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Motorcycle taxis in transition? Review of digitalization and electrification trends in selected East African capital cities

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ABSTRACT

The number of motorcycle taxis has soared in East African cities over the last decades, filling a gap in mobility needs while providing revenue opportunities to drivers. However, poor road safety combined with contribution to carbon emissions and air pollution creates a sustainability conundrum, which has led governments to control or repress the mode, yet without much success. After reviewing the characteristics and regulation of motorcycle taxis in Nairobi, Kigali, and Kampala, this study investigates the existence and impacts of two recent trends: digitalization and electrification. A comprehensive approach is adopted with a systematic review of the literature and policies, completed by field research and key informant interviews. We find out that electrification is mostly associated with positive impacts covering a spectrum of environment, economics, health, and social-related benefits, while the benefits of digitalization are more uncertain or contested. Impacts are however limited for both at the time of study as digitalization is highly volatile and electrification nascent. In conclusion, the paper identifies an interlinkage between the trends via the example of data, and further key research needs.

1. Introduction

Sub-Saharan African cities experience unique mobility patterns characterized by low motorization rates, a dominant and by-default reliance on walking, and collective transportation mostly offered by self-organized paratransit modes. Car ownership rates are still low yet rising, especially in large and capital cities. Within this geographical context, the widespread use of two-wheelers as commercial means of transport (hereafter motorcycle taxis), represents a further salient characteristic.

Motorcycle taxis have soared on the African continent over the last decades (Baffi et al., 2021; Black et al., 2018; Diaz Olvera et al., 2012, 2020; Ehebrecht, 2020; Ehebrecht et al., 2018; Kumar, 2011; Sietchiping et al., 2012). They have become a "major public transport mode" (Diaz Olvera et al., 2012) and "an integral part" of urban mobility in numerous African cities and rural areas (Sietchiping et al., 2012). There are multiple reasons for their expansion, which can be grouped in two categories of "pull" and "push" factors. "Pull" factors attracting urban dwellers towards moto-taxis include: rising mobility needs driven by fast urbanization and population growth; increased availability of motorcycles via globalized supply chains; attractivity stemming from the provision of door-to-door services and the ability to access rugged terrains; perceived affordability of moto-taxi services; self-employment opportunities; all taking place in a loosely regulated environment (Kumar, 2011; Martin, 2020). "Push" factors encompass the lack of sufficient public transport services by buses creating mobility and accessibility gaps, coupled with the combination of urban sprawl, rising congestion, poor road infrastructure conditions, and deficient quality of bus services (Kumar, 2011; Martin, 2020; Pirie, 2014). The numbers of transport providers of two- and three-wheelers increase as there are fewer entry barriers compared with larger vehicles (Diaz Olvera et al., 2020). Growing numbers of motorcycle taxis are not only observed in African cities: motorcycle taxis have been qualified as "the most rapidly growing form of informal transport services" in several parts of the globe, twenty years ago (Cervero, 2000). They are particularly present in Asian countries such as Vietnam, Sri Lanka, and China and in some Latin American countries, notably Brazil (Ehebrecht et al., 2018). In Sub-Saharan African cities, motorcycles are commonly used to ferry passengers or carry goods rather than solely for private mobility, in part due to the unaffordability of private vehicles (Kumar, 2011). This growth is not uniform on the continent: degrees of penetration and characteristics of motorcycle taxi fleets importantly vary between

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countries and rural/urban contexts (Black et al., 2018; Ehebrecht et al., 2018), with some particularly strong penetration in Nigeria, Niger, Cameroon, Benin, Uganda, Kenya, Rwanda, Angola, Ethiopia, Ghana, Togo, Tchad, and Tanzania (Baffi et al., 2021; Diaz Olvera et al., 2020; Ehebrecht et al., 2018; Kumar, 2011). In countries where motorcycle taxis have been present since the 1960s already, the expansion process has greatly accelerated in the last decade, triggered by factors such as the introduction of cheaper vehicles from Asia or more favorable tax regimes, for instance in Kenya (Ehebrecht et al., 2018). A double-edged approach towards motorcycle taxis in East Africa is often observed, considering the mode's benefits in terms of mobility, accessibility and employment, which coexist with significant negative externalities such as high accident and fatality rates, air pollution, greenhouse gas emissions, and alleged criminality. A "sustainability conundrum" is thus identified (Martin, 2021). This ambivalence has prompted several governments to attempt to control their operations, or to ban them, especially in city centers, although these bans are generally poorly enforced (Baffi et al., 2021; Graaf et al., 2021).

Concomitantly with this expansion, researchers observe an "exponentially" increasing number of studies in the last 15 years (Diaz Olvera et al., 2020; Ehebrecht et al., 2018) at a Sub-Saharan African (Baffi et al., 2021; Black et al., 2018; Diaz Olvera et al., 2020; Ehebrecht et al., 2018), at sub-regional level (Diaz Olvera et al., 2012; Ehebrecht, 2020), or at city levels (for instance: Diaz Olvera et al., 2016; Ehebrecht and Lenz, 2018; Evans et al., 2018; Goodfellow, 2015; Heinrichs et al., 2017; Ibrahim and Bize, 2018; Kemajou et al., 2019; Kisaalita and Sentogo-Kibalama, 2007; Kumar, 2011; Martin, 2021; Rollason, 2020; Rollason, 2017; Vanatta et al., 2022; Yi, 2016). Some mobilize the theoretical lenses of informal transport, criticized but still used in the "lack of a more appropriate universal term for the non-conventional modes of public transport in developing world cities" (Diaz Olvera et al., 2012), paratransit, popular transport, or "institutional or urban bricolage" to overcome the formal-informal dichotomy (Heinrichs et al., 2017). Despite increasing research, the lack of precise and up-to-date data collected by institutions at national, regional, or city levels hinders analyses of the mode on a more granular level. Several topics still need deeper analysis: vehicle ownership or leasing contracts, impact on poverty reduction, function and roles, accessibility enabled by this mode, environmental impacts, and digitalization (Ehebrecht et al., 2018).

In the East African region, the number of publications on motorcycle taxis is unequally distributed, with a higher number of studies found for Kampala than for Kigali or Nairobi. Moreover, data found in research, policy or planning documents frequently date back to the beginning of the 2010s in Kigali and in Nairobi. Findings may not be accurate anymore as the sector is evolving fast, in particular with regards to governance (e.g. the Uganda moto-taxi association Boda Boda 2010 mentioned in Ehebrecht, 2020 having ceased to exist). Several new policies have been enacted at the national or local level over the last four years (KCCA, 2020a; Ministry of Infrastructure, 2021; Ministry of Transport, Infrastructure, Housing and Urban Development, 2020; RURA, 2021a; RURA, 2018).

Finally, data and research about more recent evolutions are scarce, such as electrification and digitalization (Sovacool et al., 2022). In their overview of motorcycle taxis in Sub-Saharan Africa, Ehebrecht et al. (2018) identify that solutions to mitigate carbon emissions and air pollution, and digitalization in the form of mobile apps, are two key research gaps to address. Against the background of these research gaps, the objective of this study is to investigate *whether* and *how* digitalization and electrification affect motorcycle taxis in East African cities. The research focuses on digitalization and electrification based on two common criteria: first, these two trends are present in all studied cities; secondly, they have not been systematically analyzed yet from a regional perspective. More specifically, the research asks the following questions:

(1) to what extent are these two trends present in the cities, and with which characteristics?
(2) to what extent do they impact motorcycle taxi operations, both positively or negatively? If positive impacts are found, do they answer (parts of) the sustainability conundrum and improve the sustainability of this transport mode?

We narrowed down the analysis to three East African capital cities: Nairobi (Kenya), Kigali (Rwanda), and Kampala (Uganda). This selection was based on three factors: a large modal share of motorcycle taxis or a high degree of activity based on visual observations; the presence of the two trends; and the long-term residence of the co-authors in the cities to allow for continuous visual observations. We consider that taking a regional perspective is highly relevant in the light of cross-border phenomena such as digital or electrification companies operating in two of the three countries, the circulation of knowledge and exchange between researchers and practitioners in this geographical area, and lastly, the influence that some countries have on others, such as Kigali often portrayed as the "best practice" in the region (Rollason, 2020). This article does not aim to provide findings for the whole region since it does not include all capital cities of East African Community countries, nor secondary cities which may show different patterns.

2. Materials and methods

We adopted a successive approach starting with a systematic review of the literature, of policy and planning texts, followed by field observations, and completed by interviews with key informants (Table 1).

To identify the literature to review, we used the terminology of "motorcycle taxis", "moto-taxis", "boda bodas" on Google Scholar, Mendeley and ScienceDirect. This was enlarged to technical and policy reports in justified cases and in the aforementioned dearth of peer-reviewed analysis, followed by a review of laws, regulations, policies and planning documents. Findings from this two-pronged review were deepened through field observations and semi-structured interviews with key informants, selected on the ground of their expertise or involvement in motorcycle taxis in East Africa. A minimum number of 10 interviews per city was set, targeting a balanced diversity of experts affiliated with local or national public institutions, private companies, motorcycle taxi federations, international and local non-governmental organizations, as well as academic researchers and urban planners. Interviews were coded using the software ATLAS.ti; applying deductive coding following key thematical areas identified during the literature review and enriched with additional codes emerging during interviews. Codes were grouped into five main themes ("Existence", "Characteristics", "Impacts", "Intersection", and "Other trends" to identify dominant or recurrent narratives and statements.

An analytical framework was developed to analyze results from the data collected via the four methods, to analyze the temporality and typology of the three trends (Table 2). For the impact category, we build on Litman (2007) classification of "Economic", "Social", and

Table 1
Methods.

Step		Purpose
1. Review of literature	65 documents	Identification of existing research and gaps, characteristics of moto-taxis
2. Review of laws, regulations, policies, planning documents	20 documents	Identification of regulatory, digitalization and electrification requirements
3. Field research	February 2021-May 2022	Identification of operational characteristics and application of regulation
4. Semi-structured interviews with key informants	31 interviews, March -November 2021	Consolidation and critical assessment of literature review findings

Table 2
Analytical framework.

	Temporality	Typology
(1) Characteristics of trends Digitalization Electrification	Past, Present Planned	Two existence categories: - Formal: e.g. policy *enacted*, company set up - Real: e.g. policy *implemented*, company active
(2) Impacts of trends Digitalization Electrification	Observed (past; present) Hypothetical (future)	Five categories: - Health: air quality, road safety, personal security - Environment: carbon emissions, air quality - Economics: expenses, revenues, ownership - Social: image, accessibility - Efficiency: space use, congestion, integration with public transport

"Environmental" indicators, which we adapt to account for thematic focus areas critical to the operation of motorcycle taxis in Sub-Saharan Africa, as identified through the literature review: "Health" gathering aspects of air quality, road safety, personal security, and "Efficiency" addressing space use, congestion, integration with public transport.

3. Context

3.1. Characteristics of motorcycle taxi services in the selected cities

A first step is to identify data available on key characteristics of motorcycle taxis in the three cities. In Tables 3-5, we draw on the classification in supply and demand operated by Ehebrecht et al. (2018), while making minor adaptations or adding categories such as the number of drivers per city, trip purposes, and growth forecasts. The data found has, to the best of our knowledge, not been systematically compiled for these cities in previous research.

This data is marked by limitations: limited comparability due to different methodologies, lack of update of some data, issue of aggregated data (for instance in Nairobi, motorcycle taxis aggregated with bicycles for the modal share), limited quality of some data (for instance, median without information on the interquartile range or standard deviation; small sample sizes).

Despite these limitations, this data compilation enables a few observations. On one hand, we identify very similar perceptions of a perceived growth of the sector, as well as positive traits related to service functions of motorcycle taxis (speed, filling mobility gaps, accessibility, circumventing congestion). In the three cities, motorcycle taxis are recognized as providing public services or being part of the public transport system as per legal texts (Ministry of Transport, Infrastructure, Housing and Urban Development, 2020; RURA, 2018; Uganda Government, 2016). At the same time, a similar negative image is dominantly found in policy and planning documents: motorcycle taxis are associated with a plethora of flaws including, "crime, violence, accidents" (KCCA, 2014), "criminal activities", "air pollution and noise" (Ministry of Transport, Infrastructure, Housing and Urban Development, 2020), "potential negative externalities of moto and car taxis, including increased congestion, poor safety for NMT users, and pollution" (Ministry of Infrastructure, 2021). A focus on lacking road safety is found in all documents with special emphasis on motorcycle drivers, considered to "commonly break traffic laws" (Ministry of Transport, Infrastructure, Housing and Urban Development, 2020), criticized for "recklessness driving, drunkenness, violation of traffic lights, abuse of Zebra Crossings and dangerous maneuvers such as over-taking in hotspots" (Ministry of Infrastructure, 2021). In addition, similar characteristics are found regarding age and gender of drivers, fleet typology and ownership patterns.

By contrast, the extent of their presence in the three cities greatly

Table 3
Key characteristics – Supply side: drivers, fleet.

	Nairobi	Kigali	Kampala
Numbers of drivers: mostly dissimilar, limited comparability	No data found, minimum of 14,000 estimated by the motorcycle taxi federation (Martin, 2020)	High variation: from 12,383 (Spea Engineering & Logit, 2019) to an estimated 26,000 (Ashimwe, 2020), deemed too low (interview 12)	High variation: 50,000 (Sebaggala et al., 2014) to an estimation of 250,000 (Odwokacen, 2015)
Growth of drivers' numbers: similar, limited comparability	Stated but unquantified growth (EPRA and UNEP, 2020; NCC, 2014)	Growth since 2008 (Japan International Cooperation Agency, 2018; Rollason, 2017); expected moderate increase by 2050 (City of Kigali, 2020; Japan International Cooperation Agency, 2018)	Grown significantly since the late 1990 s; slowdown from 2013 to 2015
Age: mostly similar	Majority (61%) between 25 and 40 years old [8]; average of 36 years found by Minter (2021)	59% being 35 years old or younger (Thom et al., 2020); average 36 years old (Bishop and Courtright, 2022)	Average 32 years old (Muni et al., 2019), 33 years (Bishop and Courtright, 2022)
Gender: similar	All male in Martin (2020), Minter (2021)	All male in Thom et al. (2020)	All male in Kisaalita and Sentogo-Kibalama (2007)
Education level: limited comparability	58% with secondary education in Martin, (2020), versus 40% only in Minter (2021)	80% with up to primary school completed (Bishop and Courtright, 2022)	Average 8 years of education (Muni et al., 2019)
Working hours: limited comparability	No data found	Average 9.3 h/days, 5.8 days/week (Bishop and Courtright, 2022)	Average 12 h/day, 6 days/week (Muni et al., 2019)
Fleet: mostly similar	Concentration on Indian brands (Martin, 2020), Bajaj and TVS (Minter, 2021)	Mostly Indian brands, e.g. TVS (Farquharson, 2019)	Indian brands: 90% Bajaj, 5% TVS (Calzavara et al., 2021)
Ownership: mostly similar	81% of drivers owning the vehicle (Martin, 2020)	70% owning their vehicle in 2019 (Thom et al., 2020), 68% owning in 2022 (Bishop and Courtright, 2022), yet with practices of subletting motorcycles (Rollason, 2020)	63% owning or on path to ownership (Hatchile Consulting et al., 2020), up to 85% (Bishop and Courtright, 2022)
Revenue before expenses: limited comparability	Mean monthly 480 USD (Minter, 2021), consistent with median daily 15.6 USD found in Martin (2020)	Estimated monthly revenue range 240–480 USD (Thom et al., 2020)	305 USD Jan. 2023 (Courtright, 2023)
Income after expenses: limited comparability	*Daily* mean 8 USD subtracting all costs except vehicle leasing (Minter, 2021); daily median of 12.3 USD subtracting only fuel expenses (Martin, 2020)	Average *weekly* net income of USD 10.24 (Bishop and Courtright, 2022). Mean *daily* 1.60 USD as 11 USD subtracted for fuel and vehicle leasing costs (Ampersand Solar, 2022)	Average *daily* 4 USD in Jan 2023 (Courtright, 2023) and *weekly* mean of 23.5 USD in Oct. 2017 (Muni et al., 2019) and 21 USD in Oct. 2020 (Calzavara et al., 2021)

Table 4
Key characteristics – Supply side: trips.

	Nairobi	Kigali	Kampala
Modal share & traffic counts: mostly dissimilar, limited data comparability	Moto-taxis & bicycles jointly representing 5.4% of total motorized and non-motorized passenger trips in 2013 (latest data); motorcycles being 4.9% of vehicle counts (NCC, 2014)	16% of total passenger trips (Gouldson et al., 2018; Spea Engineering & Logit, 2019); 54% vehicle traffic counts (City of Kigali, 2020)	No recent data for passenger trips; motorcycles representing 42.4% of vehicle counts in the latest data collected in 2011 (Kitaka, 2011)
Distance per trip: similar in Nairobi and Kampala, not Kigali	2–3 kms for 57% of drivers; mostly trips in the neighborhood with occasional drives up to 12 km for 25% (Martin, 2020); longer distance of 5.2 to 6.9 km via digital apps (Martin, 2020; Mugo and Weru, 2020)	Average 8.6 km/ trip using a ride-hailing app (Farquharson, 2019), (interview 20); constant circulation through the city instead of waiting (interview 18)	Average 3 km/ trip from the motorcycle financing company Tugende (Evans et al., 2018)
Daily mileage: mostly dissimilar	Average 90–100 km/day stated by drivers (Martin, 2020; EPRA and UNEP, 2020), over 100 km stated by 65% of drivers (Minter, 2021)	Strong variations: 128 km/day (Gustavsson et al., 2019) to 175 km (Sudmant et al., 2020), 190 km (Gouldson et al., 2018)	E-motorcycles: from 149 km/day pre-Covid to 70 in July-Dec 2020 (Calzavara et al., 2021)
Trips per day: limited comparability	74% reporting 10–15 trips/day and more (Martin, 2020), 85% 10 and more (Minter, 2021)	No data	18 trips/day (Muni et al., 2019) to 12 (Courtright, 2023) and 23 (Evans et al., 2018)
Average fares: limited comparability	High variations (interviews)	*Average* 1 USD per trip (Thom et al., 2020), 1–1.9 USD (Japan International Cooperation Agency, 2018)	*Average* USD 0.28–0.84 (Yi, 2016)
Spatial organization: similar in Nairobi and Kampala, not Kigali	Waiting areas called "stages" providing physical, financial and social infrastructure, mostly at arterial intersections or near minibus stops (Ibrahim and Bize, 2018; Martin, 2020)	Higher circulation throughout the city as waiting on sidewalks is not allowed (interviews 12, 13) and only 47 parking areas authorized (interview 17)	"Stage" system similar to Nairobi (Doherty, 2017; Evans et al., 2018)

varies, with a much lower modal share and number of drivers in Nairobi compared to Kigali and Kampala, where the highest number of drivers are found. Conclusive findings on the number of drivers are challenging in the absence of surveys and practices of unregistered drivers. Operational aspects such as the distance per trip and daily mileage also vary importantly: drivers in Nairobi and Kampala mostly undertake trips in the neighborhood around waiting points, while Kigali's drivers are reported to drive more throughout the city in the search of customers. This heterogeneity calls for localized analyses as there are no uniform regional patterns.

Table 5
Key characteristics – Demand side.

	Nairobi	Kigali	Kampala
Service functions: mostly similar	Speed, access to challenging roads, beating traffic jams, luggage carriage, both feeder and door-to-door (Mugo and Weru, 2020), filling gaps in bus transport services	Both feeder and door-to-door, filling gaps in bus services (availability, frequency), rapidity, affordability (City of Kigali, 2020; Japan International Cooperation Agency, 2018; Rollason, 2017; Sudmant et al., 2020)	Door-to-door, gap-filler, deliveries, feeder to main roads (Howe, 2003)
Trip purposes and frequency: limited comparability	No clear data; mostly occasional use (Mugo and Weru, 2020)	Mostly for work & health purposes (Spea Engineering & Logit, 2019); 43.90% using them every day (Dusabe, 2019)	Used for all trip types (Evans et al., 2018)
User gender: limited comparability	No data at city level	50.9% male, 49.1% female in (Dusabe, 2019)	No data at city level
User income levels: limited comparability	No data found	Similar to drivers (Japan International Cooperation Agency, 2018); increase in use with income level	All income types; slight increase in use with income (Howe, 2003)
Perceptions: similar	Poor image: young and uneducated group, lack of respect for traffic laws, road accidents, harassment, criminality (Ministry of Transport, Infrastructure, Housing and Urban Development, 2020; NCRC – National Crime Research Centre (2019))	Poor image: low-income group young, association with criminality, congestion, poor road safety, pollution (Dusabe, 2019; Japan International Cooperation Agency, 2018; Ministry of Infrastructure, 2021; Rollason, 2020; Rollason, 2017)	Negative image of reckless young men, criminality, poor road safety (Goodfellow, 2015)

3.2. Regulation of motorcycle taxi services in the selected cities

3.2.1. Characteristics of regulation

Government authorities oscillate between tolerated acceptance of motorcycle taxis, claimed planning for the mode, attempts to control motorcycle taxis or phase them out. The desire to exclude motorcycle taxis is found in Kampala, with the intention "to discourage the use of low passenger volume vehicles that include taxis and Boda Boda motorcycles" (KCCA, 2014), the announced ban of these vehicles in specific areas including the central business district (KCCA, 2020a). In Kigali, an evolution can be identified from similar previous phasing-out intentions (Goodfellow, 2015; Rollason, 2020; Rollason, 2017) to a more recent support to motorcycle taxis conditioned to an activity as feeder services ("the role of moto-taxis should be regulated to ensure they complement public transport systems or act as feeders", City of Kigali, 2020). In Nairobi, a contrast is found between city-level measures to ban operations in the city center (Republic of Kenya, 2018) or limit them to specific zones (Republic of Kenya, 2018; Republic of Kenya, 2019a) and supportive national-level policies integrating them in a category of "non-motorized and intermediate means of transport" which should benefit from infrastructure investments and planning, and mentioning a

"Government's long term plan … to support the boda-boda and tuk-tuk services … particularly in the rural and *peri*-urban areas"(Ministry of Transport, Infrastructure, Housing and Urban Development, 2020).

Beyond this fluctuation with regard to planning, a minimum set of regulatory operational requirements, listed in Table 6, is found in the three cities. This table only indicates their inscription in texts, not the degree of implementation, enforcement or compliance. This table shows a relatively similar set of minimum regulatory requirements to operate motorcycle taxis. In contrast, national regulation in Rwanda goes further by adding requirements linked with digitalization. All drivers must be registered with one of the digital platforms as per the revised National Transport Policy and Strategy, which also requires companies to share data with the government (Ministry of Infrastructure, 2021; Republic of Rwanda, 2013). Furthermore, ride-hail digital platforms have a central role in implementing cashless payment and regulated fares via the provision of connected fare or "smart" meters using two GPS devices to drivers. However, implementation of the meters has been contested and delayed (Kanamugire, 2022; Teta Ufitiwabo, 2022). In Kampala, the Kampala Capital City Authority requested in 2020 all drivers to be registered with either motorcycle-taxi digital platform companies, associations *or* stages (KCCA, 2020a), yet only through a press release and not an ad-hoc policy, and this was not implemented.

Most of these top-down requirements are however not complied with, implemented or enforced in Nairobi and Kampala. Firstly, motorcycle-taxi drivers are commonly exposed as not abiding by the regulatory requirements in the two cities, especially in the media (interviews 1, 5, 7, 8, 9, 11, 21, 22). This is particularly the case for the absence of a helmet or a safety vest, practice of circulating without a driving license (interview 2, field observations), breach of traffic rules by driving in the opposite direction or on the sidewalk (field observations), the operation without an operating permit or license in all three cities (interviews 16 and 17). Explanations for these practices included a lack of (quality) driving training, of sensitization to road safety, and inconvenience of helmets, especially for women (interviews 1, 3, 7, 8, 12, 15, 29). In Kigali, such breaches of road safety rules are less often observed visually; regulations are more detailed when it comes to suspension or revocation of licenses in case of breach of rules (RURA, 2018), with doubts however casted on real application of measures in the continuity of practices to sublet motorcycles to unregistered individuals (Rollason, 2017; Rollason, 2020).

In addition, requirements or policies are also not always operationalized via measures, or not yet. This is the case of the design of waiting points or restricted zones for operation in Nairobi or Kampala (Republic of Kenya, 2019a; KCCA, 2020a; field observations). The planned support for motorcycle taxis, as part of the broad category of Non-Motorized and Intermediate Means of Transport (NMIMT) in Kenyan national policy documents, was considered not to be translated into operational measures (interview 5).

Lastly, authorities are seen as not enforcing measures in Nairobi (interviews 5, 6, 7, 8, 9, 11) and Kampala (24, 25). This lack of political willingness (interview 6) would stem from "heavy politicization" of the sector (interview 25), a reluctance to alienate drivers representing a "very dynamic (population)" and representing "a big political force", especially when close to elections (interviews 24, 6). Repressive approaches such as bans to operate in city centers were criticized as not based on underlying data on mobility needs, counterproductive in the lack of adherence of the population, and thus partially or fully unapplied in Kampala and Nairobi (interview 29). When enforced, regulations are often less seen as pathways to improve road safety than as bribery opportunities for the police in Nairobi and Kampala (interviews 1, 11, 19, 24), less in Kigali where interviewees stressed the fight against corruption (interviews 15, 17).

Overall, these three elements of non-application create confusion over the existing framework even among transport practitioners (interview 5, 19). This environment of regulatory uncertainty is a key dimension to consider when examining the introduction of digitalization and electrification. On one hand, these technological innovations are portrayed as addressing some of the regulatory gaps (smart meters in Rwanda, personal identification of drivers and promises for personal security, mitigation of emissions through low-carbon vehicles). On the contrary, a loosely regulated environment may lead to uncontrolled development of technological innovations, such as high commission levels, predatory prices, lack of interoperability of solutions, or lack of integration of services.

Table 6
Key motorcycle-taxi regulatory requirements.

		Nairobi	Kigali	Kampala
Operational requirements				
Safety	Helmet(s)	N, C	N	N
	Vest with identification number	N, C	N	N
	Maximum passenger and load	N, C	N	N
	Minimum passenger age	N	-	N
Operation	Connected fare metres	–	N	–
Documents	Driving permit/license	N	N	N
	Operating permit/licence	C	N	N
	Third party/commercial insurance	C	N	N
Payments	Regulation of fare levels	–	N	–
	Cashless payments	–	N	–
Organisational requirements				
Member of a group, cooperative or SACCO		N, C	N	–
Registration with a ride-hail platform		–	N	–
Spatial requirements				
Parking at designated spaces		C	N	N, C
Integration in the wider transport system		–	N, C	–
Limitations	Limitation to specific zones	C, N	N	–
	Ban of operation in specific zones	C	–	C

N: requirement in national documents; C: found in City or county documents. Sources for Kenya/Nairobi: Ministry of Transport, Infrastructure, Housing and Urban Development, 2020; National Transport and Safety Authority, 2015; Republic of Kenya, 2019a; Republic of Kenya, 2018; for Rwanda/Kigali: City of Kigali, 2020; Ministry of Infrastructure, 2021; RURA, 2021a; RURA, 2021b; RURA, 2018; for Uganda/Kampala: KCCA, 2020a; KCCA, 2020b; KCCA, 2014; Uganda Government, 2016.

4. Digitalization

4.1. Characteristics of digitalization

The digitalization of motorcycle taxis in East Africa takes a variety of forms, ranging from adoption of smartphones by drivers for improved communication with clients; creation of apps for digital ride-hailing and deliveries; digital payments; and digital fare meters (interviews 5, 6, 8, 9, 14, 19, 23, 24). This research focuses on one of the most notable and widespread of these innovations, the digital ride-hailing apps, allowing passengers to order rides on smartphones, connecting them with drivers with the app as a medium. Other aspects, like the digitalization of driving licenses, will not be addressed here.

Over the past five years, there has been a strong uptake in the founding and usage of ride-hailing apps for motorcycle taxis in East African primary cities, as shown in Table 7. Homegrown companies such as SafeBoda in Kampala (launched in 2014) and SafeMoto (2015) or Yego Moto (2018) in Kigali, as well as international competitors including Uber and Bolt (previously Taxify) have entered the scene. The number of drivers affiliated with these platforms is not publicly known.

Company-driver relationship runs along a spectrum, creating two

Table 7
Private digital boda boda passenger ride-hail platforms.

	Nairobi	Kigali	Kampala
Existing companies as of August 2022	Uber, Bolt, Little	Yego, AC Group, Pascal	SafeBoda, Uber, Bolt, MakBoda, SOTBoda
Past companies (year ended or exited the country)	SafeBoda (2020)	SafeMoto/ Cango (2020)	DialJack (2019), ORI Rides (2020), Little Ride (2019), Mondo Ride (2018)

broad models. In one model, drivers sign up to a single platform expecting exclusivity from the driver who is to use this app only (e.g. Yego Motos, Kigali, interview 12), implying accrued control over conditions of operation (e.g. helmets, vests), but also support from the company through training or financial support in accessing new vehicles (Baffi et al., 2021). The other model consists of drivers signing up to multiple platforms, potentially improving service availability for passengers and the ability for drivers to find a passenger, while reducing companies' abilities to control operations. Kampala has recently seen a rise in non-exclusivity; observations in Nairobi also show non-exclusive practices with drivers simultaneously using several apps (Martin, 2020), interviews 1, 8, 11) and wearing equipment provided by various platforms, for instance a helmet and a vest from two different platforms (field observations, Osamuyi, 2019).

Five key factors have driven the adoption of ride-hailing: deemed convenience, promises for increased road safety and personal security, access to assets for drivers, and regulatory pushes. First, applying the fare indicated on the app instead of negotiations between the driver and passenger is seen as providing more convenience (Divall et al., 2021). Traceability and rating of drivers are deemed to deliver security benefits to passengers by assuring that their drivers are vetted, and that drivers can be followed in case of misconduct or criminality. Road safety gains are expected through the increased availability of reflector jackets, passenger helmets carried by the drivers, or road safety training for drivers (ITF, 2019). Drivers have been incentivized to join apps by the loans provided by platforms for motorcycles or platforms, and branded gear (interviews 12, 24). Lastly, the adoption in Rwanda is also pushed via mandatory registration with one of the digital platforms (Ministry of Infrastructure, 2021).

Nevertheless, unless offline options are offered, the expansion of digital ridesharing faces challenges of limited access to mobile services, due to low mobile phone or smartphone ownership and a lack of affordability of mobile data plans (interview 12; ITU, 2021). This challenge is particularly salient for women, who are 37% less likely to use mobile internet compared to men and have less access to mobile phones (GSMA Association, 2021; ITF, 2019). Besides, there are doubts about the economic sustainability of digital ride-hailing platforms, acting as a third party between riders and passengers and taking a commission. Indeed, both riders and passengers also have the ability to drop off the app to negotiate offline and avoid commissions (interviews 8, 30). This practice is frequently observed in Nairobi and Kampala since commission levels, ranging between 10 and 25% (Baffi et al., 2021; interviews 6, 11), are considered too high (Minter, n.d), in particular in the context of limited net incomes for drivers (Table 4). Apps may also require passengers to accept a longer wait time in pursuit of traceability-derived security, reducing the convenience of using an app (interview 28). If riders and passengers are in low density on the streets, cancellations and density can spiral downwards together, as riders and passengers become frustrated with waiting times or cancellations. Some ride-hailing apps such as SafeBoda have started using geofencing to prevent matching beyond a certain distance to reduce customer frustrations (interview 29). Overall, as an executive in Kampala explained, "[ride-hailing] is a subsidized model. It wasn't really one…that's very sustainable" (interview 23).

For these reasons, the sector is marked by significant volatility, with six companies having ceased operation or exited a country of operation (Table 7). Insufficient profitability was cited for the exit of Dial Jack in Kampala and SafeBoda from Kenya (interviews 3, 7, 8), alongside intense competition (interviews 9, 29) and a rejection of tighter rules on (costly) helmets and vehicles by drivers (interview 11). The exit of SafeMotos/Cango from Rwanda was seen as stemming from unattractive high fares, or a failure to meet government requirements (interviews 12, 16). However, the recent obligation to be registered with one digital ride-hail platform in Rwanda, if thoroughly implemented, may change the situation for the platforms' viability. Lastly, passenger ride-hailing companies have struggled during COVID-19 lockdowns, with SafeBoda seeing a significant drop in passenger helmet use (interview 31). The economic downturn resulting from the pandemic was also cited by SafeBoda as their reason for exiting Kenya (interview 20).

4.2. *Transformative effects of digitalization*

A widely hailed benefit of digitalization lies in the potential for improving personal security through traceability. The usage of GPS devices with smartphone apps or installed in the motorcycle is seen as allowing companies to trace the motorcycles in cases of absconding or theft, and to reduce default payment risks (interviews 12, 15, 22, 23, 29). As the CEO of a ride-hailing and asset financing company in Kampala noted, tracking drivers "minimizes risks of loss, it minimizes the risks of crime, because at least it prevents someone with the bad intentions [from doing] wrong" (interview 22). Additionally, the traceability provided by GPS-linked apps – whereby both passengers and drivers must indicate at least their name and phone number – is seen as reinforcing personal security for female users in Nairobi (interviews 1, 7), as well as for drivers, since it may limit the risk of ferrying criminals. In Kigali where the government mandates data-sharing from the companies and the installation of fare meters (Table 6), traceability is seen by authorities as a vector to better understand motorcycle taxis operations and revenues (interviews 12, 16). However, there are doubts about real traceability as users sometimes find drivers not corresponding to the profile indicated on the app or using a different motorcycle due to lending practices (interview 11; authors' observation in Nairobi and Kampala).

Examining another claimed benefit of digitalization, the opportunities for road safety improvements, also provides a mixed picture. The safety focus is visible via the companies' names (SafeBoda, SafeMotos). A large range of interviewees expect improvements for road safety (interviews 1, 5, 7, 8, 20, 23, 25) as drivers receive road safety and driving training, as well as safety equipment provided by the company (one to two helmets for SafeBoda, reflective jacket). Muni et al. (2019) observe that signing up on platforms compels drivers to follow safety measures (helmets, driving license, traffic rules), reducing the risk of accidents. These rules can also be enforced through passenger ratings and quality assurance officers. In addition, some companies verify that drivers have the requested documents before onboarding them on the platform (Divall et al., 2021). Nevertheless, improvements vary widely by service company: while SafeBoda has been a flagship promoter of'road safety, first aid, customer service, training, entrepreneurship" (interview 29), others such as Uber simply proceed to document checks and hand over traffic rules instructions (interviews 12, 29). With regards to SafeBoda helmets, while nearly all drivers wear them, field observations show that is very rarely the case for passengers -although drivers are said to be equipped with two helmets-, and compliance dropped by 60% in the wake of Covid-19 (Safe Way Right Way, 2022). Lastly, in dominant models of non-exclusivity in Nairobi and Kampala, companies may be disincentivized to invest in safety training as drivers work interchangeably for different platforms (interview 8).

With regards to economics, both positive and negative impacts are identified. A report found that drivers using mobile apps earned 29% on average more compared to those not using them (Bishop and Courtright, 2022). Platforms can integrate drivers into the wider digital economy

with e-deliveries, which have increased during the Covid pandemic, and improve digital literacy (interviews 4, 7, 15, 29). Using delivery and ride-hailing apps can help drivers connect with customers that may have been beyond their social or spatial networks, thus expanding their customer base. Further economic benefits are posed via improved financial inclusion and facilitated access to bank services as incomes can be traced (interviews 15, 20), as well as access to financial services via the platforms themselves (Thom et al., 2020). However, direct financial disadvantages are also identified. Passengers sometimes benefit from lower fares, imposed by the ride-hailing company on the driver (interview 9, Nairobi), reducing drivers' earnings (interview 23, Kampala). The commission levels of 10 to 25% taken on revenues per trip, as the time of study, limit driver earnings. As some ride-hail platforms also act as asset financing companies offering loans, for instance, to access smartphones, drivers intending to leave the platform find themselves in a difficult financial situation to reimburse the asset (interview 12, Kigali).

One unclear impact is whether ride-hailing apps undermine the "stages'' (waiting points) in Kenya and Uganda. Some interviewees feared that platforms would encourage drivers to spend more time driving and less at the stage, thus removing the need for these places and the social trust involved (interviews 7, 8 22). Others noted however that after five years of ride-hailing apps, stages have not disappeared and that places for waiting and social connections are needed (interviews 4, 23).

Overall, while there has been a sizeable uptake of mobile apps, volatility in the sector is high due to profitability issues and intense competition. Platforms brought promises to improve road safety, security via traceability, drivers' earnings but our study shows a much more nuanced and controverted picture.

5. Electrification

5.1. Characteristics of electrification

As of August 2022, a total of at least 19 small companies working on the electrification of motorcycle taxis were identified in the three cities. While electric motorcycles were deemed "almost non-existent" in Africa until 2018 (Black et al., 2018), where the uptake of electric vehicles is comparatively lower (IEA, 2022a), electric mobility companies started emerging in 2018 in the three cities. These companies first undertook market research before entering steps of prototyping, imports and assembly, vehicle commercialization, and operation of charging infrastructure. We observe a strong heterogeneity in terms of maturity and fleet size. Among the companies listed in Table 8, only three companies had more than 100 operational motorcycles as of mid-2022: Ampersand, Zembo, and Rwanda Electric Mobility (REM); all three are present in either Kigali or Kampala. In contrast, Nairobi shows a higher number of companies but at a less mature stage, with a few dozen vehicles or prototypes as of mid-2022. One company, Ampersand, is active in two cities (Kigali and Nairobi). Contrary to digital platforms, we do not identify major companies having ceased operation. The stakeholder landscape may evolve rapidly as companies with larger fleets, such as Spiro based in Benin and Togo, will deploy in Uganda in 2023 (Ministry of Works Transport, 2023).

Table 8
Existing companies, as of August 2022.

	Nairobi	Kigali	Kampala
Companies	Thirteen companies identified, yet at stage of few vehicles or prototypes (Ecobodaa, Ampersand, Kiri EV, Stima Mobility, Fika Mobility, Roam, ARC Ride, Alternet, eZuri, e-Safiri, Powerhive, Mazi Mobility, Omnivoltaic)	Three companies with a total fleet of circa 700 motorcycles (Ampersand, REM, Safi)	Four companies with a total fleet of circa 300 motorcycles (Zembo, International University of East Africa – IUEA, Bodawerk, Modjo Energies)

Nb. Other companies work on other types of electric two-wheelers, for instance eWaka in Nairobi, or on charging infrastructure, for instance M−Kopa in Nairobi. Sources: Galuszka et al., 2021; Martin, 2021; Farquharson, 2019; Gustavsson et al., n.d; Republic of Rwanda, 2021; Sudmant et al., 2020; personal communication C. Irambona 03.08; Vanatta et al., 2022; field observations.

Motorcycles are expected to be electrified faster than larger vehicles, owing to smaller battery sizes and consequent lower costs. Another driver for the transition is the shorter lifespan of internal combustion engine (ICE) motorcycles compared to other vehicle types, allowing a faster replacement rate of the fleet (Gustavsson et al., n.d; Ogot et al., 2018). In Kenya, a study forecasted a penetration rate of 13% of the total fleet (355,000 motorcycles) by 2030 in the most ambitious scenario, against 4% for electric buses and 3% for other vehicles (UKAID, 2021). Kenya is seen as having a particularly large potential in East Africa owing to the large fleet of motorcycles, with 659,492 to 738,501 motorcycles estimated in service between 2009 and 2016 (Ogot et al., 2018). Rwanda has a comparatively smaller motorcycle fleet, but a feasibility study also expects a fast transition reaching up to 60,699 motorcycles in 2029/30, representing 33 % of the total fleet (Gustavsson et al., n.d). A first set of policies, financial and non-financial incentives and standards have been adopted to support this transition in Rwanda and Kenya (Galuszka et al., 2021; Government of Kenya, 2018; Ministry of Energy, 2020; Ministry of Infrastructure, 2021; Ministry of Transport, Infrastructure, Housing and Urban Development, 2020; Republic of Kenya, 2019b; Republic of Rwanda, 2021), yet not in Uganda as of mid-2022, to the best of the authors' knowledge.

A typical barrier to electrification is the high purchase cost of an electric vehicle (EV) (Adhikari et al., 2020; Browne et al., 2012; Rezvani et al., 2015), which is also identified in Sub-Saharan African countries where access to reliable and sufficient electricity constitutes a further hurdle (Baffi et al., 2021; Collett et al., 2021; Sovacool et al., 2022). However, high purchase costs can be balanced by the reduction in operational costs; Collett et al. (2021) identify lower operational costs for EVs compared to ICE vehicles in *all* Sub-Saharan African countries except Liberia. For motorcycle taxis in East Africa, we observe that specific charging and business model schemes have been designed to address challenges of affordability and electricity reliability. Instead of a model of purchase of plug-in vehicles commonly found in high-income countries (Eccarius and Lu, 2020; IEA, 2022b), all companies mentioned in Table 7 except Safi, rely exclusively or partly on a battery swapping or Battery-as-a-Service (BaaS) model.

In an exclusive BaaS model, batteries are centrally charged by the mobility or energy provider and exchanged in a few minutes, removing the need for the driver to charge home. This model has been implemented by the three largest electric fleet providers in East Africa, for instance, Zembo with 27 swap stations as of early 2022 (Zembo, 2022), or Ampersand with ten stations in Kigali and three in Nairobi as of mid-2022. Swap stations come in a variety of forms and locations, using refurbished containers located near public transport hubs (Kigali) or at fuel stations (Nairobi, Kigali), in small shops or offices (Kampala, Kigali, Nairobi) or via standalone battery cabinets (Nairobi) (field observations). Electricity unreliability can be tackled by the company by charging at different times of the day, possibly completed by solar panels with energy storage systems. This is relevant in contexts of lacking access to unreliable electricity at the driver's home, especially in lower-income areas or informal settlements. In 2020, 69.9% of the urban population in Uganda had access to electricity, 86.4% in Rwanda, and 94% in Kenya (World Bank, 2023).

Swapping batteries is particularly relevant for motorcycle taxis having high daily mileages as it removes the need to wait for recharging, and the range anxiety provided there are sufficient swap stations, or strategically located stations in regard to the drivers' needs. As batteries

mostly enable a range of 60 to 90 km per charge (Bishop and Courtright, 2022), a swap may be necessary once or twice per day depending on typical local mileage (Table 4). With regards to economics, decoupling ownership of the vehicle and of the costly component of the battery enables innovative financial models. Access to the motorcycle without the battery is possible via different models (lease-to-own including transfer of ownership at the end of the leasing period, pure rental, or upfront purchase), with comparable leasing rates to ICE motorcycles. Batteries are only rented out, and corresponding costs are integrated into the battery swap costs – mostly via pay-as-you-go schemes where fees vary depending on consumption (battery exhaustion levels).

Companies have so far mostly applied a strategy of importing new vehicles and batteries, partially assembled locally, adding a few minor parts locally manufactured. Converting ICE motorcycles has been explored but is less pursued due to the rapid wear of vehicles, potential legal risks with original manufacturers, difficulty to purchase sufficient volumes of well-maintained motorcycles, and ad-hoc assessment of each motorcycle to retrofit. Overall, companies still experiment with different models along the following variables: own automobile design or externalization to Asian manufacturers, import of batteries or local assembly of battery packs, battery size, body shape in particular for the passenger seat, or various types of swap stations. Challenges still exist, such as the identification of models sufficiently robust to navigate unpaved roads over a longer period of time (Galuszka et al., 2021), slower pace of uptake due to high investment costs in swap stations and extra batteries to swap, the development of a sufficient network allowing *peri*-urban trips, and possible impact on grid peak loads (Sheehan et al., 2021).

5.2. Transformative effects of electrification

As moto-taxi electrification is recent in the region, most studies assess impacts by modeling or questioning drivers and experts on expected effects, while only a minority of studies investigate real-life cases. Applying the analytical framework (Table 2), we find that most studies focus on environmental benefits, primarily in the form of important reductions in carbon emissions. In Kampala, a study found a reduction of carbon dioxide by 97% based on the 2020 grid (Calzavara et al., 2021), and another study a lower decrease by 36%, assuming increased reliance on thermal fuel generation (Vanatta et al., 2022). The former study included battery production emissions, used calculated driver-sourced fuel economy estimates, and was based on the current hydro-dominated grid, while the latter study had lower gasoline-related emissions by using manufacturer-provided fuel economy. In Kenya, one study points out an 80–85% reduction potential for motorcycles (UKAID, 2021; little methodological details). In Rwanda, a lifecycle analysis showed a 75% reduction of greenhouse gas emissions for motorcycle taxis in a swapping model by 2030 as compared to a business-as-usual scenario (Gustavsson et al., n.d). Gouldson et al. (2018) identify motorcycle electrification as having one of the highest potentials among several climate-saving measures. In Kigali, full electrification of the motorcycle taxi fleet would reduce *total* city transport-related emissions by 10% (Sudmant et al., 2020). Interviewees from different backgrounds stress these gains (interviews 6, 12, 16, 25). Climate mitigation gains are particularly high in countries with a large share of renewable sources in the electricity generation mix, such as Kenya with a share of 92.3% in 2020 (geothermal, followed by hydro and wind energy, KNBS, 2021), and Uganda as high as 99% when including bagasse-burning plants, with 90% coming from hydropower (IRENA, 2022). Recent severe climate-related droughts, whose frequency will increase, will however negatively impact the capacity of hydropower plants playing an important role in electricity generation in all three countries.

Studies find diverging results about the impact on air quality vary, depending on the scale scrutinized and electricity generation mix. In Kigali, a study identified significant air quality improvement and corresponding health benefits at city level (Sudmant et al., 2020) also highlighted by interviewees 15, 21, 25, 30). A research in Uganda, however, assuming an increase in thermal fuel generation, finds at *country* level a strong increase of sulfur oxide, particulate matter 2.5 and 10 caused by non-renewable electricity generation sources (Vanatta et al., 2022). Other environmental dimensions such as the end-of-life management of batteries were not mentioned in interviews.

Economics is another dimension where gains are modeled or observed. At the macroeconomic level, achievable benefits for governments are identified via reduced fossil fuel subsidies, reduced fuel imports, and higher revenues for electricity-generating companies (Collett et al., 2021), although reducing fuel tax revenues too. On the micro-economic level, lower energy and maintenance costs of electric motorcycle taxis are expected to enable higher net incomes for drivers in Nairobi (Martin, 2021; Martin, 2020) and Kenya, with a lower total cost of ownership of 10 to 20% (UKAID, 2021). In Kampala, a study shows a reduction of 68% in weekly energy costs and 55% in maintenance costs (Calzavara et al., 2021). In line with these studies, interviewees across a wide spectrum of electrification, digital companies and asset financing companies, government, researchers and urban planners state similar expectations of improved earnings for drivers across (interviews 1, 2, 5, 6, 10, 12, 16, 19, 28, 30). These gains are expected to increase as fuel prices continue to rise. However, a researcher cautions against the influence of electric mobility companies on narratives, as a form of "marketing" (interview 1). A transport practitioner states that gains may be kept by electrification companies as they face large investment costs for swapping batteries and stations, rather than benefit drivers (interview 9). Lastly, charging and swapping fees could increase if companies acquire dominant or monopoly positions (interview 8). Our research shows a need to rethink the economic challenge, which may be less of limited affordability of plug-in vehicles purchased upfront – as seen in the Global North -, but of financial and operational dependence on swapping providers as schemes are not interoperable. Further expectations lie in the "social" category, as improved acceptance towards drivers of electric moto-taxi was found among public administration, police, users, and other drivers (Calzavara et al., 2021), also benefitting from a more positive "innovation" narrative (interview 30).

In summary, while electric motorcycles are appearing in the streets of Kigali and Kampala, to a much lesser extent in Nairobi, this trend is still very limited with not much more than 1000 motorcycles as of mid-2022. This could however evolve rapidly. A range of benefits is identified, with more documented input on the reduction of carbon emissions and air pollution at the city level, followed by economic and social gains.

6. Discussion and conclusion

6.1. Summary of context and trends

The key metrics of motorcycle taxi operations showed homogeneity along a perceived growth of the sector, positive traits related to service functions coinciding with a negative image among decision-makers and planners, and a minimum similar set of regulatory requirements. On the other hand, the extent to which motorcycle taxis operate significantly varies in the three cities, with a much larger presence of motorcycles in Kampala, followed by Kigali, and lastly Nairobi. Heterogeneity is also found for key metrics such as the number of trips, distance per trip, daily mileage, and spatial patterns, which calls against thinking of uniform regional patterns. Overall, data is largely limited by limited comparability due to dissimilar collection methods or a lack of recent updates, which calls for caution when using data. In all three cities, the two technology-driven trends of digitalization and electrification are found, with different characteristics. Digital companies have been present for a longer period but several platforms have already ceased operations due to challenges of financial sustainability or in the wake of the Covid pandemic. This volatility is not observed for electric mobility companies, which are at stages of development or expansion, yet with very limited fleet sizes still. Fig. 1 gives an overview of the existence and

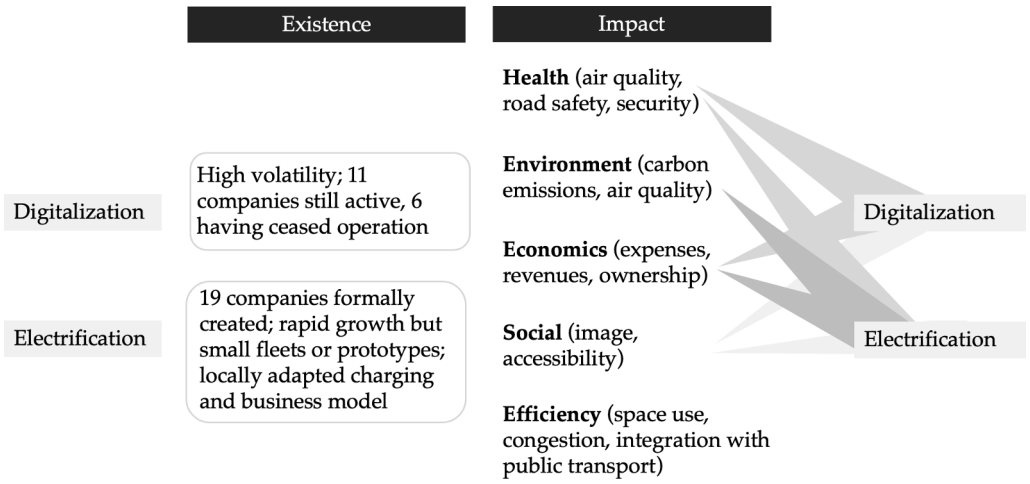

Fig. 1. Overview of the existence and impacts of innovations of motorcycle taxis.

impacts of these two trends.

The analysis presents a mixed picture of the impacts of digitalization. Applying the analytical framework (Table 2) shows that digitalization may positively impact the categories of health (potential for improved road safety via training, helmets, background checks, rating, and personal security via traceability), economics (promises for higher drivers' revenues, access to e-deliveries and financial inclusion), and society (image or respectability). However, the research casts doubt on some of the digitalization promises. Safety-related measures have been weakened post-Covid; several platforms do not really or regularly control conditions of operations in Nairobi and Kampala. In addition, potential negative economic impacts for drivers are found via high commission levels or imposed reduced fares, and asset reimbursement traps.

We find that electrification is associated with a larger number of positive impacts covering a broader spectrum of the environment (reduction of carbon emissions), economics (potential gains for drivers), health (air quality at the city level), and social-related benefits (improved image). However, possible challenges may appear over time, such as dependence on a few swapping providers or, to the contrary, a further scattered company landscape, interoperability challenges, and infrastructure duplication. Lastly, perspectives around impacts need to be enlarged beyond the "obvious" focus on environment, health and economics aspects, to include spatial dimensions and life-cycle aspects including asset end-of-life management.

Exogenous technology-driven innovations could be identified by policymakers as possible vectors to address external costs of moto-taxis of carbon emissions, road safety issues, and personal security, thus potentially answering elements of the "sustainability conundrum". However, this research uncovers various limitations in terms of volatility (digitalization), nascent stage (electrification), or even controversial impacts (digitalization), which calls for caution against seeing innovation actors, in particular digital platforms, as support to improve the mode. Lastly, problems of limited efficiency remain, in the absence of planning for the integration of motorcycle taxis in the transport system.

6.2. *Interlinkages and the question of data*

The paper showed a connection between the regulatory context and digitalization via the integration of digital platforms in regulatory requirements in Kigali, to a much lesser extent in Kampala. No such connection was identified between regulation and electrification. With regards to digitalization and electrification, partnerships between e-mobility companies and digital platforms to deploy vehicles and recruit drivers are discussed and likely in the future but have not been observed at a large scale yet.

Here, we further observe a *theoretical* interconnection between regulation, digitalization, and electrification with regard to data. This study exposed a dearth of quality and comparable data in all cities, which creates uncertainties for authorities on how to appropriately plan and regulate the sector. Digital and electrification companies have on their end, critical data: ride-hail platforms have access to operational, spatial and financial data of drivers, as well as official driving and identity documents; electric mobility companies commonly proceed to GPS data collection campaigns as part as market assessment prior to the start of operations, and collect data during operations, for instance via charging. Data-sharing requirements put upon private companies with adequate data protection, anonymization, and aggregation, would have the potential to provide government authorities information to coordinate motorcycle taxi operations, but also to plan electrification strategies and modal integration. Data from e-mobility companies could help understand the impacts on sustainability, on the electric grid, and the types of regulation (and enforcement) needed in the sector. Sharing aggregated, anonymized data around road traffic incidents, near-misses, helmet usage, and safe driving behaviors, could help give us a clearer picture of the impact of ride-hail companies on safety and sustainability. Limitations of this approach with ride-hail platforms should, however, be recognized as data would not reflect patterns of drivers not registered with platforms, and as the membership to a platform may impact trip patterns (e.g. longer distances found in Nairobi, see Table 4).

6.3. *Outlook*

This research is a first step toward understanding whether and how innovation trends shape the activities of motorcycle taxis in East-African capital cities, and how they may address some sustainability challenges of the mode. We call for further longitudinal research on the topics exposed in this paper: due to the characteristics found of volatility (digitalization) and limited maturity (electrification), the impacts of these two trends may evolve and should be further investigated. In particular, we recommend taking a stronger focus on data collection with operators and users of transport services (surveys, interviews, focus groups), which have been missing so far for the analysis of electrification, as identified by Amedokpo and Boutueil, 2023. We also suggest refining the plurality of impacts, by detailing effects for transport operators, users, and the wider environment (impacts on jobs, on the environment, etc.). Such research should also further investigate further interlinkages between regulation, electrification, and digitalization, and explore policy answers to electrification and digitalization. A comparative analysis could be undertaken to study these trends in West African countries having high numbers of motorcycle taxis, active digital platforms, and electrification initiatives such as Benin, Togo or Nigeria.

Lastly and beyond the two trends examined in this paper, we identified during our research four gaps to address in future research: first, the effect of Covid19 on motorcycle taxis in the region. Secondly, the presence, role and impacts of formal asset financing companies, which play an increasingly important role in the access to vehicle ownership in place of arrangements between individuals and to connect drivers to digital and electrification companies, while raising questions on fair and financially sustainable access to financing. Thirdly, research could look at modalities to plan for the operation of motorcycle taxis within an integrated transport system. Finally, further research is desirable on modalities to increase the participation in decision-making of associations representing motorcycle taxis operators, to enable more inclusive and effective regulation of the mode.

CRediT authorship contribution statement

Emilie Martin: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Thomas Courtright:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Alphonse Nkurunziza:** Investigation, Writing – review & editing. **Oliver Lah:** Funding acquisition, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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List of interviewees

Interview 1 – Academic researcher, Nairobi.
Interview 2 – Electric mobility association, Nairobi.
Interview 3 – Motorcycle taxi national federation, Nairobi.
Interview 4 – Electric mobility company, Nairobi.
Interview 5 – Urban planner, Nairobi.
Interview 6 – Civil servant City transport authority, Nairobi.
Interview 7 – Academic research, Nairobi.
Interview 8 – International organization, Nairobi.
Interview 9 – Development cooperation organization, Nairobi.
Interview 10 – Electric mobility company, Nairobi.
Interview 11 – Electric mobility company, Nairobi.
Interview 12 – Ride-hail passenger platform, Kigali.
Interview 13 – Electric mobility company, Kigali.
Interview 14 – International non-governmental organization, Kigali.
Interview 15 – National transport institution, Kigali.
Interview 16 – National transport institution, Kigali.
Interview 17 – Civil servant, Kigali.
Interview 18 – Electric mobility company, Kigali.
Interview 19 – Electric mobility company, Kigali.
Interview 20 – Ride-hail passenger platform, Kigali.
Interview 21 – Civil servant, Kampala.
Interview 22 – Ride-hail passenger platform, Kampala.
Interview 23 – Electric mobility company, Kampala.
Interview 24 – Motorcycle taxi national federation, Kampala.
Interview 25 – Academic researcher, Kampala.
Interview 26 – Electric mobility company, Kampala.
Interview 27 – Academic researcher, Kampala.
Interview 28 – Asset financier, Kampala.
Interview 29 – Ride-hail passenger platform, Kampala.
Interview 30 – Electric mobility company, Kampala.
Interview 31 – Ride-hail passenger platform, Kampala.

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