct interviewees (employee affiliated with Nairobi City County and employee of the Sustainable Transport Africa -STA- association). Indeed, many consider it will not only bring change but that it can allow a break from the current boda ecosystem, from the status quo, and become part of a betterment strategy for this mode. Flone Initiative stated that “it's not every day in public transport [that] you get an innovation where you have the chance to do it right from the start”. Interviews from Nairobi City County, STA and the start-up incubator C4D Lab based at Nairobi University called for a “disruption”, the former also qualifying it as “shock therapy”.

These narratives seem for several interviewees, to be anchored or linked with a technophilia that would be specifically Kenyan (start-up B, incubator C4D Lab, Nairobi City County). Therefore, technology start-up companies that have been recently growing in numbers according to the C4D Lab, tend to benefit from a favourable image among experts. The belief that issues will be solved through technological solutions seems to be well spread. For instance, the interviewed urban planner stated that “with technology, there's always a way of finding a solution for that”. Such statements and trust in technologies as brought forward by small private companies were also found when discussing e-waste.

A further strong theme emerging from the interviews was the nascent phase of electrification projects, still at a phase of pilots or prototypes. This leads to a certain degree of uncertainty among stakeholders over real impacts of boda electrification. According to start-up A, this newness dimension is not a purely Kenyan phenomenon but an African one, electric mobility being less developed on this continent.

Even though interviewees could very precisely identify some opportunities and risks (see upcoming subsections 5.2.2 and 5.2.3), they recurrently employed conditional wording ("if", "whether", "depending on the data", "maybe", "possible"), expressing doubts, admitting little knowledge or even openly asking for facts and data. As stated above, several dimensions of the pilots are not determined yet, in particular charging locations and business models where options will be tested first. Several interviewees based their assessment on personal intuitions or beliefs, admitting lacking technical information, hence a significant need for more research. Such lack of evidence-based data and predominance of personal beliefs also resulted in heterogeneous opinions when interviewing several employees within a single organisation, even involved in electric mobility, such as the European donor agency, Start-up B or STA. In this absence of data, fragility and interrogations over technical, financial and legal stability could be felt in several interviews.

Related with this lack of data is the fact that information on vehicle, infrastructure and business model strategies is not uniformly spread, especially on more innovative elements such as battery swapping. According to the interviewed MoTIHUD civil servant, this lack of knowledge is also observable within national ministries and public agencies.

Last but not least, this uncertainty translates into current indecision over policies that could be enacted and projects that could be supported at city or national level. Nairobi City County is developing a strategy for carbon pathway development by 2050 and the national level is reviewing its 2012 Integrated National Transport Policy which mentioned electrification only for railways. Both documents will include electric mobility, but both scope and content still seem uncertain.

Themes spontaneously emerging from the interviews

As a first approach to the interviews content, Figure 16 shows the frequency of occurrence of the 22 codes which tackle the three dimensions of sustainability (environmental, social, economic) among the 46 identified codes in total. This frequency is not associated with any positive or negative meanings. For instance, the category "jobs" does not say whether stakeholders thought that electric bodas would improve or worsen the employment market. It rather indicates dimensions that were important for interviewees, for reasons that may well vary: they may expect a strong impact of electric bodas on this particular dimension or raise questions on it. The fact that some aspects of electric bodas were not extensively discussed does not necessarily mean that the interviewee considers this aspect as irrelevant, but rather that they spontaneously focused on other dimensions.

As shown by Figure 16, the code "drivers' earnings and costs", classified under the economic theme, distinctly emerges as by far the most frequently discussed item (59 occurrences). Other codes come relatively far behind, first "e-waste and batteries" (23), "safety" (22), followed by "air pollution" (18), "jobs" (16), a group of environmental aspects of "environmental awareness" and "climate change" (15 and 14), "induced demand" (13) and "socio-economic resistance" (13). Subsection 5.2.3. will qualitatively describe this prevalence of the economic dimension of drivers' earnings and costs, narratives around other codes, as well as compare with the questionnaire results.

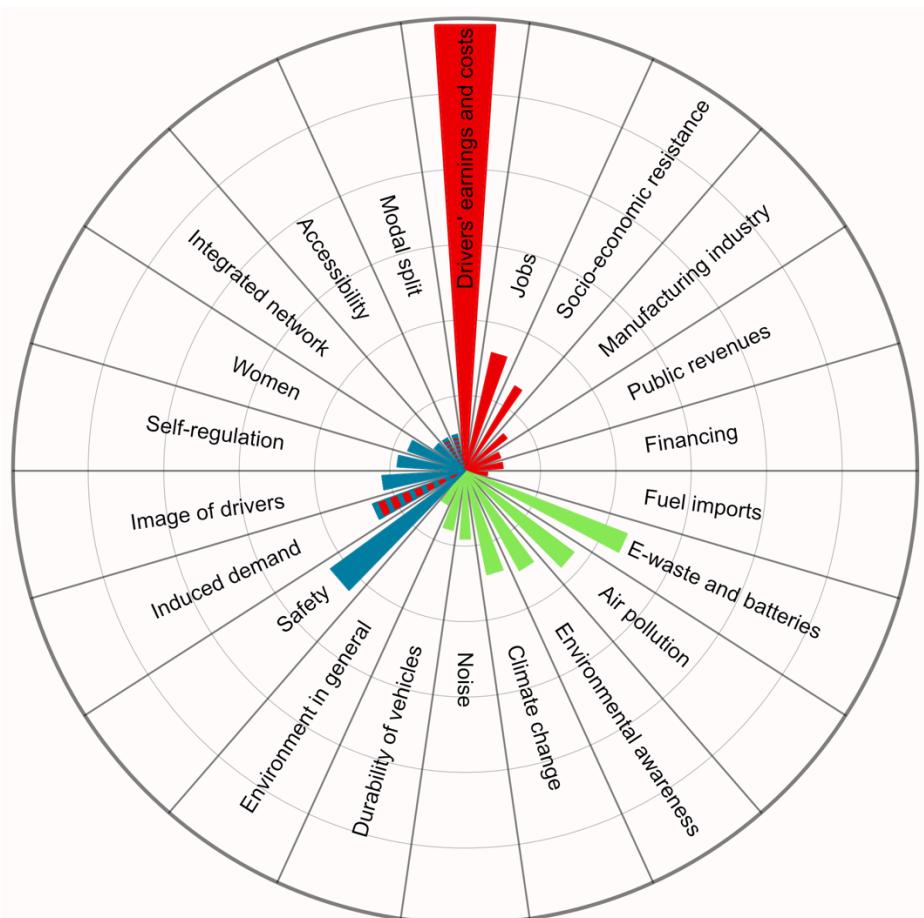


Figure 16: Occurrences of sustainability codes from the semi-structured interviews
(red representing the economic dimension, green the environmental one, and blue the social one)

5.2.2. Second part: questionnaires

Interviewees were asked to rate a list of possible impacts and feasibility aspects of electric bodas stemming from the Sustainability Assessment on a scale from 0 (no significance) to 4 (highest significance). They could also indicate not to have an opinion. In three cases, two employees of the same organisation filled distinct questionnaires.

Impacts

Opportunities

Opportunities were ranked on average between 2.2 and 3.5. "Reduction of air pollution" came in the first position, closely followed by "reduction of operation and maintenance (O&M) costs" and "climate change mitigation" which ranked identical. This high position of two environmental aspects shows that stakeholders were aware of environmental aspects but did not mention them much during interviews, as shown in subsection 5.2.1. Reasons for this divergence will be discussed in subsection 5.2.3.

A mix of economic and social aspects came then: first two economic aspects ("emergence of a national manufacturing industry" and "jobs") before a series of social topics ("renewed boda regulation", "no wounds from the tailpipe", "improved image") and again economic ones ("reduction of fuel imports", "motorcycle batteries used to stabilize the grid", "development of solar energy"). "Building an integrated transport network" was the lowest opportunity identified. Social aspects ranked in the lowest part of the list.

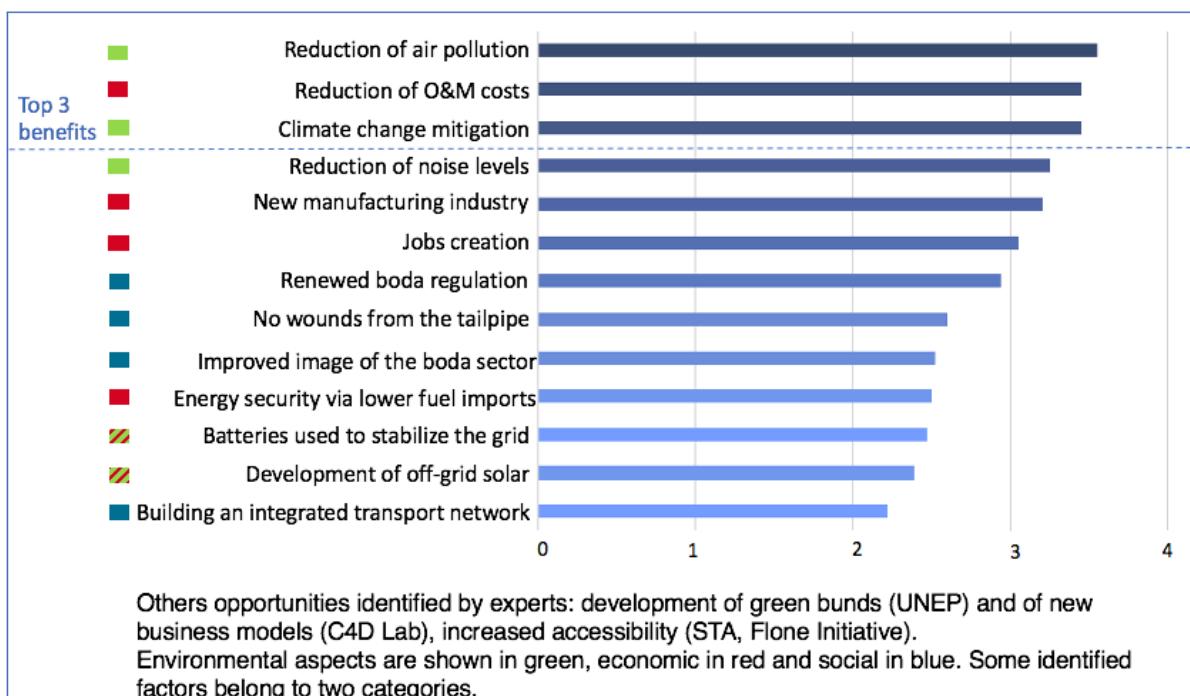


Figure 17: Impacts: opportunities as rated on average by experts

Risks

Risks were given slightly lower grades and were less dispersed, between 2.05 and 2.5. Increased safety risks stemming from silent electric bodas ranked highest. This was followed by doubts over the capacity to handle depletion and toxicity of batteries in a Kenyan context of nascent electrical and electronic waste management, fear for an increase of boda traffic (induced demand), and again a battery-related risk of constant supply of components. The lowest identified risks were job destructions and uncertain safe operations of batteries.

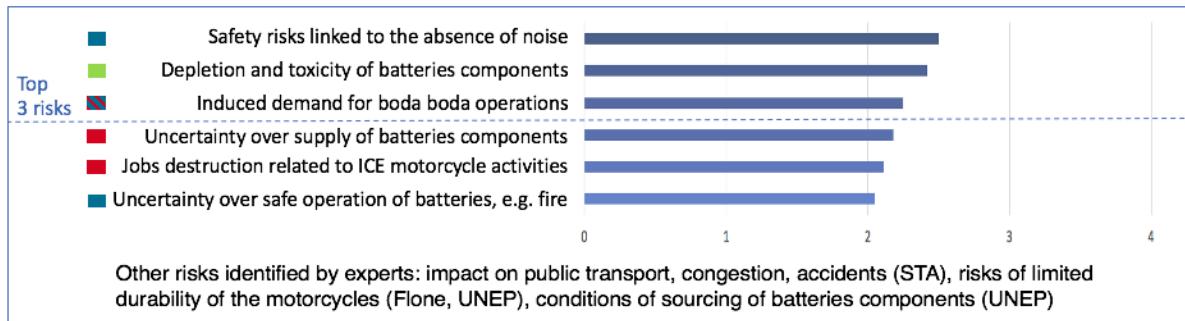


Figure 18: Impacts: risks as rated on average by experts

Feasibility

Facilitators

Cost savings were on average rated as the highest facilitating variable, a result coherent with the codes occurrences. Currently existing standards and tax reductions for EVs came second, followed by another economic aspect of the reduction of fuel imports and consequential impact on the currency exchange balance.

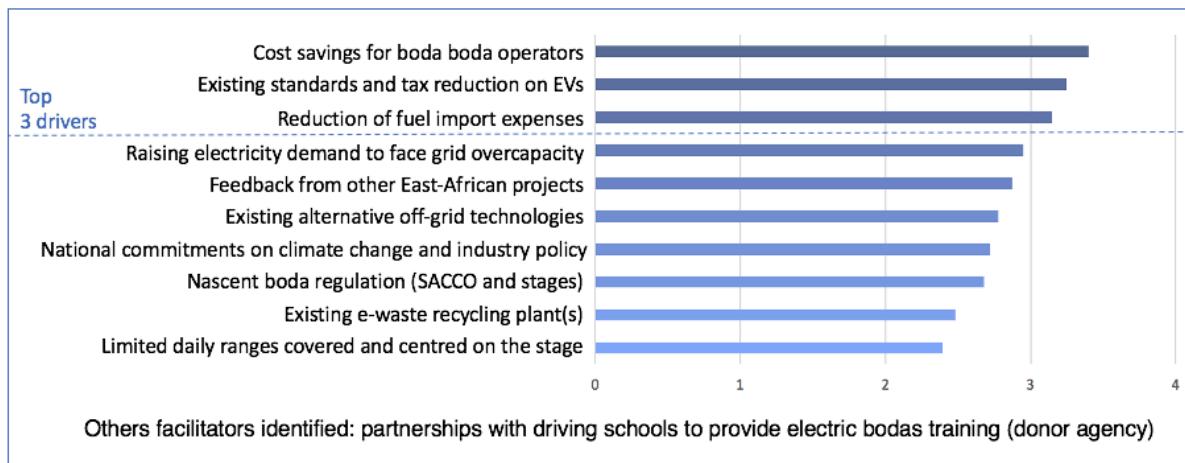


Figure 19: Feasibility: facilitators as rated on average by experts

Barriers

Again, the list of top three barriers was opened by an economic dimension, which is the higher upfront investment cost incurred in case of EV purchase. The financial burden of implementing a network of stations as well as the time needed for it came as an average second barrier. In third position came the fact that motorcycle drivers use motorbikes to drive outside of Nairobi. Finally, similar to a perception of low risks of job destruction, opposition from sectors facing employment risks came on average as the lowest barrier.

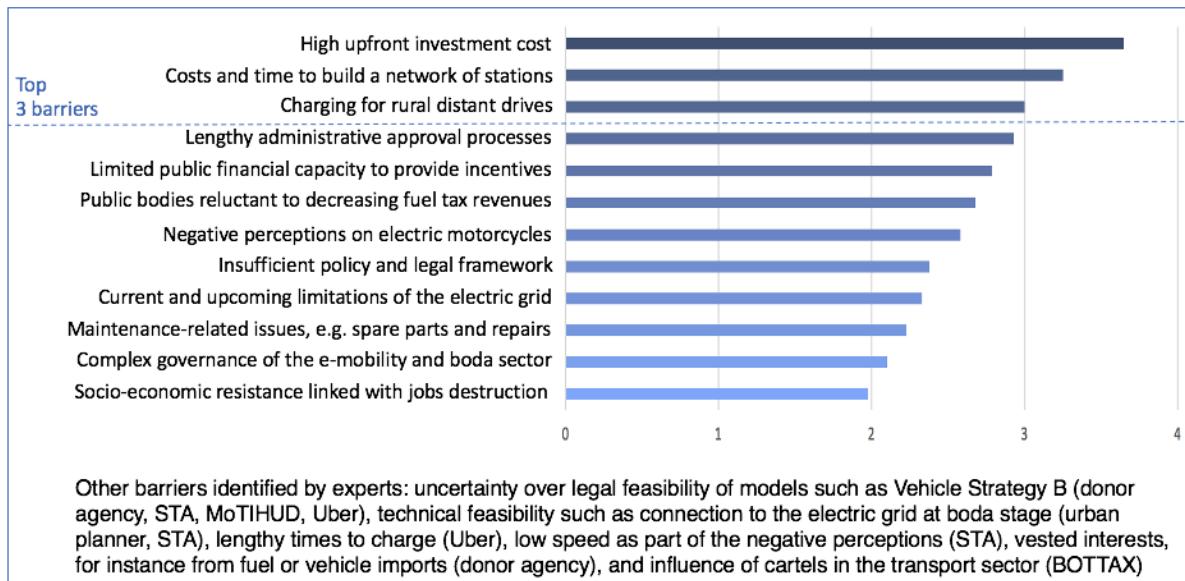


Figure 20: Feasibility: barriers as rated on average by experts

5.2.3. Combined results from the interviews and questionnaires

Situating stakeholders on an impact and activity scale

Figure 21 shows the position of stakeholders based on two variables: their perceived impact ratio (measured by the difference in average grades for opportunities and risks from the questionnaire) and their degree of activity from the information collected during the interviews. This degree of activity was measured for the specific topic of boda electrification – not electric mobility in general -, and at the time of interview. Arrows represent a quickly evolving situation, with stakeholders in the process of rapidly increasing their level of activity in this specific topic.



Figure 21: Experts positions on an impact and activity scale

Perceived impact ratio

To the exception of ITDP, all stakeholders have a positive impact ratio, meaning that they perceive higher benefits than risks. This is coherent with the favourable tone used when discussing electrification of bodas (subsection 5.2.1). Start-ups logically rank particularly high, displaying enthusiasm to launch their projects. Interviewees working at local and national public authorities also had high positive ratios.

ITDP represents an exception, considering that impacts are not given per se but rather depend on accompanying policy measures and electrification of other modes. The negative ratio stems from the fact that the interviewee answered the questionnaire as assuming the absence of such complementary policies.

Degree of activity

Stakeholders involved in the various electrification projects have the highest level of activity: start-ups, UNEP, STA, national ministry MoTIHUD, Nairobi University's Department for Mechanical Engineering. The UNEP interviewee used the term "coalition of the willing", stating that it aimed at gathering a broad array of stakeholders and that only a few players such as police forces or the East-African Secretary are missing. Going through the process of interviews however gave a more nuanced picture on the governance of boda electrification projects.

Governance of boda electrification in Nairobi

A first discrepancy appears in the level of involvement between the national level, incarnated by the transport ministry MoTIHUD, and the city level, represented by the agent affiliated with the Nairobi City County. While MoTIHUD is one of the leading entities in the process, Nairobi City County is only at an early stage, gathering thoughts on potential electrification projects. Furthermore, the County administration does not seem to have been very involved in projects and discussions, as of the information communicated by the interviewee. A paradox emerges as a future pilot is envisioned on Nairobi County grounds while the city administration does not seem to be involved. The Nairobi City County interviewee framed it as "people from the Ministry coming to run a project at the County level without ownership at the County level".

It is important to note that this does not imply a systematic lack of cooperation or a vertical decoupling between national and city levels in Kenya. For instance, MoTIHUD has been discussing with Kisumu governor on the pilot in this County, located in the Eastern part of Kenya. Rather, it gives indirect insight into the poor image of Nairobi policymakers and growing distrust. The interviewed European donor agency showed a strong level of discouragement resulting from the failure to implement urban mobility projects in Nairobi in a timely manner. The interviewee affiliated with Nairobi City County himself qualified Nairobi's governance as "crazy", an adjective repeated 15 times, and "insane". This governance crisis experienced a peak in February 2020 with the transfer of transport responsibilities from the County to the national level.

Secondly, boda representatives seem to be limitedly involved. The Boda Boda Safety Association of Kenya (BAK) Chairman was invited to see the motorcycle currently present at UNEP premises ahead of the remaining 49 ones but did not mention further contacts with the "coalition of the willing" or with start-up A. The mechanical engineering professor, member of the "coalition", stated that BAK was not involved in the pilot. This contrasts with the fact the BAK interviewee had a rather high impact ratio and asserted that its members (drivers) are enthusiastic about electric bodas and have requested to test them. Recently, when approached by start-up B, BAK facilitated contacts with drivers.

The union BOTTA is lying further behind, not in contact with any stakeholders, possibly due to its headquarters based in the city of Mombasa. BOTTA states to regret this lack of involvement: "in our country, they only look at the profit, not at the people. Unions are not involved. The actual consumer is not involved."

Third, a strong narrative related to governance arises from the interviews, namely a belief in private forces and the market capacity to drive betterment projects in Kenya, as opposed to public forces. As the UNEP interviewee phrased it: "there is an equal balance between the public and the private, anything is bad with

governance, there is an equal positivity with the private sector". Stakeholders celebrate start-ups, the "enterprising spirit" (C4D Lab), a "strong kind of business community" (professor in sustainable urban development) that earned Nairobi the qualification of Silicon Savannah. Start-ups tend to have limited trust in decision-makers, not awaiting many benefits from the policy side and "risk managing negative aspects" (start-up A). Based on the belief that private start-ups will successfully bring forward motorcycle electrification, complex governance of electric mobility and of the boda sector only ranks as the second lowest barrier, while insufficient policy and legal frameworks rank at only the fifth lowest perceived barrier. Here, a distinction must be made between civil servants, as some of them are mobilised in climate change mitigation and electric mobility projects but are seen as having very little influence, and politicians who are particularly decried.

Analysing narratives and ratings around the three sustainability dimensions

Most of the interviewees did not spontaneously use the terms "sustainable" or "sustainability", to the exception of a few pointing out specific dimensions of sustainability: sustainable impact on other modes and on safety (ITDP), sustainable understood as economically viable (WEEE Center), as durable, solid and well-accepted vehicles (Flone) or as sustainable conditions for mining batteries components (UNEP). This subsection focuses on impacts and less on feasibility, as the impact aspect is closer to the main research question on anticipated sustainability effects.

Economic dimensions

Drivers earnings

Subsection 5.2.1 on the frequency of codes occurrence showed how the theme of drivers' earnings and costs was by far the most discussed aspect spontaneously brought by interviewees. When asked about general impacts of boda electrification, most interviewees started with this dimension, to the exception of some stakeholders having professional interests in areas such as climate change or urban development (European donor agency, urban planner). Most interviewees considered that a shift to electric motorcycles would reduce O&M costs for drivers, as a result of switching from fuel to electricity and of reduced maintenance need. This reduced need would stem from the much smaller number of parts contained in EVs compared with conventional ones. Such assertions were mostly general ("cheaper", "much lower costs") but one start-up, the mechanical engineering professor and UNEP quoted reduction figures varying widely from 30%, 50% to 60-80% respectively. Such variation may be explained by the important number of variables to consider, including the business strategy, the creation of a network of stations versus home charging, drivers' purchasing power as estimated by companies etc.

Not everyone agrees on the level of certainty of cost savings. On one side of the spectrum, the former employee of the off-grid energy company M-Kopa stated that this decrease was "established", "in science". On the other side, many still had questions about the level of savings, using conditional wording or waiting for the results of the pilots (UNEP, C4D Lab, urban planner, BOTTAX, STA, Uber).

The particularly high significance attached to this topic of earnings is confirmed by the questionnaire results: the reduction of O&M costs ranks on average as the second highest benefit, equal with climate

change mitigation. Increased earnings for drivers deriving from cost savings is seen as the main facilitator, as expressed by start-up A: “possible savings is [sic] the absolutely most important facilitator when it comes to actually reaching the market. The rest of them [...] you can absolutely get a pulling help [...] but I don't see them as a one necessity”. This narrative is found not only in start-up interviews, who directly have an interest in economic interest for drivers, but also infuses a broader range of society actors including universities, international organisations, NGOs. A Kenyan national working at the European donor agency associated economic primacy to a specific Kenyan characteristic: “from a [...] typical Kenyan perspective it's more economical, looking at finances [rather than an environmental perspective]”.

Other economic impacts

Other economic effects come comparatively further down. There were only few mentions over the potential to develop a national manufacturing of electric motorcycles during the interviews. This aspect was ranked as the fifth highest benefit. A possible hypothesis may be that this aspect plays a role in the longer term. For instance, start-up A intends to design its own motorcycles and have them manufactured in Kenya, but as a second step. Current national priority to develop an industry policy was not seen as a very strong facilitator, ranking as the fourth lowest one.

The topic of jobs is double-sided: on one hand, electrification bears the promise of employment opportunities linked with new companies, electric technical skills, charging and exchanging batteries at swapping stations. This opportunity ranks on average as the sixth highest benefit. On the other hand, it also entails a risk to destroy current activities related to the operation and maintenance of conventional motorcycles. Reduced need for maintenance stemming from a smaller number of parts may impact informal mechanics repairing and providing spare parts, commonly named as “jua kali” (start-up A, professor in urban development, Uber). This may also lead to lower revenues at fuel stations that would not be needed for fuel nor for gearbox oil, hence a potential threat on employment at fuel stations.

This destruction risk is however mostly not perceived as a critical issue, ranking as the second lowest risk. Some interviewees envision an opportunity to upgrade skills to higher value activities (UNEP), even though professional training components are not integrated in programmes yet. This matter is seen as a long-term dimension. The professor in mechanical engineering showed a lack of interest in these informal activities, considered unprofessional and incompetent: “we don't have competent mechanics. Less maintenance is better. The mechanics will lose jobs, but I would say sorry [to] them”. In contrast, the professor working on urban development saw it as “one of the biggest risks”.

Fears of job destruction were discussed during interviews as anticipated socio-economic resistance from concerned sectors. Several examples of resistance over past years were cited, ranging from mechanics having opposed the introduction of automatic gears in cars, taxi drivers who fought the start of Uber operations or the opposition of matatus stakeholders to the Swvl company intending to modernise the minibus segment. The latter was the only successful example of opposition (C4DLab, Uber, European donor agency). A common perception was that job creations “balance out” destructions (C4D Lab) as part of a creative destruction phenomenon. This may also be linked to the view that mechanics will not constitute a critical mass, remaining atomised resistance. Socio-economic resistance is indeed ranked, on average, at the lowest perceived barrier.

Last but not least, the energy dimension is not anticipated as a major benefit, but as a facilitator for electrification. Energy was mostly discussed as an economic topic rather than an environmental one, likely deriving from the already high share of renewable energies in the electricity mix, combined with persisting issues for the stability of the grid and financial viability of the incumbent company (section 3). Fewer fuel imports and related expenses leading to higher energy security rank as the fourth lowest benefit, but as the third highest facilitator. Stabilising the electric grid through the use of motorcycle batteries at swapping stations - station-to-grid instead of vehicle-to-grid- is rated on average as the third lowest benefit. This low rank stems from the proportionally lower energy contained in motorcycle batteries as compared to car batteries, limiting any stabilisation potential. This would also require the development of smart grids. Additionally, use of solar systems at charging or swapping stations ranks as the second lowest benefit as solar appears as a source of energy completing the necessary connection to the grid ensuring sufficient power, not as a stand-alone option (UNEP, start-ups A and B, Flone).

Environmental dimension

The primacy given to economic dimensions during the interviews does not mean that environmental ones are ignored. A significant contrast can actually be observed on environmental matters: while these were relatively briefly discussed during interviews, air pollution comes in first place from the questionnaire answers on potential benefits. Climate change mitigation comes second, equal with reduction of O&M costs; reduction of noise levels follows at the third place. The same applies for risks: issues of batteries depletion and toxicity rank as the second highest perceived risk. Stakeholders therefore seem aware of environmental effects but were not discussing them at length.

Air pollution is “probably the highest [benefit]” for the UNEP interviewee, given the high level of exhaust emissions resulting from poor maintenance of motorcycles and a lack of control. Air quality issues and associated health problems were mentioned by UNEP, Nairobi City County, MoTIHUD, Flone Initiative, the urban planner, the boda association BAK, ITDP and both urban development and mechanical engineering professors. The latter stressed that at national level, motorcycle emissions surpass those of cars since 2014 due to the rapid increase of motorcycle vehicles in the country. However, emissions at local level have not been calculated yet (Nairobi City County).

Climate change mitigation was ranked high as a benefit but not extensively discussed. The donor agency contrasted by having climate change as an entry point into the topic of electric mobility and assessing that their research has shown that “electromobility [has the] second highest mitigation potential”. Climate emergency as a narrative was mentioned three times but not detailed (“climate crisis [as] the backdrop” for the urban development professor, comparison with a “fire” for the UNEP interviewee, a “massive” “global warming agenda” for the Uber interviewee). Both national and local levels are reviewing or enacting policy documents having a stronger focus on climate change mitigation and electric mobility, the 2012 Integrated National Transport Policy and a City Climate Action Plan. However, stakeholders don’t trust national climate change commitments as a powerful facilitator for a transition to electric motorcycles, ranking them as the fourth lowest one.

Last but not least, absence of noise as a benefit was the least discussed theme, mentioned by UNEP, the urban planner, the boda association BAK and a low one for the donor agency. It will be discussed as a risk under the forthcoming paragraph on safety.

To explain the contrast between interviews and questionnaire results, some elements from the interviews may help build assumptions. First, the high share of renewable energy in the Kenyan electricity mix (section 3), mentioned by UNEP, start-up B and the urban development professor, may lead experts to assume that a clean electric mobility in Kenya is a given. Secondly, the environment and specifically air pollution does not seem to be a narrative present in public discourse, representing an issue of lacking environmental awareness that was underlined by several interviewees. The union BOTAX mentioned that air pollution was a “language [...] understood only by people who went to school”, too abstract when not linked with diseases and cancers (UNEP). The Nairobi City County interviewee told the story of a conversation with a boda driver “completely unaware” of air quality. Due to this limited awareness, air pollution may not be seen as a *selling point* when discussing electric mobility, with several stakeholders in the process of persuading others of their project or product. Thirdly, the current main narrative around bodas, found in the press for instance, revolves around safety, not around air pollution: “people don't look at [boda bodas] in the sense that they're polluters, we look at them in a sense that they drive really badly” (donor agency).

Relation between economics and environmental aspects

During interviews, some stakeholders highlighted that benefits are not exclusively, or not mostly environmental. Some start from the economic to go to the environmental: start-up B stated to focus mainly on economic outcomes, but “still” to care about environmental ones. The UNEP interviewee qualified emissions as a “co-benefit”. Environmental projects are not identified separately but coupled with economic purposes: “we are lucky that we have a situation where we have an environmental goal that marry so well with an economical goal, or a socially attractive goal [...] for me altruistic environmentalism is dead” (UNEP). In contrast, Nairobi City County interviewee started from environmental benefits to go “beyond” and identify socio-economic ones.

Batteries as an environmental risk

The topic of the supply and end-of-life (EoL) management of batteries offers a nuanced picture. It ranked on average as the second highest risk. The urban development professor and Flone identified the issue of waste mismanagement and distrusted the capacity of the National Environment Management Authority (NEMA) to enforce proper regulation. E-waste management is indeed still at a nascent stage, piloted by small-scale private initiatives such as the WEEE-Center. Names of other initiatives were not identified. Nevertheless, several interviewees again expressed their trust in private forces and technology to handle this waste, for several reasons. The high financial value of Li-ion batteries – used in the three identified motorcycle projects in Nairobi instead of lead-acid ones – is seen as triggering interest in reusing or recycling them (UNEP, start-up A, Uber, boda association BAK). A growing number of companies are said to enter this market. In addition, start-up A and mechanical engineering professor consider the current amount of batteries to handle as limited, the latter mentioning this point to be addressed at a later stage.

Two further noteworthy aspects in batteries EoL management can be identified. First of all, concepts of reuse and recycle may be applied. Feasible reuse was identified by several interviewees: when the motorcycle battery reaches a certain use threshold at circa 80% and decreased efficiency, it may be reused for stationary purposes as inverter systems or residential storage units for solar energy. This is often termed the battery's second life (start-ups A, B, UNEP, STA, WEEE-Center). In addition, the WEEE-Center goes further as it recycles laptop batteries by disassembling cells, testing them and reassembling into new battery packs used for motorcycles. This strategy, similar to Bodawerk's one in Uganda (section 3) leads to the concept of the three battery lives. Doubts were however raised over financial and technical feasibility given the need for constant and significant volumes of e-waste streams, combined with the decreasing price of new batteries (start-ups A and B, UNEP). The second reason is that business and infrastructure models may have an impact on EoL management: for instance, in the case of batteries being leased to motorcycle drivers and swapped at stations, ownership and responsibility is retained by companies, possibly enabling higher trackability (UNEP).

Even if these two last aspects provide some avenues worth exploring, the WEEE Center states that legal and regulatory challenges persist, especially the absence of a specific regulatory framework on e-waste. Finally, other aspects need to be considered, such as possible economic uncertainty linked with the supply of batteries that are imported, ranked as the fourth risk, and the conditions in which battery materials are extracted, particularly in Africa, that ought to be better monitored (UNEP, urban development professor). The economic risk regarding an uncertain supply security of batteries and battery components was less envisaged, ranking on average as the fourth highest risk.

Durability of electric motorcycles

Interviewees raised a point that does not seem comprehensively developed in literature, which is the risk of limited durability of vehicles or lack of adaptation to local conditions. Flone mentioned the risk to "bring in literally about 100,000 bikes and then within a couple of months they are not working". UNEP also used the conditional when talking about "bikes that are working [...] not crappy". Initial prototypes may need to be adjusted to fit local conditions such as rough terrains and heavy loads. On the other hand, start-up A assessed that electric bodas would last longer given the smaller number of "complicated components".

Social dimension

Safety

Again, opinions on safety linked with electric bodas presented a contrasted picture. More silent motorcycles led interviewees to identify an augmented probability of accidents as the highest risk. This silent characteristic was also associated with crime opportunities (Uber). Moreover, the fact that electrification could increase the motorcycle fleet as a rebound effect, together with the perceived easier use of such vehicles, were viewed as risk factors leading to more accidents (STA, urban planner). Contrarily, unsafe operations of EVs, for instance fires in the case of a collision were seen as the lowest risks, and as issues that may be addressed through education and training (mechanical engineering professor).

Yet, electrification was also seen as an opportunity to improve the poor safety situation. Current boda boda services are perceived to be unsafe, characterised by a lack of proper driving training, lack of adherence to

driving with a license, lack of respect of the allowable maximum number of passengers, reckless overtaking and the high number of accidents and fatalities (mechanic engineering professor, STA, Nairobi City County). Interviewees mentioned the lower speeds of electric motorcycles as a factor to improve safety. Start-up B and STA assessed maximum speeds at 70 to 80 km/h. The two start-ups and UNEP mentioned the technical options of limiting speed threshold at production stage or monitoring speeds through the battery software management. Although mentioning such avenues, project holders have not integrated them, or not yet. Additionally, transition to a new technology and new players was mentioned as an “opportunity of rein in safety in the sector” by including dimensions of training and licenses (UNEP). Start-up B considers provision of safety equipment such as helmets and reflectors, a practice however already implemented by ride-hailing companies. Start-B could go further, evoking a reduction of motorcycle purchase prices in exchange for participation in safety training. The donor agency suggested to include driving schools in such endeavours, and the boda association BAK to have licenses controlled by vendors when selling an electric motorcycle. However, these ideas are only at a conceptual phase and not much developed. ITDP expressed scepticism, “not seeing safety brought up as such a core element of that transition”. According to MoTIHUD, the national boda task force conclusions address regulation and safety but do not make any connection to electric mobility.

Regulation of the boda sector

As aforementioned, electrification is seen by some as a pull strategy to “bring [boda drivers] back [...], bring them into the mainstream” (UNEP) after the punitive approach trying to push them away from unsafe driving habits failed. While such improvements were mentioned for road safety, it was less clear whether electrification could provide for fresh grounds for the structuration of the sector. A potential benefit to renew regulation was ranked on average at the seventh place; the existence of an embryonic boda self-regulation at stage and SACCO level was rated as the third lowest facilitator only.

The mechanical engineering professor, STA, MoTIHUD, start-up A envisioned charging or swapping stations located at boda waiting stage. However, none of them identified that such infrastructure development could strengthen boda self-organisation at stage level.

The boda association BAK explained how it finds itself in the process of collecting data from drivers and compiling them in an online platform (22 categories of information, including name, ID and telephone numbers, county, sub county and stage of operation, motorcycle number, driving license, insurance number etc.). BAK claims that public authorities do not themselves have this data. The association also conducts programmes to sensitise drivers on safety, organises occasional driving training and joint events between police forces and boda drivers, two groups often antagonistic. It estimates that there are around 14,000 boda boda drivers in Nairobi, not specifying if it concerns the County or the larger metropolitan area.

Despite these efforts, self-regulation is still considered at a nascent phase (start-up B) and the situation of stages “pretty chaotic” (Nairobi City County). In contrast, trust seems to be higher in companies providing delivery services via motorcycles, viewed as more reliable partners and low-hanging fruits for electrification projects (STA, Uber, Nairobi City County). Start-up B expressed reserves on the current organisation at stages, preferring to install stations at new, “inclusive” locations understood as open to any driver, not only the ones constituting the stage.

The UNEP and Nairobi City County interviewees invoked the need to create a sense of ownership for the boda drivers. This contrasts the seemingly limited involvement of boda association or unions.

Image of boda drivers

Improvement of the image of boda drivers when shifting to a cleaner technology was not seen as one significant benefit, coming on average at the fifth lowest potential gain. The boda association BAK, the donor agency and WEEE center did not consider that it could improve their image.

In fact, interviewees identifying an image benefit linked it to safety. More originally, the Nairobi City County interviewee suggested to include a gender component to improve the image, for instance electric boda bodas driven by women as a change that would be associated with cleanliness and formalisation.

A further characteristic found in the interviews was the persistence of negative perceptions around boda drivers, seen as having very limited knowledge and reluctant to experimenting with innovations (STA, Nairobi City County, mechanic engineering professor). The boda association BAK contradicted this perception, stating that its members had been approaching the Chairman to do EVs test drives.

Induced demand and impact on other modes

The questionnaire included a risk factor entitled "induced demand for motorcycle taxi operation", understood as an unintended rebound effect, where improvement of boda operations through electrification would raise supply or demand of boda services. To the exception of ITDP, no interviewee spontaneously raised this topic; rather, they asked about the meaning, triggering a discussion on it. 13 interviewees over 18 did not know the concept. After explanation, which entailed a possible bias in the questionnaire answer, this aspect came to the average third position in the list of risks.

Some interviewees identified a rebound effect solely in terms of supply, namely the number of people intending to become boda drivers. They observed that if electrification bears the current promise of increased earnings, the sector may attract more individuals given the context of high unemployment (UNEP, union BOTTAX, mechanic engineering professor). In terms of risks, this influx of boda drivers may occasion more accidents in a context of insufficient driving training. It may also lead to a decreased number of trips per driver if the demand for boda services does not increase. It can also be seen as an economic opportunity for individuals previously without activity, even if such activity would be informal and self-employed.

Regarding a potential increase in demand, namely more people travelling by boda, opinions diverge. The C4D Lab, former employee at the energy company M-Kopa and Uber interviewees discarded the risk of increased boda traffic, considering that there is no latent demand. This topic is actually closely related to the question on prices, namely whether cost savings will translate into reduced fares. Such reduced fares could increase the attractivity of this mode. However, most interviewees talked about costs, not about fares. As an exception, the WEEE interviewee stated that prices would not change.

The interview with the Uber employer is worth observing more closely: while he predicted a reduction of costs -not mentioning fares-, he subsequently referred to the success of Chapchap, their "revolutionary product". Chapchap is a cheaper car service than their premium saloon car service UberX. One could therefore raise the hypothesis that the company could envision launching a new boda electric service with reduced fares, as a new market segment.

ITDP and the urban planner predicted an increase of both supply and demand. They did not consider such increases as economic or accessibility opportunities, rather as a risk for other modes, particularly minibuses

and cycling. To the contrary, boda association BAK and union BOTTAX did not associate such an increase with a risk, rather with a positive evolution, likely meaning more members and additional revenue. Last but not least, STA foresaw an increase of privately-owned motorcycles, not only for-hire bodas.

This future supply and demand for boda services, as influenced by electrification, is closely linked to the question of the desired modal split in Nairobi. Stakeholders have been witnessing that bodas do not provide solely first and last mile services but tend to do longer trips in a context of increasing congestion as they weave through traffic (STA, urban development professor, C4D Lab, urban planner, Uber). One ride-hailing company communicated to the author an average distance of 6.9 km per trip as of 6th February 2020 (interpersonal com. on 4th March, authorization to use the figure against anonymity). This shows that numerous trips occur outside neighbourhoods.

Growing competition between boda bodas and minibuses or non-motorised transport, namely walking and cycling, were already observed. The urban development professor, the urban planner and ITDP voiced concerns that competition would increase in the event of a stronger boda boda attractivity. Therefore, the latter called for a careful design of incentives, looking at possible rebound effects and addressing all modes when electrifying, in priority those deemed as critical in the concerned city. As one can observe from this list, such concerns were expressed by stakeholders having a background in urban sciences.

Integrated transport network

Using electrification as an opportunity to build a more integrated transport network was considered on average as the lowest benefit. Some interviewees claimed to be aware of the importance of connectivity (UNEP, former employee of the energy company M-Kopa, Nairobi City County, urban development professor). Nevertheless, they mostly think that this will not be automatically induced by electrification and, more importantly, they don't suggest including such a component in projects.

When discussing the infrastructure of charging or swapping stations, different locations (fuel stations, boda boda stage, residential areas, kiosks, malls, newly identify areas) were mentioned but no interviewee suggested promoting intermodality and connection between modes at these locations, with the exception of the urban development professor evoking the possibility of "charging stations that would cater to multiple modes".

Perceptions on feasibility

In line with the economic primacy identified, the first and third main drivers perceived are the promise of future reduction in costs for drivers and in expenses for petroleum imports. According to start-up A, "possible savings is the absolutely most important facilitator when it comes to actually reaching the market. The rest of them [...] you can absolutely get a pulling help from [them], but I don't see them as a one necessity". Regulatory options already in place, namely vehicles standards -not infrastructure ones- and reduction of import duty for EVs came in second position. Experts also count on increased electricity demand generated by EVs and information gathered from regional electrification projects to leverage interest on electric motorcycles. In contrast, policy commitments on climate change and industry policy, nascent self-regulation at boda stage, emerging e-waste initiatives and limited trips around the stage are seen as weaker facilitators.

Experts also suggested further incentives to promote electric motorcycles, mostly with regards to import taxes, electricity tariffs, partnership and involvement of public bodies. Further reducing excise duty for imports of ready-made EVs or of components for local assembly to a possibly zero rate level was mentioned by UNEP, MoTIHUD and Nairobi City County, in line with the EPRA and UNEP report's recommendations (2020, p.63) which were finalised after the end of the interviews. Reducing rates applied to imports of ready-made vehicles would favour Vehicle Strategy A, while reduced taxation for imports of components to be locally assembled would support Vehicle Strategy B. In addition, reducing power tariffs for public charging, possibly at fuel stations, was also mentioned by MoTIHUD and the donor agency, the urban planner even suggesting temporary complimentary charging at stations as an awareness-raising method. Another approach is to install public charging stations at the location for governmental bodies -for instance at EPRA as mentioned by MoTIHUD-, or at public places such as the Kenyatta International Convention Centre. However, these two strategies relate to private passenger cars and taxis in the form of cars (Nopea). Two interviewees, the urban development professor and ITPD, warned over the design of incentives that should, in their opinion, prioritise the most sustainable modes of collective transport and imports of bicycles.

With regards to barriers, a typical challenge of initial high investment costs is identified as the main issue. This is followed by the costs and time needed to implement a network of charging or swapping stations. Here it must be specified that these barriers are not always present but rather depend on the charging solutions and business models that will be selected. For instance, high upfront investment costs do not occur for drivers if a model of swapping and leasing batteries – the most expensive component - is selected, shifting the risk to the company. However, this option requires the development of swapping stations, that is not incurred when charging at home is preferred. In this second option, still envisaged by the WEEE Center, connection to the electric utility grid suffices. However, it entails the significant caveats previously identified of doubts on access to electricity at a residential place.

Stemming from the survey with drivers, the issue of further occasional trips undertaken by drivers to rural destinations, that would require charging options outside of Nairobi or higher-capacity batteries, came to the average third place. Further barriers follow, including challenges with administrative approval, limited capacity of public bodies to award financial incentives or even opposition from them to see fuel consumption decrease, as taxes attached to fuel result in a source of public revenues.

In general, barriers were given high rates, with a total average of 2.66 for barriers versus 2.86 for facilitators. The ratio for feasibility is 0.2, slightly less positive than the average impact ratio at 0.65. Interviewees also added further barriers, linked with uncertainty over technical and legal feasibility in a concept of projects still at the prototype or pilot phase. A technical unresolved aspect is the ease to connect a stage to the electric grid, with views diverging. Opinions were also diverging on the legal feasibility of Vehicle Strategy B using components from ICE motorcycles, raising the question of a possible opposition of manufacturers to the creation of an EV visually looking the ICE motorcycle alike.

5.3. Limitations

As stated in the methodology part, a few key stakeholders could not be interviewed as they did not reply to requests, or because of time constraints. In addition, two stakeholders had not been identified at the time of interviews, namely companies Kibo and Fika Mobility. Kibo intends to provide upscale electric motorcycles, possibly too expensive for boda boda drivers, and Fika Mobility, a leasing model for batteries combined with swapping stations. Regarding Nairobi City County, the interviewee was affiliated with the county government, working on climate change mitigation. Despite various attempts, no County civil servant working on boda boda regulation could be interviewed.

The newness of the research topic, combined with the rapidly evolving landscape in terms of information diffusion and connection between stakeholders (shown with the arrows in Figure 21), suggests conducting such analysis over a longer period of time, with similar data on stakeholder perceptions collected at various intervals. Such a longitudinal study would better capture the evolution of perceptions over time than a cross-sectional one, as well as allow for feedback loops regarding first project impacts. A longer period of time would also allow identifying and addressing a broad range of stakeholders, that is a valuable aspect since electric mobility is characterised by a multiplicity of actors in terms of nature, field of activity and scope of intervention.

A further caveat lies in representativity: while interviewees work in given entities, one may not always assume that they represent an official position from these entities rather than personal views. This was particularly clear when interviewing several employees of the same entity who occasionally disagreed.

Last but not least, no opponents to boda electrification could be precisely identified and interviewed. Diverse avenues were explored, such as companies involved in fuel imports and operation of fuel stations or vendors of conventional motorcycles. One employee of the donor agency stated there often were vested interests in Kenya, “very influential private people” who “sleep behind the curtains but [...] push everything”, being particularly pessimistic about chances to identify and reach out to these people. This interviewee cited the failed electrification of the Mombasa-Nairobi railway line, stemming from vested interests in fuel imports. Opinions were more balanced on fuel stations, some identifying them as potential opponents due to loss of revenues from fuel operations (one STA employee, C4D Lab), others as proponents of business diversification in a peak-oil context (start-up A, other STA employee, mechanical engineering professor). A study conducted over a longer period of time could include interviews with fuel station operators and OEMs to clarify their positions. In addition, conducting a focus group would help stakeholders brainstorm on the identity of possible opponents. Some stakeholders are already in the process of attracting them to electric mobility with incentives, for instance MoTIHUD suggesting lower electricity tariffs for fuel stations offering electric charging services.

Section 6 – Discussion and recommendations

6.1. Summarised findings

The study aimed to investigate sustainability impacts of motorcycle electrification in Nairobi as anticipated by stakeholders. To do so, data was collected with two groups of stakeholders considered as essential, drivers of boda bodas and electromobility or urban mobility experts, using a mixed-method approach.

Both groups had a dominantly positive perception of electrification. A higher number of drivers identified benefits than risks, while all experts but one ranked opportunities higher than risks on average.

Among these benefits, a very similar primacy given to cost savings and drivers' earnings could be observed in both datasets. Economic gains emerge not only from the replacement of fuel by electricity, but also from the emergence of a new model of battery leasing and swapping, which lifts the purchase burden from the driver. This is critical as the high upfront investment cost is commonly cited as a key barrier for the take-up of electric mobility. Secondary economic benefits included the development of a new manufacturing industry and the creation of new jobs, while the risk of job destruction was discarded by many experts.

Environmental aspects lag behind, almost exclusively ignored by motorcycle drivers. Experts, in contrast, were aware of environmental aspects and identified significant potentials to curb carbon and other polluting emissions. They however did not discuss these beneficial aspects at length, rather focusing on economic gains and feasibility. A couple of hypotheses could be raised on this relative omission, including cleanliness of Kenyan electricity viewed as a given, or environmental benefits not seen as a selling point in a context of limited environmental awareness. By comparison, different methods to manage batteries EoL were more frequently discussed, linked with possible solutions to increase trackability, reuse and recycling.

Furthermore, social aspects were neither extensively mentioned nor highly ranked by drivers and experts, to the exception of safety which currently drives narratives around boda boda operations. Rebound effects were discussed by experts, but as a reaction to one factor listed in the questionnaire, not a topic spontaneously brought by them. Little thought was given to impacts on self-regulation at the stage level, involvement of drivers, but also on the opportunity to use electric mobility to create an integrated transport network.

Regarding risks, boda boda drivers mostly focussed on the feasibility of electric motorcycles, rather than impacts. Experts primarily identified traffic accidents as a risk deriving from silent vehicles, environmental issues related to batteries and a potential increase in the number of boda boda drivers or traffic. Job destructions were not viewed as a main risk.

The prevalence of economic dimensions could be also observed in the feasibility analysis with drivers and experts, the latter rating cost savings as the key driver on average and upfront investment cost as the main barrier. From the survey conducted with boda boda drivers, the fact that they more frequently identified

benefits over risks may be an important facilitator in terms of acceptability of a new technology. Adding up to the existing standards and tax reduction for EVs, possible further incentives were mentioned by experts, such as continued tax cuts, reduced power tariffs and public demonstration projects. A number of barriers were identified, linked with investment costs, more distant rural trips, possible oppositions to electrification projects or remaining uncertainty over technical, legal and financial feasibility in a context of prototyping and piloting. In an unexpected way, the fact that most daily trips are spatially limited within the neighbourhood and revolve around the stage, which could turn a significant asset for limited-capacity batteries and to install charging or swapping stations at the stage, was ranked as the lowest facilitator on average. This may stem from the fact that data is nearly non-existent, many interviewees stating not to know about current patterns of boda boda operations in Nairobi.

Here it must be noted that interviews were conducted at the very beginning of the spread of the coronavirus disease. Discourses and questionnaire rates could have been different if collected a few months later, regarding aspects of battery supply chains, fuel imports and fuel prices.

6.2. Interpretation

Stakeholders perceptions

A hierarchy of sustainability *benefits* anticipated by stakeholders emerge from the findings, led by economic, followed by environmental and finally by social aspects. Electrification is principally discussed as a strategy for cost-effectiveness, with economic gains as the key opportunity and the driving factor for implementation. This contrasts with the identified academic literature on electrification which envisions it as a low-carbon measure with potential co-benefits. Some studies identify economic benefits based on a lower total cost of ownership, but this dimension is brought to the forefront in the specific case of Nairobi. This case study research therefore suggests a reversal of perspectives, from a low-carbon strategy with co-benefits to a socio-economic project with environmental co-benefits.

This reversal and the precedence given to cost savings may stem from a couple of factors. Most immediately, the presence of start-ups infusing discourses around projects puts the focus on economic gains. However, these narratives are not limited to private entities but spread to public authorities, international organisations, associations and universities. A deeper explanation may lie in the use of motorcycles in Kenya not for private purposes but as taxi services in a lower middle-income country (World Bank 2020, n.p.), marked by high informality. These vehicles are therefore not only seen as mobility instruments, but also as vectors for livelihoods in a development context. Any reform project is scrutinized under the short-term economic impact for self-employed drivers. This differs with electrification studies that did not entail such a taxi component. Further research could explore whether concepts linking climate change mitigation and development such as "low-carbon development" (Bakker et al 2014, 340-341) would apply.

Economic gains were viewed in a short-term dimension in the form of reduced costs. Neither longer-term socio-economic impacts such as the evolution of fares were much considered by interviewees, nor broader effects on neighbouring sectors such as maintenance, repairs or fuel operations. Also, stages were occasionally identified as places for swapping stations; however, no expert suggested that this infrastructural development could have a long-term effect on self-regulation of the sector that is currently

concentrated at stage level. Therefore, one may argue that a longer-term and holistic vision is lacking to fully respond to the three dimensions of sustainability.

Answering the sustainability question

When it comes to an overall assessment of the sustainability of boda boda electrification, it must be reminded that this research did not aim to quantify possible impacts, but to identify perceptions. For instance, the fact that reduced O&M costs were widely anticipated does not mean that it is certain to happen as expected. However, features from the local context analysis, combined with opinions of stakeholders give valuable response elements. These constitute a nuanced picture involving several variables.

The analysis primarily suggests that electrification of boda bodas could bring significant improvements. On one hand, electrification would address two currently unsustainable features of this mode, namely a high contribution to climate change and urban air pollution. On the other hand, this transition would score highly on a couple of sustainability criteria. Cleanliness of the Kenyan electricity mix, which was identified as a key sustainability factor in electrification literature, is a first anticipated benefit arising from the particularly high share of renewable energies. The widely shared assumption of economic gains for drivers, that would still need to be verified during projects implementation, may contribute to an economic development strategy.

However, beyond these two aspects, the sustainability of various dimensions is not ensured but depends on the way electrification projects will be implemented. Therefore, this research suggests a combination of accompanying policies that can improve the sustainability outcome of boda boda electrification. Such policies address risks identified for sustainability, having a specific focus on two factors identified in Section 2: batteries and modal shift. They also address other sustainability aspects relevant for the Nairobi context that seem insufficiently addressed in the author's opinion.

6.3. Policy recommendations

The study identifies eight areas where policies could help align electrification projects with society-wider economic, environmental and social gains.

Achieving desired economic impacts. Even if widely anticipated, economic gains resulting from reduced O&M costs, with corresponding impacts on informal transport operators' livelihoods, are not per se guaranteed. Entities involved in electrification projects are developing models based on many variables, including vehicles, batteries, charging infrastructure, which results in uncertainty over their future successes. This study sees the value to identify financial mechanisms to initially support these entities, for a couple of reasons. A first justification lies in the innovative characteristics of battery or vehicle leasing that shifts the economic risk from the individual driver to the company, ensuring a more immediate impact on drivers' livelihoods, while improving e-waste trackability. Additionally, financial support provides a stable ground to first test prototypes adapted to local contexts, a condition for environmental durability of vehicles. Seed funding could be leveraged via international, multilateral or bilateral development finance institutions, rather than national institutions characterised by budgetary constraints. This could be linked

to conditionalities of safety and multimodality, that will be detailed below. In addition, further ways to reduce operational costs could be sought, such as reduced power tariffs at charging stations.

Regarding tax incentives, careful arbitration should be made between facilitating imports and supporting local manufacturing and assembly. This latter goal of industrial development could be explored via the support of Vehicle Strategy B projects, since these use some locally manufactured parts and intend to develop their own EV designs to be produced in Kenya. A cross-cutting grouping gathering public and private stakeholders could identify subcomponents that are more easily reachable targets for developing an electric motorcycle production industry, address manufacturing deficiencies and list possible incentives, including cooperation between public entities and OEMs, tax incentives for green projects, green bonds or public guarantees.

Safety. Safety is a key dimension for motorcycle taxis in SSA. Involved stakeholders have announced their intentions to include this component in electrification projects. Nevertheless, no concrete plan was detailed, raising scepticism from ITDP. This study therefore recommends concretizing these endeavours. Start-ups implementing projects certainly have a role, but may be reluctant to adopt a restrictive stance, for instance on speed limitation, as this could impede their development. The lower speeds of EVs that were mentioned during interviews, at 70 to 80 km/h, still seem too high to allow per se for safe operations in urban environments. This study suggests a role for international donors, which could include a safety component in financial assistance conditions, for international organisations and associations accompanying projects implementation, and for universities studying the phenomenon, in collaboration with the safety authority NTSA. In addition, national and local governments could allow for a preferential treatment to companies bundling electric vehicles and safety. Such bundling measures could include speed limits, speed monitoring via the battery management software, use of collected metrics for safety awards, pairing drivers having good safety ratings with those having a poor one to trigger a learning effect etc.

A preferential treatment could be, in the case of Nairobi, to allow access to the CBD for companies providing electric and safely operated boda bodas. In any case, this study critically views incentives that would weaken current regulation of boda bodas, as safety regulatory requirements are not implemented and transparency over numbers of operating boda bodas is not present. Therefore, it sceptically views the recently proposed incentive by the energy regulator EPRA to reduce licensing and registration requirements for electric boda bodas or classify them as bicycles (EPRA and UNEP 2020, p.63).

Rebound effects. This research showed how stakeholders anticipate decreased energy costs for drivers, leading *ceteris paribus* to higher revenues. Two possible rebound effects, referring to unintended consequences, were discussed. A first possible increase of supply of services was envisaged if new drivers enter the market, attracted by the promise of higher earnings. In case that the decrease of costs is translated into reduced fares, a second phenomenon could be an increase of the demand for boda boda services together with the number of trips. Such evolution could be led by ride-hailing companies that have shown fare reduction strategies in the passenger car segment. Also, reduced boda boda fares could near those of minibuses, jeopardising the latter modal share in a context where some boda bodas already provide more than first and last mile services.

Yet, to be sustainable, electrification should not lead to a reversed modal shift, namely from collective transport to lower-capacity motorcycles, even if provided as taxis. Modal shift is indeed the third

sustainability variable identified for electrification in the literature review. In other words, and going back to the concept of Avoid-Shift-Improve, “Improve” should not endanger “Shift”. One could suggest that this risk does not mean electrification should not be pursued, but that effects must be carefully assessed, and incentives thoroughly designed. Incentives must balance between the support necessary for uptake of electric motorcycles and possible disproportional advantages over other modes.

A second recommendation is linked with the quantification of transport emissions. Data is currently collected at national level, showing a higher level of CO₂ and other pollutants emitted by boda bodas compared with cars. Data is however not available at local level, in the process of being collected by the Nairobi City County administration. In fact, national findings on which modes are the most polluting may not be valid in Nairobi where boda bodas are less present than in other cities and rural areas (section 3). In Nairobi, minibuses and buses have a much higher modal share than bodas (respectively 28.5%, 12.2% and 4.3% as of 2013). Matatus may well emit more harmful emissions than bodas. This research therefore argues that there is a need to *localize* the debate on electric mobility in Kenya, looking at each specific urban ecosystem. In Nairobi, modal split would suggest prioritizing matatus when electrifying, or at least simultaneously electrifying boda bodas and matatus, and considering incentives for both. Matatus electrification could bear the opportunity to renew perceptions, operational modes, possibly introducing new vehicles. The fact that the start-up Opibus envisions projects on both vehicles types is an advantage.

Modal integration. Urban planning is currently not much considered in the electric mobility debate. The two interviewed start-ups envisage battery swapping; location of these swapping stations is however not yet decided. This research recommends giving priority to locations where modes share a common space, wait or park close to each other, in order to promote multimodality and accessibility. Charging infrastructure will not be the same given different technical conditions for buses or motorcycles; however, having the station in a common place could encourage a spillover effect from modes more advanced in the electrification process. One example is the Taj Mall roundabout in the industrial area of Embakasi, where a few interviews took place, as this area is home to a fuel station -a likely low-hanging fruit given the existing connection to the grid-, boda boda and matatu stage. Locations where boda bodas really serve as feeder services could also be selected in priority, to promote complementary between modes rather than competition. Here, having an urban planning approach to understand multimodality and impacts at the neighbourhood scale seems desirable, by including urban planners in the list of involved stakeholders.

E-waste. E-waste is a significant risk factor identified in electrification literature. This research underlines features that may mitigate the risk of EoL mismanagement: economic interests stemming from the economic value of Li-ion batteries, existing recycle and reuse models, swapping models facilitating trackability. These aspects could be supported if integrated in projects, promoted by donors and international organisations. More generally, involvement from public institutions is necessary to clarify the legal framework and increase transparency of e-waste management.

Training. While professional training and upgrading of maintenance skills were briefly mentioned, no programme seems to have been designed in this regard. This research suggests doing so to include it as a part of a broader economic development strategy, as a safety component and an awareness vector as well.

Drivers involvement. Locating charging or swapping stations at boda boda stages raises the technical issue of connection to the grid, but also the opportunity to involve drivers, to renew regulation from a passive or repressive stance to a more inclusive one. Furthermore, drivers are little involved for the time being and are seen as more complex to partner with than deliveries companies that, while perceived as low-hanging fruits, do not meet a strong mobility need but represent an emerging market. This raises issues over ownership of electrification projects. In addition, this study suggests conducting longitudinal research works in the wake of implementation of electrification projects, to investigate how electric mobility has transformative effects on organisational, spatial and financial features of informal transport. This study identifies potential to contribute to the informal transport debate and possibly new forms of triple “institutional bricolage” (Heinrich et al 2018, p.141) if projects are jointly led by private forces as individuals (drivers) and companies (start-ups) together with public authorities.

Holistic approach and institutional cooperation. Summing up, a transition to electric boda in Nairobi entails promising elements but it needs to be looked at beyond short-term impacts, in a holistic approach encompassing urban planning and addressing weak sustainability points. This should be in line with the Slocat definition of sustainable transport as striving for accessibility and development while avoiding longer-term harmful effects (Bakker et al 2014, p.345, Section 2). Cross-cutting cooperation may also require inter-ministerial or interdepartmental working groups at national and local level. Finally, companies are driving forces in a context of limited public resources, but there is a need for public entities, together with donors, academia and international organisations, to frame the process and steer it in a sustainable direction.

Section 7 – Conclusion

The growth of motorcycle taxis is an observed phenomenon in many Sub-Saharan African countries. This transport mode, while raising significant environmental and social concerns of carbon emissions, air pollution and poor road safety, also prosaically meets mobility needs of rural and urban population and represents a source of revenues deriving from self-employment as drivers. Based on this binary assessment, a discussion has arisen on pathways to improve the mode by tackling its negative externalities. This research sought to contribute to the debate by investigating how a transition to electric mobility may help reshape the sustainability of boda bodas operated in Nairobi, understood in its environment, social and economic dimensions. Anticipated impacts were investigated through the perceptions of two key stakeholder groups: boda boda drivers and electric and urban mobility experts.

The study showed the need to localize the question of electrification, since motorcycles are of different types than the lighter-weight electric two-wheelers preponderantly identified in Asian contexts, heavier and more adapted to SSA terrains and poor road conditions. In addition, boda bodas are tied to socio-economic aspects deriving from their operations as taxis, contrasting with privately used motorcycles.

Electrification literature envisions electrification of two-wheelers as a low-carbon strategy, primarily expecting environmental benefits in the form of curbed emissions of greenhouse gases and other pollutants. Economic and social consequences are in some cases identified, but as co-benefits. A first finding of this research is that Nairobi stakeholders operate a reversal of this initial theory, shifting from a low-carbon strategy with possible socio-economic co-benefits to a socio-economic endeavour with environmental co-benefits. Indeed, expected economic gains resulting from cost savings as electricity is substituted to fuel, combined with fewer parts to maintain, comes in the first position of benefits spontaneously identified by both drivers and experts, as well as the main feasibility driver. It seems probable that this derives from the characteristic of taxi-like services where short-term impact on revenues are closely scrutinized, in a national context of focus on economic development. Further principal economic benefits identified were the emergence of a manufacturing industry and of new employment opportunities, while threats of job destructions and socio-economic resistance were not seen as main risks and barriers on average.

This economic prevalence does not imply that environmental aspects were ignored by all: while it was the case for drivers who almost exclusively omitted this dimension, experts rated climate change mitigation and reduction of air pollution among the most substantial benefits expected. This unexpectedly contrasted with the semi-structured interviews where they did not mention such aspects at length. Several hypotheses were raised on this, including them factoring in a perceived lacking environmental awareness among the population that would not make communication on environmental benefits a key driver to facilitate uptake of electric mobility. Beyond these perceptions, application of the environmental sustainability criteria identified in the electrification literature showed that a transition to electric motorcycles in Nairobi would score highly on the first variable of electricity cleanliness, deriving from the particularly high share of renewable sources in the national electricity mix. The second environmental criteria of the batteries end-of-life management will depend on the way projects are implemented; this risk factor was incorporated in the set of regulatory actions that this study recommends.

With regards to social dimensions, not mentioned by drivers, experts mostly discussed the topic of road safety on several levels: as a mitigable risk stemming from more silent EVs or as the opportunity to improve the safety situation via electrification projects, for instance by training drivers or by better implementing existing regulatory requirements, even though these endeavours are at a very nascent, conceptual phase. By contrast, impacts on self-regulation by boda drivers, for instance at the stage, or the opportunity to create an integrated transport network via electric mobility projects were given little thought. Possible rebound effects were rated as the third highest risk, also a significant sustainability variable identified in electrification literature, and discussed in terms of possible increase of supply or demand for boda boda services, nonetheless in reaction to a corresponding variable listed in the questionnaire that the majority of interviewees did not initially understand, not as a topic spontaneously brought to discussion by interviewees.

While the research mainly focused on investigating anticipated impacts through the triple sustainability lens, it also identified key feasibility elements as perceived by drivers and experts. Some significant facilitators are the promise for economic gains and reduction in fuel import expenses, the existing standards and reduction of import duties for electric vehicles. Beyond these main facilitators perceived by experts, the survey with boda boda drivers and the analysis of the local context showed how the emergence of new business and infrastructure models shifting the high upfront investment cost from the driver to the company leasing batteries, but also the predominantly spatially limited daily distances and the centrality of the waiting stand or stage where charging or swapping stations could be installed, could play a key role in facilitating the emergence of electric boda bodas. With regards to barriers, a combination of classical obstacles from the literature could be found in the specific case of Nairobi, such as initial investment costs in vehicles and infrastructure, however depending on implementation models chosen, together with specific local barriers such as occasional rural drives outside of Nairobi requiring additional power or charging options.

As an applied research, this study ends on a set of policy recommendations seeking to improve the sustainability footprint of a transition to electric motorcycles taxis in Nairobi. These recommendations address the relevance to financially support some innovative models, to bundle electric mobility and safety, ways to minimize risks of rebound effects, the value to promote intermodal integration, the thorough design of batteries end-of-life management, the need to accompany employment transformations and to involve boda boda drivers in the electrification process, as well as the recommendation to take a holistic and cross-cutting approach, also between different levels of public administration.

This research intended to contribute to ongoing debates on forms and consequences of electrification projects by looking at a specific case study. It emphasized the need to look at local conditions and specific modes. Based on its findings, it appears necessary to continue deepening understandings of processes at stake by conducting longitudinal research works on electrification projects in the East-African region, examining over time the real transformations incurred. This study shows the theoretical transformative impacts electric mobility may have on informal transport modes in Sub-Saharan Africa, which is worth further investigation.

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List of Figures (sources)

Figure 1: Research framework: Sustainability Assessment (SA) of electric motorcycles in Nairobi (own figure)

Figure 2: Three-pronged review of academic literature (own figure)

Figure 3: Annual new vehicles registrations between 1968 and 2017

Ogot, M., Nyang'aya, J., Muriuki, R. (2018): *Characteristics of the in-service vehicle fleet in Kenya*. GIZ. https://www.changing-transport.org/wp-content/uploads/Characteristics_of_the_In-Service_vehicle_fleet_in_Kenya.pdf, accessed 15.11.2019, p.5

Figure 4: Registration of motorcycles, 2005–2017 and forecasts up to 2030

EPRA, UNEP (2020): *Combined Reports on the Development of Electric Mobility Policies in Kenya. Integrating Electric 2 and 3 Wheelers into existing Urban Transport Modes in Kenya* [Unpublished]. EPRA, UN Environment, IKI, p.9

Figure 5: Electric mobility in Kenya: policies, projects and recommendations

(own representation based on Government of Kenya 2018a, pp.62,66 and 2018b, pp.96,101; EFRPA and UNEP 2020, pp. viii, 63; Notter et al 2018, p.16; The Kenya Gazette 2018, p. 3753; Mbugua 2019, n.p.; Otuki 2019, n.p.; Wachira 2019, n.p.)

Figure 6: Evolution of modal split in Nairobi between 2004 and 2013 (% of person trips; p.p.: percentage points) (own representation and calculation based on NCC 2014b, p.7-12)

Figure 7: Drivers survey: locations of questionnaire administration (own representation based on Open Street Map)

Figure 8: Boda boda drivers waiting at an unpaved stage localized at the Taj Mall Roundabout, in the industrial area of Embakasi (own picture, 17.12.2019)

Figure 9: Paved stage with a shed under the Northern Bypass in the high-income residential area of Runda (own picture, 16.12.2019)

Figure 10: Data on drivers' gender, age, education (in %) (own figure)

Figure 11: Drivers knowledge of electric motorcycles (in %) (own figure)

Figure 12: Drivers perceptions of opportunities related to electric motorcycles (in %) (own figure)

Figure 13: Drivers perceptions of O&M costs of electric motorcycles (in %) (own figure)

Figure 14: Drivers' perceptions of risks related to electric motorcycles (in %) (own figure)

Figure 15: Identified and interviewed expert stakeholders (own figure)

Figure 16: Occurrences of sustainability codes from the semi-structured interviews (own figure)

Figure 17: Impacts: opportunities as rated on average by experts (own figure)

Figure 18: Impacts: risks as rated on average by experts (own figure)

Figure 19: Feasibility: facilitators as rated on average by experts (own figure)

Figure 20: Feasibility: barriers as rated on average by experts (own figure)

Figure 21: Experts positions on an impact and activity scale (own figure)

Annex 1 – Questionnaire administrated to boda boda drivers

I (name), student at (university department) collect data for a research study looking at possible introduction of electric motorcycles in Kenya and Nairobi, following similar projects in Kigali, Kampala, Kisumu.

The results of this study will help better understand the conditions in which boda bodas currently operate, identify perceptions of boda bodas drivers on electric motorcycles, and identify how electric mobility could impact your operating conditions.

This questionnaire takes around 10 min. Your identify and information will stay **strictly confidential and anonymous**. Thank you very much for contributing to it!

Place of survey:

Date of survey:

Time of survey:

Survey number (Number + name, e.g. 01Emilie):

1. Gender

Tick only one box

- Female
 Male

2. How old are you?

Tick only one box

- Under 18 years old
 18 to 24
 25 to 29
 30 to 34
 35 to 40
 41 to 50
 50 and above

3. What is your highest education level? Tick

only one box

- Primary
 Secondary
 College/university
 Vocational/professional training

4. What is the motorcycle brand?

- Bajaj Boxer X150
 Bajaj Boxer 100
 TVS HLX 150
 TVS Start 125
 TVS Star LX100
 King Bird 150
 Hero Dawn 125
 Hero Dawn 100
 Yamaha Crux 106
 Yamaha Crux Rev 110
 Evalast Kuga 150
 Suzuki GT 125
 Suzuki EN 125
 Suzuki GD 110
 Suzuki Hayate GE100
 UM MAX XL125
 Nami CG 125
 Other (Name + CC capacity):

5. Are you the owner or driver of the motorcycle?

Tick only one box

- Driver only
 Owner and driver

Go to question 9

Go to question 10

6. If you are the driver only:

6.a. Do you know how old is the motorcycle?

- Yes:Years
 No

6.b. How long motorcycles last in general?

.....Years

6.c. Do you know if the motorcycle was bought:

- New
 Second-hand
 No information

6.d. How much do you pay to rent the motorbike? (Ksh.) Fill only one case

| Per day | Per week | Per month | Per year |
|---------|----------|-----------|----------|
| | | | |

6.e. Do you have a written agreement with the owner?

- Yes
 No

6.f. Do you have an agreement with the owner that the motorbike will belong to you after a certain amount of time?

- Yes
 No

If yes, after how many months?

.....months

7. If you are both owner and driver:

7.a. Why did you choose this brand?

| |
|--|
| |
|--|

7.b. Did you buy the motorcycle:

(tick only one box)

- new
 second-hand? 7.c. How old was it when you bought it 2nd hand?
..... years

7.d. How old is the motorcycle now?

.....years

7.e. How long motorcycles last in general?

.....years

7.f. How much did you pay for the motorbike? (Ksh.)

.....

7.g. How did you finance the investment?
(multiple choices possible)

- Own resources
 Loan from a cooperative. Name:
.....
 Loan from a bank. Name:
.....
 Relatives and friends

7.h. How much do you pay in loan repayment? (Fill only ONE case, Ksh.)

| Per day | Per week | Per month | Per year |
|---------|----------|-----------|----------|
| | | | |

Perception of electric motorcycles

8. Have you heard of electric motorcycles?

- Yes
- No

If yes, where did you hear it about?

- Friends and acquaintance
- Internet
- Social media, e.g. Facebook
- Newspaper
- Television
- Motorcycle's owner
- Other:

9. Do you think electric motorcycles are cheaper or more expensive to operate than conventional motorbikes?

- Cheaper
- Same costs
- More expensive
- No opinion

Possible comments on costs:

10. Do you think electric motorcycles can improve your business?

- Yes
- No
- No opinion

In what way? (free answer)

11. Do you think electric motorcycles can have negative impacts on your business?

- Yes
- No
- No opinion

Details (free answer)

Geographical aspects

12. Living place

12.a. In which neighbourhood do you live?

Information remains confidential

.....

12.b. Do you have access to electricity at home?

- Yes, with Kenya Power
- Yes, other type of connection than Kenya Power electricity network
- No

13. Stage/stand

13.a. Are you waiting for customers at a "stage"/stand?

- Yes
- No

13.b. If yes, where is stage located?

13.c. How many drivers wait at this stage in average?

.....

13.d. After dropping a client, do you go back to the stage?

- Yes
- No

14. Where do you park your motorcycle at night?

- At home

- At another place: Where?

If you pay to park elsewhere at night, how much do you pay? (Khs)

.....

15. How many customers do you have on average per day?

- Less than 5
- 5 to 9
- 10 to 14
- 15 and more

16. Please indicate us:

Frequent trip starting point:

Frequent trip ending point(s):

17. How many kilometers do you drive every day?

.....km

18. How much do you pay for fuel? Only fill one of the two boxes

| Per day | Per week |
|---------|----------|
| | |

19. Do you sometimes drive longer distances, e.g. to reach rural areas?

- Yes
- No

If yes, where:

How frequently:

| Per day | Per week | Per month |
|---------|----------|-----------|
| | | |

Financial aspects

Revenues

| | Per day | Per week | Per month | Per year |
|--|---------|----------|-----------|----------|
| 20. How much money do you earn from customers, before any other expenses? (Ksh.) Only ONE box to tick (choose) | | | | |
| 21. Do you receive money to put advertisement on your safety vest: (information will remain confidential) Type of advertisement: How much do you receive for it? (Ksh) | | | | |

Expenses

| | | | | |
|---|---------|----------|-----------|----------|
| 22. How high are your expenses? (Ksh.) Nb. Rent/loan, fuel already informed | Per day | Per week | Per month | Per year |
| Maintenance of the motorbike e.g. oil (how often?.....) | | | | |
| Servicing (how often?.....) | | | | |
| Fines/bribes from the police | | | | |
| Driving license | | | | |
| Insurance (e.g. Public Service Vehicle insurance, 3 rd party insurance) | | | | |
| Fee to belong to the stage | | | | |
| Fee to belong to a SACCO | | | | |
| Any other payment Detail:..... | | | | |

Institutional aspects/safety

- 23. Is your stage/stand organised in a formal association, e.g. parking association?**
- Yes
 No
- 24. What kind of services does the stage/stand offer?**
- Savings scheme
 Small loans
 Set internal rules and resolve possible conflicts between drivers
 Others:
- Possible further details (free answer)
- 25. Do you belong to a SACCO?**
- Yes
 No
- If yes, what is its name?
- 26. Services offered by the SACCO?**
- Organise road safety training
 Setting fares
 Setting internal rules
 Representation of the interests of boda bodas drivers
 Others:
- 27. Are you organised in any other kind of association related to your job?**
- 28. Are you using a ride-hailing app? (multiple ticks possible)**
- Yes:
 Uber
 Bolt
 Safe Boda
 Others:
- No
- 29. Do you have a driving license?**
- Yes
 No
- 30. Did you receive training to drive motorbikes?**
- Yes
 No
- 31. If you receive driving training, which organisation trained you?**
- 32. If yes, how long lasted the training? (only tick one box)**
- | | | |
|----------------------|----------------------|----------------------|
| Day(s) | Week(s) | Month(s) |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
- 33. Did you ever have any accidents?**
- Yes. How many:
- No
- Do you have ideas on how safety could be improved? (free answer)

Annex 2 – Sustainability Assessment

| Impacts: Opportunities | Sust. Impacts |
|--|---------------|
| Climate change mitigation through the reduction of fossil fuel consumption and GHG emissions. <i>Sources: academic literature</i> According to the Asian Development Bank (ADB) (2009, p.vi), electric scooters can nearly halve the emissions caused by conventional motorcycles, a figure also found by Koossalapeerom et al (2019 p.619) in the city of Khon Kaen (Thailand). This decrease was estimated to up to 66% in the case of Macao by Mou et al 2013 (p.9). For freight services, Gota (2018, p.12) calculates a reduction from 4300 to 900 gCO2/t-km when switching from an ICE two-wheeler to an electric one. In the case of Vietnam, ADB (2017, p.54) identified that increasing sales of E2Ws is one of the two measures having the strongest mitigation potential for the transport sector. For India, Dhar et al 2016 (p.144) estimate that nearly all two-wheelers need to become electric to stay within a 2-degree scenario. Further mentions of climate change mitigation without emissions calculation can be found in Bakker et al (2019, p.1), Suatmadi et al (2019, p.228), Bakker (2018, p.102); Black et al (2018, p.1); Wahab and Jiang (2019, pp.22-23), Eccarius and Lu (2020, p.1), Jones et al (2013, p.2). | Environmental |
| Reduction of air pollutants in cities and associated health hazards. <i>Sources: academic literature</i> The absence of tailpipe emissions from electric motorcycles tackles the growing and severe issue of air pollution (Dhar et al 2016, p.148, Kerdlap and Gheewala 2016, p.1399, Gota 2018, p.21, Bakker 2018, p.102. Jones et al 2013, p.2). The amount of nitrogen oxides, particular matter 10 and carbon monoxide is reduced, while those of sulfur dioxide and particulate matter 2.5 depends on electricity generation (Asian Development Bank 2009, p.vi, Weiss et al 2015, p.354). Yet, a part of emissions and associated health issues are delocalized from cities to remote areas for the production of electricity and batteries (Weiss et al 2015, p.352, Dhar et al 2016, p.145). | Environmental |
| Reduced operational and maintenance (O&M) costs <i>Sources: academic literature, press</i> Systematic conclusion may be difficult to draw on O&M cost advantages as these depend on local electricity and fuel prices. However, a couple of studies identify lower O&M costs and maintenance needs for E2Ws (Kerdlap and Gheewala 2016, p.1399, Black et al 2018, p.2, Ching 2013, p.3). Resulting from higher upfront investment costs but lower O&M costs, Ching (2013, p.5) calculates a break-even point after 14 months. However, Weiss et al 2015 (p.356) and Wahab and Jiang 2019 (pp.24-25) seem less conclusive on an O&M cost advantage. In Uganda and Rwanda, companies launching electric motorcycles using swappable batteries claim to halve O&M costs (Szentpetery-Kessler (2019, n.p.). | Economic |
| Reduced noise levels <i>Sources: academic literature</i> Several studies identify an opportunity to reduce noise levels (Kerdlap and Gheewala 2016, p.1409, Weiss et al, p.348, 357, Bakker 2018, p.102, Black et al 2018, p.1). Sheng et al (2016, p.73) specify that this impact is felt only in cities having a significant modal share for motorcycles. | Environmental |
| National energy security <i>Sources: academic literature</i> Reducing dependency on fuel imports and related financial expenses is a recurrently cited opportunity (Bakker 2018, p.102, Dhar et al 2016, p.140, Black et al 2018, p.2). | Economic |

Possible emergence of a national manufacturing industry

Economic

Sources: academic literature

This benefit can be achieved if electric motorcycles are produced locally rather than being imported (Black et al 2018, pp.2,3). Motorcycles production is seen as an easier entry segment than cars for instance, given the lesser numbers of parts, and a strategy having proven effective in Asia.

Job creation

Economic

Sources: academic literature

Introducing a new vehicle type requires additional jobs and technical skills, as well as training professionals on the use and maintenance of the vehicle, including repairs, and safe charging or swapping of batteries (Brown et al 2010, pp. 3803, 3805). This job creation aspect is stronger if a national manufacturing industry for the different motorcycle parts is developed as well (see above, Black et al 2018, pp.2,3). It could range from mechanics providing low-scale occasional repairs to electric engineers.

Development of solar off-grid energyEnvironmental
and economic*Sources: local context, author's hypothesis tested with experts*

The projects WeTu - electric cargo bike in Western Kenya – and E-Solar cycles – cargo tricycles being tested in Nairobi – both use off-grid solar energy. Net metering for small solar energy production has recently been allowed. This hypothesis is meant to explore if solar energy could play a role in charging infrastructure for electric motorcycles.

Improved image of the boda bodas sector

Social

Sources: academic literature, author's hypothesis tested with experts

The introduction of a modern technology to a transport mode mostly seen as an archaic one, marked by perceived unruly operations and opposition to the State (Cervero, p.9, press) could improve perceptions and image of boda bodas.

Opportunities for renewed regulation of the boda bodas sector

Social

Sources: local context, author's hypothesis tested with experts

To be successfully implemented, policies supporting the transition of boda bodas are likely to require discussions between public authorities, companies and representative organisations of motorcycles drivers and owners, i.e. SACCOS and stage associations. Current regulation of the access to Nairobi city center could be renewed, as well as the current regulatory framework around safety requirements. In addition, driving and training could be addressed through sensibilization on EV safety.

Opportunities to build an integrated transport network

Social

Sources: academic literature

Eccarius and Lu (2020, p.1) and Gota (2018, p.28) both consider that E2Ws can participate in the creation of a more sustainable urban system, when planned in integration with other transport modes. This could be the case for instance with charging or swapping stations strategically located at connections with mass transit.

Secondary use of batteries for the electricity grid

Economic

Sources: academic literature

Dhar et al (2018, p.426) indicate that using the vehicle batteries may help stabilising the electricity network (vehicle-to-grid).

Reduction of other health issues linked with ICE tailpipe

Social

Sources: academic literature

Risks of burn wounds are suppressed with the removal of the ICE motorcycle's external tailpipe (Eccarius and Lu 2020, p.11).

| Impacts: Risks | Sust. Impacts |
|--|------------------|
| Depletion and toxicity of batteries materials <i>Sources: academic literature, local context</i> | Environmental |
| These risks depend on the types of batteries, lead acid or lithium-ion -the latter viewed as more environmentally sustainable by Weiss et al (2015, p.358) and Gota (2018, p.29)- , the existence of efficient battery production, recycling chains, end-of-life management and corresponding institutions (Brown et al 2010, p.3801, Kerdlap and Gheewala 2016, p. 1403). Toxicity of li-ion batteries may be nearly fully avoided through recycling (<i>ibid</i>). Recycling of Waste Electrical and Electronic Equipment (WEEE) proved to be a significant issue in China (Weiss et al 2015, p.354). In Kenya, e-waste management is embryonic, mainly informal and characterised by insufficient awareness and regulatory framework (Otieno and Omwenga 2015, p.663-664) | |
| Sourcing of batteries materials <i>Sources: academic literature</i> | Economic |
| Securing the supply of batteries materials in the long-term, and the stability of related prices, might be a challenge (Dhar et al 2016, p.140). | |
| Jobs destruction related to conventional motorcycle related activities <i>Sources: drivers' survey, author's hypothesis tested with experts</i> | Economic |
| Current activities related to the purchase, operation and maintenance of ICE motorcycles, such as repair shops, spare parts, gearbox oil, but also importers and fuel stations, could be negatively impacted in the case of a strong uptake of electric mobility. However, this could take the form of an incremental change and be mitigated. | |
| Increased safety risks linked to the absence of noise <i>Sources: academic literature</i> | Social |
| Electric motorcycles, not producing ICE sounds, are often considered riskier when driven at limited speeds as they may be less easily detected by other vehicle drivers (Weiss et al 2015, p.357, Eccarius and Lu 2020, p.11, Gota 2018, p.28). However, this seems less relevant at higher speeds and could be mitigated through added sound (Eccarius and Lu 2020, p.11). | |
| Uncertainties over safe operations of electric motorcycles <i>Sources: academic literature, local context</i> | Social |
| Lithium-ion batteries are characterised by a high energy density, raising questions of safety and fire accidents, especially in case of inappropriate use of batteries or road crashes (Feng et al 2018, pp.263-264, Brown et al 2010, p.3805). In a current context of lacking implementation of driving and safety requirements, it may be arduous to implement safety sensibilization programmes on the use of e-vehicles and batteries. Existence of standards, trained technicians and proper charging and use of batteries are key aspects in that respect. | |
| Rebound effects as induced demand for motorcycle taxi operation <i>Sources: author's hypothesis tested with experts</i> | Socio – economic |
| Increased number of people intending to provide boda bodas services or to use them may arise as an unexpected consequence of policies supporting electric motorcycles and increasing attractivity of the mode. On could also hypothesize that strategies focusing on providing new electric motorcycles rather than retrofitting existing ones could lead to an increase in vehicles number. | |

Feasibility: Facilitators

Reduction of fuel import expenses (macro-economic level)

Sources: academic literature

Decreasing dependency on fuel imports and related expenses, and sparing foreign exchange, is a recurrently cited potential driver for electric mobility uptake (Bakker 2018, p.102, Dhar et al 2016, p.140, Black et al 2018, p.2, Wachira 2019, n.p.). In 2018, imports of fuel represented 327.8 billion KES (circa 2.90 billion EUR), representing 62.6 billion more than in 2017 (KNBS 2019a, p.147).

Potential savings for informal transport operators (micro-economic level)

Sources: local context, boda boda drivers' survey

In Uganda and Rwanda, companies launching electric motorcycles using swapping systems claim to enable a reduction by half or more of O&M costs (Szentpetery-Kessler 2019, n.p.). The boda boda drivers' survey showed that they mostly identified economic gains related to savings in fuels and gearbox oil.

Potential to increase on-grid electricity demand

Sources: local context

Increasing electricity demand may help tackle the issue of grid overcapacity in Kenya that has negative financial consequences (Kamau 2019, n.p., Muchira 2019, n.p., KNBS 2019a, p.147)

Stage-centric boda drives and limited urban daily distances

Sources: boda boda drivers' survey

The survey identified a centrality of the stage, as 98% of drivers wait there and 88% return there after a trip. The majority (57%) are active within the neighborhood, and 25% in extended neighborhood. Short distances, revolving around the stage, may help initiate electric infrastructure projects at this location.

National policies on climate change and industry policy

Sources: local context

Kenya's National Climate Change Action Plan for the period 2018-2022 includes the promotion of electric mobility (Government of Kenya 2018, p 62, 66). Electric mobility also fits within the national focus on industry development as one of the four biggest political priorities ("Big 4 Agenda").

Existence of alternative off-grid models

Sources: local context

Off-grid infrastructure and business models have gained traction in Kenya recently, with successful companies providing leasing for solar-panels and products such as M-Kopa Solar, the development of solar-powered e-mobility projects (WeTu, E-Solar cycle) and net metering recently allowed.

Existing standards and tax reduction on EV vehicles

Sources: local context

Standards on battery-electric motorcycles were adopted in 2018 (Authority of the Republic of Kenya 2018, p.59, and the excise tax for the imports of electric vehicles reduced from 20% to 10% in 2019.

Existence of located embryonic boda self-regulation

Sources: academic literature, boda boda drivers' survey, author's hypothesis tested with experts

The existence of more institutionalized stages may ease local implementation of charging stations.

Feedback from East-African projects

Sources: local context

Electric motorcycles have been launched in 2019 or are in a commercial phase in Uganda, Rwanda, Kenya and Nigeria at least. Feedback from these projects could facilitate uptake in Nairobi, along with the fact that these projects are mostly driven by the private sector.

Existence of an electronic waste recycling plant

Sources: local context

The WEEE centers collects, separates and reassemble electric components to build battery packs (Mbithi and Moraa 2019, n.p.). This could support a scenario similar to the Bodawerk electric motorcycle found in Uganda, using second-hand components for the motorcycle batteries (Kuhudzai 2019a, n.p.).

Feasibility: Barriers

High upfront investment costs

Sources: academic literature

High purchase prices for electric vehicles are classically identified as one of the most significant barriers (Wahab and Jiang 2019, pp.24-25, Rezvani et al 2015, p.129). This is even more the case for vehicles using Li-ion batteries instead of lead-acid ones. Kerdlap and Gheewala (2016, p.1406) evaluate upfront investment costs to acquire electric motorcycles using Li-ion batteries at 80% of the total costs, versus only 36% for those using lead-acid batteries and 26% for conventional motorcycles. This adds to a context of limited financial resources available to informal transport operators to undertake investments (Cervero and Golub 2007, p.448).

Lack of demand and negative perceptions on e-mobility

Sources: academic literature, boda boda drivers' survey

Black et al (2018, p.1-2) identified very low demand levels for electric motorcycles in Sub-Saharan Africa, in a context of low-motorisation. Additionally, demand may be limited as a result of negative perceptions of electric vehicles, classically of perceived limited range allowed by these vehicles or charging inconvenience (Wahab and Jiang 2019, pp.25-26, Feng et al 2018, p.246, Rezvani et al 2015, p.129, Eccarius and Lu 2020, p.11). The boda boda drivers' survey found out that 25% of drivers associated electric motorcycles with negative characteristics, mostly having a technical aspect such as range anxiety, lack of power, charging inconvenience etc. In addition, feedback from other projects implemented in East-Africa is still limited.

Maintenance-related issues, e.g. spare parts and repairs skills

Sources: boda boda drivers' survey

Among the 25% drivers associating electric motorcycles with negative impacts, 2 expressed a fear of lacking spare parts and adequate repair skills. During informal discussions that followed the survey administration, driven often raised this aspect.

Possibly needed network of charging or swapping stations

Sources: academic literature, boda boda drivers' survey

The feasibility to charge e2W batteries at home- e.g. that can be removed from the vehicle - is mentioned in academic sources as facilitating the uptake of these vehicles, in contrast with other electric vehicles such as cars that necessitate a charging infrastructure network (e.g. Eccarius and Lu 2020, p.10, Kerdlap and Gheewala 2016, p.1399, Longo 2016, p.7). However, home charging requires connection to the electric utility grid, which is not provided in 19% of Kenyan urban areas (IEA, IRENA, UNSD, WB, WHO 2019, p.25). With regards to this research's survey, 96% of boda boda drivers stated to legally have access to the Kenya Power electricity grid, yet this is to be considered with specific caution given documented difficulties to access to electricity in some Nairobi informal settlements (Corburn et al 2012, p.34) and a possible bias in answers. Therefore, electrifying motorcycle taxis in Kenya may require the development of charging or swapping stations. Projects in Kampala and Kigali have opted for swapping stations. Developing a sufficient number of these stations to reduce range anxiety and ease operations may be a barrier in terms of financial resources, speed of implementation, availability of public or private space (Wahab and Jiang 2019, p.25, Eccarius and Lu 2020, pp.11-12)

Resistance of sectors at risk of job destruction

Sources: boda boda drivers' survey, author's hypothesis tested with experts

The survey showed how current ICE motorcycle operations are intertwined with following economic activities: fuel provision at fuel stations, regular use of gearbox oil, occasional repairs. If not participating in the transition, actors involved in these activities may resist electrification as a threat to their sources of revenues.

Public bodies reluctant to decreasing fuel taxes revenues

Sources: local context, author's hypothesis tested with experts

Kenya belongs to the category of countries taxing gasoline and diesel rather than subsidizing them (GIZ 2019, pp.2-3). Nine taxes are applied on fuel (Ilako 2019, n.p.). A significant uptake of electric vehicles would reduce fuel consumption and thus public revenues from fuel taxes, possibly leading public authorities to resist this transition in a context of limited public financial resources (Wachira 2019, n.p.).

Issue of charging for occasional rural drives

Sources: boda boda drivers' survey

Resulting from an urban-rural permeability, 39% of drivers stated to use their motorcycle for occasional drives outside of the core urban Nairobi. Some drive to neighboring towns 51 to 100 kms from Nairobi (9 drivers) but some to more remote destinations, further than 150 kms away from the capital (14 drivers). These further trips would require additional power or charging options. Not integrating these aspects in projects could hinder acceptance by drivers.

Current and upcoming limitations of the electric utility grid

Sources: academic literature, local context

Black et al (2018, p.2) identify an issue of “reliability and cost of electricity” in Sub-Saharan Africa. In 2017, Kenya experienced circa 1.2 disruptions per week, however amounting to a short duration of 0.3 minutes per week (IEA, IRENA, UNSD, WB, WHO 2019, p.31). In addition, hydropower that amounted to 36% of electricity generation in 2018 in Kenya (KNBS 2019a, p.153) is highly sensitive to climate change, raising questions on the future reliability of the grid (Notter et al 2018, p.24). In addition, electricity prices vary according to climatic conditions and impacts on hydropower plants, for instance in the case of droughts or massive rains (Okoth 2019a, n.p., Okoth 2019b, n.p.).

Complex governance of e-mobility involving a significant number of players, in a context of limited boda bodas regulation

Sources: academic literature, local context, boda boda drivers' survey

E-mobility projects operate at the boundary between transport and energy, requiring the involvement of an important number of stakeholders active in the e-mobility “value chain” composed of three components: vehicles, charging and network (Van der Steen et al 2015, p.34). Browne et al (2012, pp.148,150) identify the need for broad partnerships between stakeholders including manufacturers, operators, importers and consumers as one of supporting e-mobility policies.

On top of that, zooming into the current boda boda organisational structure reveals that institutionalization is embryonic. 42% of interviewed drivers have not set up a formal stage association and the same amount are not part of a SACCO, despite this being a mandatory requirement.

Limited public room for maneuver to provide financial incentives

Sources: academic literature

Black et al (2018, p.1) identify “fiscal constraints faced by African countries”. In this context, Kenyan public institutions may have limited resources to provide financial incentives.

Annex 3 – Questionnaire administrated to experts

Transition of boda bodas to e-mobility in Nairobi
 Assessment of opportunities, risks, facilitators, barriers

Q1: Possible benefits of a transition to electric boda bodas in Nairobi.

In your opinion, would a transition to e-bodas have a limited or strong impact on the aspects listed below? (tick one box per line)

| | Impact | | | | | No opinion |
|--|--------|---|---|---|------|------------|
| | Low | 1 | 2 | 3 | High | |
| 0 | | | | | | |
| Climate change mitigation (reduction of fossil fuel consumption and GHG emissions) | | | | | | |
| Reduction of air pollutants in cities and associated health hazards | | | | | | |
| Reduction of maintenance and operation costs of e-motorcycles in comparison with conventional engines | | | | | | |
| Reduction of noise levels | | | | | | |
| National energy security (less fuel imports) | | | | | | |
| Possible emergence of a national e-motorcycle manufacturing industry | | | | | | |
| Job creation , e.g. technical skills, repair | | | | | | |
| Development of off-grid solar energy | | | | | | |
| Improved image of the boda bodas sector | | | | | | |
| Renewed regulation of the boda bodas sector | | | | | | |
| Building an integrated transport network | | | | | | |
| Use of e-motorcycle batteries for the electricity grid (vehicle-to-grid) | | | | | | |
| Reduction of other health issues such as wounds from conventional motorcycles' tailpipe | | | | | | |
| Other(s): | | | | | | |

Q2: Possible risks of a transition to electric boda bodas in Nairobi.

In your opinion, would a transition to e-bodas have a limited or strong impact on the aspects listed below? (tick one box per line)

| | Impact | | | | | No opinion |
|---|--------|---|---|---|------|---------------|
| | Low | 1 | 2 | 3 | High | |
| 0 | | | | | | |
| Depletion and toxicity of batteries materials , context of nascent e-waste management | | | | | | |
| Uncertainty over supply of batteries materials | | | | | | |
| Jobs destruction related to conventional motorcycle related activities, e.g. fuel, gearbox oil | | | | | | |
| Increased safety risks linked to the absence of noise | | | | | | |
| Uncertainties over safe operations of electric motorcycles and batteries, e.g. fire | | | | | | |
| Induced demand for motorcycle taxi operation | | | | | | |
| Other(s): | | | | | | |

Q3: Possible facilitators of a transition to electric boda bodas in Nairobi.

In your opinion, would the following aspects play a limited or strong role in the transition?
(tick one box per line)

| | Role | | | | | No opinion |
|---|------|---|---|---|------|---------------|
| | Low | 1 | 2 | 3 | High | |
| 0 | | | | | | |
| Reduction of fuel import expenses (macro-economic level, foreign exchange) | | | | | | |
| Possible savings for informal transport operators (micro-economic level) | | | | | | |
| Potential to raise electricity demand to face current issue of grid overcapacity | | | | | | |
| Stage-centric boda drives and limited urban daily distances | | | | | | |
| National level: respect of climate change national commitments , focus on industry development in the “big 4” agenda | | | | | | |
| Existing alternative off-grid models in Kenya, i.e. solar energy | | | | | | |
| Existing standards and tax reduction on EV vehicles | | | | | | |
| Existence of embryonic boda self-regulation , at stage and SACCO levels | | | | | | |
| Feedback from East-African projects , privately initiated | | | | | | |
| Existing e-waste recycling plant | | | | | | |
| Other(s):..... | | | | | | |

Q4: Possible barriers of a transition to electric boda bodas in Nairobi.

In your opinion, would the following aspects play a limited or strong role in the transition?
 (tick one box per line)

| | Role | | | | | No opinion |
|---|------|---|---|---|------|---------------|
| | Low | 1 | 2 | 3 | High | |
| 0 | | | | | | |
| High upfront investment cost | | | | | | |
| Lack of demand and negative perceptions on e-mobility, e.g. range anxiety, charging inconvenience | | | | | | |
| Maintenance-related issues , e.g. spare parts and repairs skills | | | | | | |
| Costs and speed of implementation of a possibly needed charging or swapping stations network | | | | | | |
| Resistance of sectors at risk of job destruction | | | | | | |
| Public bodies reluctant to decreasing fuel taxes revenues | | | | | | |
| Issue of charging for occasional rural drives | | | | | | |
| Current and upcoming limitations of the electric utility grid | | | | | | |
| Complex governance of e-mobility involving a significant number of stakeholders, in a context of limited boda bodas regulation | | | | | | |
| Limited room for manoeuvre for public authorities to provide financial incentives , other financial barriers | | | | | | |
| Insufficient policy and regulatory framework | | | | | | |
| Lengthy administrative approval processes | | | | | | |
| Other(s): | | | | | | |

Annex 4 – List of experts interviewed

| Organisation | Interviewees | Date |
|--|--------------|------------|
| UNEP | One | 14.01.2020 |
| European donor agency | Three | 15.01.2020 |
| WEEE Center | One | 16.01.2020 |
| Start-up A | One | 16.01.2020 |
| ITDP | One | 20.01.2020 |
| Former M-Kopa employee | One | 20.01.2020 |
| Agent affiliated with Nairobi City County Government | One | 24.01.2020 |
| Boda boda association BAK | One | 27.01.2020 |
| Uber | One | 29.01.2020 |
| Incubator C4D Lab | One | 31.01.2020 |
| Union BOTTAX | One | 04.02.2020 |
| Transport Ministry MoTIHUD | One | 31.01.2020 |
| Start-up B | Three | 17.02.2020 |
| Sustainable Transport Africa | Two | 18.02.2020 |
| Mechanical engineering professor | One | 24.02.2020 |
| Flone Initiative | One | 25.02.2020 |
| Urban planner | One | 27.02.2020 |
| Urban development professor | One | 02.03.2020 |