Transitioning to electrified, automated and shared mobility in an African context: A comparative review of Johannesburg, Kigali, Lagos and Nairobi


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Transitioning to electrified, automated and shared mobility in an African context: A comparative review of Johannesburg, Kigali, Lagos and Nairobi

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ABSTRACT

This article focuses on the drivers and barriers afforded by three innovations—automated vehicles, electric mobility, and ridesharing and bike-sharing—in the four African urban areas of Johannesburg (South Africa), Kigali (Rwanda), Lagos (Nigeria) and Nairobi (Kenya). We ask: what are the drivers behind these innovations in these regions? What are the potential barriers? And what implications for policy or sustainability transitions emerge? Based on a review of the academic literature, we argue that these innovations are particularly important at providing low-carbon transitions for the transport sector, even though low-carbon development is an important topic that is under-researched in many developing economies. We begin by introducing these three innovations and justifying our four case studies. We base the research design on an interdisciplinary critical and umbrella literature review. We then discuss the results of our review, which is organized as a dualism of positive drivers and negative barriers, before discussing how to better harness innovation for low-carbon mobility in an African context. We find that the possible benefits of our three innovations exist only juxtaposed against negative barriers; no innovation is purely positive or negative and all of them have multiple dimensions of positivity and negativity. Although we have treated each of the three innovations as fairly isolated from one another, there are emergent (and potentially strong) couplings or entanglements between them, e.g. between electrification and two-wheelers or automation and ridesharing. In some contexts, hybridization, incrementalism and leapfrogging are seen as positive attributes and desirable characteristics of planning and technology adoption.

1. Introduction

Automobility, the continued dominance of privately-owned, petroleum-powered vehicles used primarily by single occupants, is a major contributor to climate change, air pollution, excessive congestion, and land-use impacts (Urry, 2004). Many policymakers and other stakeholders have explored and supported efforts to transition towards more sustainable forms of mobility, with recent efforts intented focused on three particular categories of innovation: electric mobility, autonomous vehicles and shared mobility. These have been referred to as the “three revolutions” (Sperling, 2018) as well as “new mobilities” for transport (Sheller and Urry, 2016). These innovations, individually or in some combination, could play important roles in future transformations of transportation sectors—substantially impacting the environment, energy use, and social well-being.

Yet there is a dearth of literature that explores what role, if any, these innovations may play in the Global South—lower income countries often situated below the Earth’s equator. In this paper, we focus on a subset of the Global South — Africa, concentrating our research on major urban areas in Sub-Saharan Africa (SSA) such as Johannesburg (South Africa), Kigali (Rwanda), Lagos (Nigeria) and Nairobi (Kenya). As just one example, global EV datasets (e.g. the Electric Vehicle World Sales Database, 2021, see https://www.ev-volumes.com/) do not adequately track sales in Africa. The EV dataset includes only one market for the entirety of “Africa and Mid-East,” which was the United Arab Emirates. Such gaps in data point to the inherent challenge in studying transport pathways or decarbonization of the transport sector in the Global South. Another reason for this challenge is because doing such study requires large interdisciplinary teams with expertise spanning History, Human, Psychology, Geography, Economics, Sociology, and Urban Planning alongside topics such as Tourism or Gender (Ingeborgrud et al., 2020). Impactful, reflective interdisciplinary research in social science and the humanities on transport sector decarbonisation encompasses studies of different modes of transport and corresponding shifts in sociotechnical systems for mobility (Wood, 2015).

As (Marei and Savy, 2021) caution, notwithstanding an increased
focus in city logistics and transport planning within the research community, the particular issues facing cities in the Global South, where modern and traditional modes of transport often coexist, remain “seldom addressed” (Njeya and Knowles, 2020), concur when they note that research on the development and impacts of air transport has hitherto focused mainly on developed countries in the Global North, and relatively little on less developed countries in the Global South. (Sovacool et al., 2018)’s review of electric mobility and vehicle to grid transitions depicts a literature dominated by institutions in the Global North. In his broader critique of the literature on transport and geography, (Schwanen, 2018) affirmed that predominantly Western worldviews, theories, concepts, methods and research practices continue to prevail in geographical scholarship on transport in the Global South.

These biases are unfortunate, given the pressing needs of communities and cities in the Global South. (Schwanen, 2018) notes that these needs are interstitial and severe, and pressing challenges include substantial increases in emissions, noise, traffic injuries and casualties, and road congestion. (Benevenuto and Caulfield, 2019) add that countries (and cities) in the Global South must often confront transport systems dealing with high levels of corruption, poor performance and levels of access, limited access to data, high rates of poverty, investments focused on appeasing political constituents rather than emphasizing what is needed and a prioritization for flagship construction projects (media-attractors), rather than maintenance or upkeep. Most countries especially in the Global South remain locked-in to petroleum-powered automobile, despite decades of progress in alternative and low-carbon fuels and technologies, and some incremental improvements taken up in the mass market (Axsen and Sovacool, 2019). A study on mobility in SSA cities by Tembe et al. (2020) revealed a relatively small public transport sector concentrated on major radial roads, and an increasing informal sector of paratransit. Household ownership of motorized two-wheelers and the private car is reported to be very low. A comparison of urban transport systems across the two cities of Nairobi, Kenya and Maputo, Mozambique identified affordability as the main concern for the use of buses and paratransit. For example, a substantial share of urban dwellers was found to have no daily access to public transport services because these are expensive and not easily accessible (Tembe et al. (2020)).

In this article, we focus intently on the drivers and barriers resulting from three innovations in the four African urban areas of Johannesburg, Kigali, Lagos, and Nairobi. We ask: What are the drivers behind automated vehicles, electric mobility, and ridesharing/bike-sharing in these regions? What are the potential barriers? And what implications for policy or sustainability transitions emerge? We argue that these innovations are particularly important at providing low-carbon transition for the transport sector. Although emissions of greenhouse gases have been historically low, they are expected to see extremely rapid growth in the coming decades; thus, locking-in low-carbon forms of mobility now has a chance to protect public health, improve efficiency, lower carbon dioxide emissions, and generate innovation simultaneously for decades to come (Noel et al., 2019; Lah, 2018; Fisch-Romito and Gutvarch, 2019; Waisman et al., 2013). We begin by introducing these three innovations, justifying our four case studies, and explicating our research design, which is based on an interdisciplinary review of the academic literature. We then present the results of our review before discussing how to better harness innovation for low-carbon mobility in an African context. Although largely empirical in nature, we also intend our contribution to inform ongoing debates over transport policy and planning, as well as sustainability transitions, which we explore in Section 4. We conclude with implications for research and policy.

2. Research methods: selecting three innovations and four case studies

This section of the paper briefly introduces the three innovations selected for analysis, the four urban areas we explore their use in, and how we collected our data and evidence for the review.

2.1. Choosing three mobility innovations

Our focus in this paper is on three innovations for urban transport (Vu and Preston, 2020): automated mobility, electrification and electric mobility, and ridesharing and bike-sharing (see Table 1). These three innovations are largely heralded as ushering in the next wave or transformation in mobility services (Axsen and Sovacool, 2019); (Sperling, 2018) even calls these three innovations “the three revolutions” for future transport, although he focuses mostly on their use in the Global North.

One closely related aspect of these innovations are the business models that can support them. The particular emergence of digital platforms are beginning to allow online information and ticketing and innovations in Mobility as a Service (MaaS) systems. MaaS systems are applicable in some cities like Lagos and Johannesburg (Magnusson et al., 2020). Even in situations that often equate urban transport with rail and bus services, various modes of transport can be differentiated in terms of capacity and costs. The low-cost public transport and low-capacity systems such as mini-/microbuses, paratransit, and taxis can be an attractive niche for many people (Preston and Bickel, 2020).

There are various debates around hype-disappointment cycles on these three innovations, and in this sense, they do not focus on (or many do not prioritize) environmental sustainability (clean energy, climate change, transport and industrial decarbonization). And that Africa is still lagging in the adoption of these options (Jacob and Lefgren, 2011). Interestingly, such innovations intersect with existing patterns of infrastructure as well as emerging new business models for mobility, including MaaS. These services are also often based on the technology that has facilitated the advent of Transportation Network Companies (TNCs) like taxifier, Uber, and Lyft. TNCs —app-based, and on-demand transportation services that connect the driver and user – were designed to serve public transit riders through more predictable pricing, and be less dependent on government subsidies, while services often designed to fill gaps in the fixed route by public bus and mass transit systems (Weinreich et al., 2020). Several app-based pilots, and on-demand programs have emerged in most countries across Africa, spurred on, in part by the mass transit administration (MTA) and its introduction of Bus Rapid Transit (BRT) programs in cities such as Lagos. Meanwhile, the emergence of deep learning techniques and their applicability in transport systems recently has equally contributed to heightened interest in TNCs (Davis et al., 2020). Jennings reveals that such sustainable mobility systems could contribute to changing the virtualization of life and work, the increasing contribution of electronic communication and

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric vehicles</td>
<td>Automobiles, buses, trucks, or other forms of mobility (scooters, micro-mobility) that use electricity as their primary source of fuel</td>
<td>Plug-in hybrid electric vehicles, battery electric vehicles, e-bikes and scooters</td>
</tr>
<tr>
<td>Ridesharing &amp; carpooling</td>
<td>The on-demand shared use of a vehicle or transport technology (bicycle) where the passenger pays for the service rather than owns the vehicle</td>
<td>Uber and Lyft, bike-share, peer-to-peer carshare</td>
</tr>
<tr>
<td>Automated vehicles</td>
<td>Forms of mobility that use partial or full automation to assist or replace a human driver in operation and use</td>
<td>Self-Driving Mini-Trucks, Autonomous Electric Cars, Satellite-Controlled Vehicles, Drones, automated light rail or rapid transit</td>
</tr>
</tbody>
</table>

Table 1
Conceptualizing “the three revolutions” in innovative future mobility and transport.

Source: Authors.
important role that social media are playing in national discourse. These trends such as teleworking and e-shopping are helping to establish new lifestyles and habits (Jennings, 2020). Teoh et al. (2020) also suggests such innovations would be useful at helping urban transport regions become more sustainable only as support a leveling off and eventual decline in car use.

2.2. Selecting four case studies

While mass transit is enabling mega infrastructure change in many of the world’s cities and providing large volumes of people with options for traveling on trains and buses, in the Global South these modes of transport are often face challenges over concerns that include reliability, efficiency, effectiveness and speed (Costa et al., 2017). Urban transport planning for many Global South regions in the 1950s and 1960s emerged almost entirely by “top-down” approaches to research and development. But “bottom-up” options including climate-compatible development pathways and natural climate solutions hold great promise in making African cities more resilient and sustainable (Fankhauser et al., 2019; Page and Fuller, 2021).

To examine the role of some potential bottom-up or leapfrogging transport innovations in Sub-Saharan Africa, we selected the four populous, carbon intensive, major metropolitan areas that also serve as capital cities shown in Table 2. As that Table indicates, each of the cities has more than one million inhabitants and some (Lagos) has more than 20 million. The four cities are fairly large, occupying at least 600 km2 or more. Johannesburg and Lagos are particularly carbon intensive. Household electricity access also vary from 70% to 87.7%. In this section, we summarize some key information and data about trends in each of the four cities to give readers more context for the sections to come.

Johannesburg met our criterion for a populous and carbon intensive city given that road-based transportation is widely depended on. One contribution of the South Africa’s apartheid structures remain a subtle and insistent feature of capitalist domination, in which racial and other divisions among labor, and the separation between working and living are rife (McCarthy and Swilling, 2001). Putting aside its infamous label for being a “post-apartheid” city, Johannesburg has been termed variously “a city of extremes,” a “neoliberal dystopia,” “Fortress Johannesburg” and even a “neoliberal dystopia,” terms that all highlight how patterns of division and inequality are built into the socio-spatial dynamics of the city (Robinson et al. 2020). The city itself is governed by a single-tier metropolitan authority that must fulfill its developmental mandate, secure its electoral base, provide for the black urban working-class and urban poor but also maintain alliances with white ethnic communities, making the city one of contrasts. Urban transport planning centers on the flagship initiative known as the “Corridors of Freedom” plan intended to take “transit orientated development” further by stimulating public transport, especially intensifying development along new BRT networks shown in Fig. 1. While on paper The Plan involves “stitching together” a fragmented city into something far more integrated and inclusive through linking centrally located affordable accommodation to public transportation, employment opportunities and a range of accessible services, in practice it has a high number of private cars, traffic congestion, and high resulting transport carbon emissions. Bus and taxi services are relatively more accessible than rail services, and the percentage of households that have access to a car is 26.1% with an average of 0.40 cars per household (Walters, 2013). This results in substantial carbon footprint for transport: nationally, 5% of petroleum liquid is consumed by industry, while 78% is consumed by the transport sector in South Africa (Vanderschuren et al., 2010). Carbon emissions from the transport sector are of a similar scale to industrial emissions in South Africa—(Isaac and Saha, 2021).

Kigali is projected to have one of the fastest growing rates for a city in the world. Between 2000 and 2015, Kigali grew at an annual rate of 5.3%, from a city of 580,000 to a city of 1.3 million, and over the coming 15 years the city is projected to grow 4.0% annually to a population of 2.4 m in 2030 (Sudmant et al., 2017). If these estimations are accurate, the city will quadruple in size by 2030. Despite this population, (Niyonzima, 2018) write that the nature and extent of public transport services remain inadequate in terms of both condition and capacity, with poor quality roads and a very limited road network shown in Fig. 2. However, between 2005 and 2011 the stock of private cars more than doubled, leading to rising congestion and contributing to high levels of particulate air pollution in the city, also ensuring high carbon emissions “for decades to come” (Sudmant et al., 2017). Unlike many other African cities, Kigali has been more active in attempting to better manage urban growth, fight poverty, and improve liability. This includes commitment to the environment in the form of a ban on plastic bags, investments in public waste, and corridors for safer walking and the use of electric buses for public transportation.

Lagos was selected because it represents not only a large, populous city (reputed to be the sixth fastest growing city in the world) but one where transport service demands centre more on two end-use services, passenger and freight transport. This however remains primarily fossil-fuelled, with the two main conventional sources of transport fuel in Nigeria, gasoline and diesel, accounting for around 99% of the vehicles operating across the country (Dioha and Kumar, 2020). Passenger transport remains dominated by bus (44.8%) and car (42.5%); motorcycle travel contributes 12.6% and rail only 0.24%. Collectively, more than 61% of travel is by petrol vehicles and the rest by diesel (Gujba et al., 2013). This is very carbon intensive, with greenhouse gas emissions expected to reach a staggering 39 MtCO2eq in 2040 (Dioha and Kumar, 2020). Seeking to better manage congestion and traffic, planners in Lagos have adopted extreme measures such as banning motorcycles (okada) as a means of commercial and private transportation on some roads (Olagiji et al., 2018). The traffic planners have also sought to expand bus links and corridors shown in Fig. 3, although these are still prone to frequent breakdowns and traffic congestions. It has been projected that out of the 7 million or so passengers that use the Lagos transport system, only around 8000 passengers a day use the rail network for transport, with water and rail transport accounting for about 1% of all travel in Lagos (Uwaje and de Vries, 2020).

Nairobi, similar to our other cities, is populous and features a mixture of different transport modes, notably walking but also a well-established paratransit network shown in Fig. 4. According to Tembe et al. (2019), Nairobi is a critical economic center for all of East and Central Africa, accounting for half of all formal employment for Kenya as well as half of gross domestic product. The city is also reported to have one of the longest average journey-to-work times in Africa due to: “Heavy congestion, high rates of walking, informal collective

Table 2

<table>
<thead>
<tr>
<th>Metropolitan Area</th>
<th>Johannesburg</th>
<th>Kigali</th>
<th>Lagos</th>
<th>Nairobi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>5.927</td>
<td>1.632</td>
<td>22.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Geographic area</td>
<td>1645</td>
<td>730</td>
<td>907</td>
<td>696</td>
</tr>
<tr>
<td>Carbon intensity</td>
<td>9.5</td>
<td>0.9</td>
<td>2.8</td>
<td>0.37</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>1503</td>
<td>637</td>
<td>393</td>
<td>185</td>
</tr>
<tr>
<td>Electricity access</td>
<td>87.7%</td>
<td>70%</td>
<td>72%</td>
<td>78%</td>
</tr>
</tbody>
</table>

* (MacroTrends April, 2021); (Manirakiza et al., 2019); (Faisal Koko et al., 2021); (Ren et al., 2020).
* (Rand Daily Mail | former newspaper, South Africa | Britannica 5 April, 2016); (Kagera River | river, Africa | Britannica 12 April, 2012); (Lagos | City, Population, & History | Britannica 12 April, 2020).
* (The Carbon Brief Profile: South Africa | Carbon Brief April, 2021); (Bola-Popoola et al., 2019); (Current Policy Projections | Climate Action Tracker April 2021); (Ren et al., 2020).
* (Muralia, 2019); (Uwayezu and de Vries, 2020); (Ogamba et al., 2020); (Cornelsen et al., 2016).
* (Longe et al., 2019); (Akpan, 2015); (Uwayezu and de Vries, 2020); (Moner-Girona et al., 2019); (World Atlas: Car sales by country, 2021).
Fig. 1. “Corridors of Freedom” Planning Areas for Urban Transport in Johannesburg, South Africa. Source: (Robinson et al. 2020).

Fig. 2. The existing road network in Kigali, Rwanda. Source: (Niyonsenga, 2018).
Fig. 3. Lagos Bus Rapid Transport networks in 2019. (Source: Lagos Metropolitan Area Transport Authority)

Fig. 4. The Nairobi Paratransit network. Source: (Campbell et al., 2019).
transportation, and the spatial distribution of jobs and residents” (Nakamura and Avner, 2021). Nairobi’s traffic congestion, caused by deficient transportation infrastructure, is argued to be crippling the economy (Raje et al., 2018). Another unique aspect of Nairobi’s transport sector is high levels of tourism related to transport, given that the city sits alongside a national park that is home to endangered wildlife including black rhinos. This makes Nairobi a “major tourist gateway” for safaris and holidays (Raje et al., 2018).

2.3. Research design: A critical and umbrella literature review

With our four urban case studies established, we then proceeded to execute an interdisciplinary literature review of peer-reviewed publications to collect evidence on their overall mobility trends as well as specific studies examining the role of automation, electrification, and shared mobility in their transport mixes. We focused on the academic literature, rather than the grey literature, for three reasons. First, we maintain that the peer-review process of academic journals produces generally higher quality research (compared to say advocacy) and minimizes bias. Second, it is often a requirement for project funding, especially from academic research councils, that researchers publish their results only in accredited, indexed peer-reviewed journals (this helps avoid predatory journals and outputs that have no quality control). Third, academic databases such as Scopus are often where most professional researchers go (and may even be trained to go) when they examine a topic.

We executed specific search strings covering the past 15 years of peer-reviewed research available on Scopus, searching for:

- Automation: the terms “automated mobility,” “autonomous mobility,” and “self-driving cars”;
- Electrification: the terms “electric vehicle,” “electric mobility,” and “electrification of transport”;
- Shared mobility: the terms “ride hailing,” “shared mobility,” and “carpooling”

Along with:

- “Johannesburg” and/or “South Africa”
- “Kigali” and/or “Rwanda”
- “Lagos” and/or “Nigeria”
- “Nairobi” and/or “Kenya”
- “Africa” and/or “Sub-Saharan Africa”

We searched these terms in English on the Scopus database and collected approximately 90 studies published in the past fifteen years, most of which we cite in the rest of the review. Admittedly, although we are able to capture some perspectives from the Global South (especially Sub-Saharan Africa, a key region within the Global South) written by author teams in the Global South, much of our evidence still arises from research looking at Global North contexts or looking at Global South contexts via Global North projects and authors.

Although there are elements of our search criteria that are systematic, we do not classify our approach as a systematic review. Instead, we classify our study as a mix of a “critical review” and an “umbrella review” (Grant and Booth, 2009). A critical review seeks to demonstrate not only that a research team has sufficiently scoured existing literature on a topic but to go beyond description to include a degree of analysis, interpretation, and conceptual synthesis. An umbrella review refers to the compiling of evidence from multiple disciplines or literature searches into one accessible and usable document, highlighting (at times) competing interpretations and uncertainties in the literature. The critical aspect of our review enables us to describe and interpret what is known, whereas the umbrella aspect of our review enables us to capture diverse interdisciplinary perspectives and also identify recommendations for research.

3. Results: electrified, automated and shared mobility in an African context

Interestingly, our review of the literature suggests that the three innovations will have neither solely positive, nor negative, impacts within each of the four urban areas. Table 3 offers a high-level summary based on some established metrics from the literature, focusing on key indicators that correspond go the three innovations we examined:

- Indicators for electrification and power outages relate directly to our examination of electric mobility as well as automated mobility depending on wireless internet or GPS data networks (which require reliable electricity);
- Indicators for poverty relate to all three innovations as they reflect the purchasing power of respective communities and households;
- Indicators for car ownership, road length, and passenger car sales also affect all three innovations as they relate to preferences for private vs. public mobility and also the general quality of mobility infrastructure;
- Indicators for registered electric vehicles relate directly to our electric mobility innovation.

These indicators were also chosen because we were able to actually find reliable data on them. With these metrics selected, Table 3 visualizes red/orange showing strong barriers to the innovations, yellow moderate barriers, and green weak barriers (i.e., more positive markets). It is telling that all urban areas have at least some red/orange, indicative of multiple red barriers. For example, electrification would be a strong barrier to Kigali and Lagos in particular, given poor coverage of electricity networks and issues of reliability in Nigeria, where a typical firm suffers about one power outage a day. All countries had few electric vehicles (EVs), three with no data at all or “0”. South Africa had 1119 EVs in 2019 (cleantechnica, 2020). Lack of roads creates a very strong barrier for automated vehicles in all of the urban areas with the exception of Johannesburg. High rates of poverty suggest low patterns of disposable income available to purchase the innovations.

In the remainder of this section of the review, we elaborate more on the specific drivers and barriers to the three innovations organized by each option.

3.1. Automated mobility and self-driving cars

Among our three innovations, automated mobility was by far the least published topic in the context of our urban areas. Nevertheless, we identified both positive drivers and negative barriers from the available literature.

Firstly, there is some potential for automated mobility to improve the efficiency of delivery for particular items especially drones (aerial automated vehicles) that can avoid the congested streets of urban areas in Africa. A study by McCall (2019) on the use of drones in commercial medical service delivery in Rwanda, reveals that Zipline’s drones currently serve 19 hospitals across the country. And this service is set to expand to cover 500 hospitals and health facilities (McCall, 2019).

Secondly, emerging social science work on possible adopters and consumers for automated vehicles (AVs) notes that many African stakeholders have positive perceptions of automated mobility. Moody et al. (2020) examined perceptions of AV safety across a diverse sample of individuals from a wide variety of countries. The study found that a significant country-to-country variance in perceptions of AV safety exist, even after controlling for the characteristics of the individuals in those countries (Moody et al., 2020). The authors examined perceptions of AV safety across 41,932 individuals in 51 countries, noting that young, high-income, employed, and highly educated males are the most optimistic about AV safety especially in Africa. Out of these 51 countries, Kenya ranked 15th in awareness, 20th in positive perceptions of safety, and 9th in terms of rapid employment. South Africa was not far behind,
Moreover, there are literatures that suggests that enhanced efficiency or delivery of freight, an important sector of non-commuting journeys, often ignored in the literature (Thomopoulos et al., 2020), could also be enabled by automated mobility. One study noted that eco-innovation initiatives in the Nigerian logistics sector (such as automation and efficiency) can aid in enhancing sustainable performance and increasing competitive advantage of freight logistics firms (Orji et al., 2019). Other evidence suggests that connected, automated cars could enhance urban tourism, enabling more economic activity by running 24 h a day, seven days a week. Cohen and Hopkins noted that the impacts of automated mobility on urban tourism could be “far-reaching” given that automation could, under particular contexts, positively influence transport mode use, spatial changes, tourism employment and the night-time visitor economy, leading to new socio-economic opportunities (Cohen and Hopkins, 2019). They emphasize that the connected, automated vehicles behind these tourism applications could indeed leapfrog to urban areas in the Global South.

These positive aspects of automated mobility sit in contrast to some barriers and risks arising from the literature. Firstly, automated mobility faces infrastructural barriers that are both digital (lack of internet connectivity) and material (lack of roads). There is a legitimate concern that most urban areas in Africa do not have the requisite ICT systems to facilitate automated mobility. Statistics on global internet access for 2019 noted that Africa as a whole had a penetration rate of only 39.3%, the lowest among all geographic continents (Yarik, 2020). And when the internet or digital apps are accessible in Africa, they are often expensive and unaffordable; digital markets sit within monopolies with few (often unfair) providers; or they lack adequate bandwidth or maintenance (Ocorian, 2019) also see (A4AI 2020). Lack of infrastructure such as roads, highways, and bridges is another impediment, with all four case cities known for having poor quality of roads and underfinanced road networks. (Sudmant et al., 2017) note that only 12% of roads in Kigali were paved even though the urban stock of private cars more than doubled. In Kigali less than 1% of the roads are constructed with granite-pavers, and the rest is rough dirt (Niyonsenga, 2018, Ikioda, 2016) notes that Lagos has only about 5500 km of tarred roads for a city of more than 20 million people. And that due to widespread migration and settlements expanding outside of the metropolitan borders of the city, road developments have been slow to catch up with the city’s population needs. These infrastructural challenges contribute to constrain the

### Table 3

<table>
<thead>
<tr>
<th>Country</th>
<th>Nairobi</th>
<th>Kigali</th>
<th>Johannesburg</th>
<th>Lagos</th>
</tr>
</thead>
<tbody>
<tr>
<td>National electrification rate (% population)</td>
<td>75</td>
<td>34.7</td>
<td>91.2</td>
<td>56.5</td>
</tr>
<tr>
<td>Power outages in firms in a typical month (number)</td>
<td>3.8</td>
<td>2.4</td>
<td>0.9</td>
<td>32.8</td>
</tr>
<tr>
<td>Population below poverty line (national poverty line at % of population)</td>
<td>36.1</td>
<td>38.2</td>
<td>55.5</td>
<td>40.1</td>
</tr>
<tr>
<td>Road length (“main” roads, in km)</td>
<td>5,792</td>
<td>2,299</td>
<td>56,262</td>
<td>7,545</td>
</tr>
<tr>
<td>Car ownership (number of private motor vehicles per 1000 people)</td>
<td>24</td>
<td>5</td>
<td>165</td>
<td>31</td>
</tr>
<tr>
<td>Registered battery electric vehicles</td>
<td>0</td>
<td>0</td>
<td>290</td>
<td>0</td>
</tr>
<tr>
<td>Passenger car sales (annually)</td>
<td>2,307</td>
<td>N/A</td>
<td>247,571</td>
<td>5,100</td>
</tr>
</tbody>
</table>

Note: Issues in red signify strong barriers to the three mobility innovations, yellow moderate barriers, green weak barriers. Categorization was undertaken based on the expert opinion of the authors.

*a (Access to electricity (% of population) | Data April 2021).

*b (Meijer et al., 2018).

*c (Statistics in Category: Energy Nation Master 2014).

*d (Electric Vehicles Initiative – Programmes - IEA Global EV Outlook, 2016.)

*e (World atlas: Car sales by country, 2021).
feasibility of automated mobility in the near-term.

3.2. Electrification and electric mobility

The literature on electrification of mobility in our four urban areas was more extensive than automated mobility, although it also identifies a mix of positive drivers and negative barriers.

Firstly, because our four urban areas are still investing in infrastructure, they could have fewer path dependencies and sunk costs related to electrification. With a majority of roads or urban infrastructure still yet to be built, the thinking is that if governments decided to, they could invest now (and leapfrog) into a future where EV is the dominant mode of transport. For example, Alsalmans et al. (2021) revealed that refuelling/charging stations would be a critical investment that urban planners could make now (Alsalmans et al., 2021). And that doing so would lock in lower carbon forms of mobility for generations to come. There would also be the ability to incorporate African led design into newer vehicles, making them more suited and adaptable to African urban contexts, including vehicle specifications, payload capacities, and aesthetics (Nur, 2020).

Secondly, for better or worse, private automobiles are becoming embedded into the norms and lifestyles of many African urban communities. Battery electric vehicles can thus help “normalize” low-carbon mobility by delivering automobility similar to the conventional cars they are replacing (Kester et al., 2020) and (Campbell et al. (2019) affirms this particularly for Nairobi, noting that it is becoming a car dependent society and thus place-based accessibility via cars is strongly preferred amid autocentric lifestyles and norms. This preference for cars also explains, in part, the non-adoption of bus rapid transit across Nigeria and South Africa. (Rajé et al., 2018) supports this benefit of EVs conforming to conventional notions of automobility by noting very high adoption rates in automobiles for Nairobi, with growth rates almost doubling for some years. Scorcia and Munoz-Raskin (2019) note similar trends for Johannesburg, which due in part to apartheid is a city of low density and spatial patterns where the poor reside very far from work or school, leading to travel demands with long, unidirectional trips well suited to private cars. A similar trend is observed in Lagos, where people drive frequently and also commute longer distances (making it difficult or impossible to walk or cycle) (Maduekwe et al., 2020). The authors note, for instance, that 60% of residents travel 15.1 to 30 km daily for work. Cultural associations, preferences and behaviours of car drivers are some of the critical issues around car-based mobility. Others include freedom, individual identity and modernity, coupled with skills requirements and assumptions of transport planners, as well as the technical capabilities of car manufacturers, suppliers, and repair shops in these countries (Magnnsson et al., 2020; Geels and Schot, 2007). EVs can also capture, nurture, support and affirm these aspects of autocentric transport.

Thirdly, and somewhat counterintuitively to the point about EVs embedding automobility, is that there are niche markets for other forms of e-mobility. For example, e-bikes and e-scooters could possibly thrive. (Temble et al., 2020) emphasizes that the urban poor in Nairobi simply walk—they do not use cars or even mass transit. This could offer an appealing niche market in the form of low-cost e-bikes, a more affordable and available technology that has taken off among the urban poor in China (Lin et al., 2017; also see Lin et al., 2018). A study on Nairobi found a strong preference for ownership of motorcycles rather than private cars or the use of buses (Oleajide et al. 2018) (see Fig. 5). Such motorcycles (and e-bikes, if they replace them) have the added benefit of being able to move more quickly through congested areas of cars (as they can maneuver in smaller spaces), and for having generally lower fuel and operating costs than private cars.

Another niche market could be the electrification of buses. Although existing bus networks are insufficient to meet the mobility needs of all urban areas and residents, those that do exist are heavily utilized. (Temble et al. 2019) documents how Nairobi’s Kenyan Bus Service, despite being underfunded and privatized, still offers millions of daily commuting trips per day. Mogaji (2020) notes that because religion is such an important part of life in Lagos, Nigeria, with a large Christian and Muslim population, thousands of worshippers travel to worship centres every day (Mogaji, 2020). This presents an opportunity for a niche market for fleets of church vehicles or for church parking lots to aggregate EVs in the form of community-scale vehicle-to-grid projects (Sovacool et al., 2020).

Fig. 5. Prolific use and adoption of motorcycle in Nairobi, Kenya. (Source: (Oleajide et al. 2018))
These probable positive aspects of electrification sit alongside equally salient negative barriers. The first is perhaps the most obvious barrier of electricity supply itself. The electrification rate in SSA is far from universal, even in urban areas. And when there is electricity, access is not always guaranteed; neither is the electricity reliable or affordable. This barrier emphasizes that the availability, accessibility, reliability, and transmission losses of electricity that have plagued the continent’s energy supply need to be assessed before EVs can be adopted (Ayetor et al., 2021). Not only does 47% of Rwanda’s population lack electricity access, there are persistent power failures and the grid is also unstable (Brönnner et al., 2020). Sovacool et al. (2019) reveals that only about 6% of electricity generation is used by households in Kenya (Sovacool et al., 2019). The high costs of electricity were also identified as barrier to electric vehicle diffusion in Johannesburg (and Cape Town) (Becker et al., 2020).

A second barrier relates to affordability concerns, not over fuel or electricity, but the capital cost of an EV itself, which remains more expensive than most fossil-fuelled private cars. This makes a private purchase of an EV extremely costly, especially in situations where, for example, about 40.1% of Nigerians still live below the poverty line (Dioha et al., 2019). Nairobi is similarly struggling with very high rates of urban poverty, with Fig. 6 showing very low housing quality (slums, incomes of less than 1300 KES, or US$12/month) to low housing quality (social housing, planned estates, incomes of less than 2165 KES, US$20/month) throughout the city (Campbell et al., 2019). It would be impossible for any such homes to afford their own EV. The trends in Kigali are similar, with 80% of the population residing in informal neighborhoods and 60% of the population employed in the informal sector; per capita income for the entire year is still only about US$650 (Sudmant et al., 2017). In Rwanda, poverty is such a stark barrier that many urban poor and especially recent immigrants cannot afford bus fares in other cities, such as Kampala (Vermeiren et al., 2015). This also implies that EV markets are well beyond their reach. This could be why when Onokala and Olajide (2020) discussed the use of electric vehicles for reducing air pollution from vehicles in developing countries such as Nigeria, they noted that only a few electric vehicles are used in Lagos roads (Onokala and Olajide, 2020).

Thirdly, for those who can afford a private personal EV in our case cities, it would do little to ameliorate traffic congestion. In large volumes such EVs would substantially contribute to traffic congestion. (Ibitayo, 2012) writes how in Lagos high numbers of vehicle breakdowns create a cause-and-effect feedback loop for traffic jams: the breakdowns create delays that then cause other vehicles to overheat and breakdown, leading to further delays. In Nairobi, congestion is just as severe, with 98% of the present mini-bus and bus routes (including intercity and intracity bus routes) starting from and terminating at the very congested Central Business District (CBD) and downtown areas, adding to the congestion challenge (Nakagawa et al., 2018). A recent study by Fraser et al. estimated transport time from road traffic collisions sites to level 4 (and above) medical facilities. The study found that even ambulances experience difficulties in clearing congestion to get to hospitals and health clinics (Fraser et al., 2020).

### 3.3. Ridesharing and bike-sharing

The literature was slightly more extensive on ridesharing and bike-sharing than automated mobility, but slightly less extensive than electric vehicles. We again see positive and negative aspects identified.

First, the literature suggests that many communities in each of our four urban areas are familiar (and therefore comfortable) with ridesharing in the form of mass transit. In addition, many African major cities are accustomed to group rapid transit (GRT), personal rapid transit (PRT), and demand responsive transport (DRT) systems. Furthermore, there are various types of tram and bus technologies, such as single-deck, double-deck, and articulated buses/coaches, and trolley buses. Public transportation systems in many fast-growing cities of Africa are

Fig. 6. A spatial depiction of poverty and housing quality in Nairobi, Kenya. Source: (Campbell et al., 2019).
dominated by informal paratransit services, a form of ridesharing. On the African continent, they are called by several local names, including Matatus (Kenya), Combis (South Africa), Cars Rapides and Ndiaga Ndiaye (Senegal), troto (Ghana), and Molues and Danfo (Nigeria), to name a few (Agyemang, 2020). For example, paratransit modes such as minibuses play a valuable role in South African transport (Woolf and Joubert, 2013). Ridesharing norms are already entrenched in Johannesburg via minibus taxis, Metrobuses, Metrorail and Rea Vaya BRT journeys (Lionjanga and Venter, 2018).

Taxi transport remains popular throughout South Africa, accounting for about 60% of the market, with an estimated 130,000 of these vehicles in operation countrywide (Groenewald, 2003). Vanderschuren noted how in South Africa over 65% of people can reach minibus taxi services within 5 min which is, essentially, what traditional taxi services provide. However, minibus taxi services serve various users at the same time. More recent options, such as UberPool and other more sustainable ride-sharing options that encourage increased car occupancy through the combination of ride request along the same corridor, include this feature (Vanderschuren and Baufeldt, 2018). Nairobi commuters have also been exposed to many forms of ridesharing especially via paratransit options and minibuses, often 14 seaters, called matatus, which are privately owned and operated by individuals or cooperatives. In the city, the majority of people rely on the paratransit system, which accounts for 40.7% of all trips (Campbell et al., 2019).

Relatedly, ridesharing and bike sharing can help supplement walking, another dominant mode of transport within the urban areas. (Rajé et al., 2018) note that because walking avoids the expense of owning a car and is suitable for short distance trips, up to half the population of Nairobi tends to walk for their mobility needs at least some of the time (e.g., weather permitting). Motorization rates in Kigali are also low, with almost half (45%) of trips made by walking or cycling (Sudmant et al., 2017). These options have the added benefit of not contributing significantly to traffic congestion, air pollution, or expenditures on imported fuel. Municipal and national governments in Rwanda have demonstrated their capacities for innovation and implementation in this sector by sponsoring wide pedestrian walkways and promoting car-free zones in the city centre—options that could also be tweaked to incentivize ridesharing.

Audikana suggests in particular that bike-sharing technology is critical in determining the economic sustainability of urban mobility patterns (Audikana et al., 2017). Bikesharing business is a typical scenario of technological innovation and competitiveness (Radzimski and Dzicielski, 2021). In South Africa, at least, parallel development of cycling facilities is a pleasing concession to slower, healthier and less carbon-intensive transport (Pirie, 2013). Doherty (2020) revealed the potential of boda boda motorcycle taxis with both ride-hailing apps and with municipal reforms in Uganda. Boda bodas are motorcycle taxis driven primarily by young men. Nationally, 1.7 million people, or 7% of the Ugandan population, received part, or all, of their livelihood from this industry (Doherty, 2020). Shibayama and Emberger (2020) study the operation of matatus in Kenya, in that traditional taxis run on pre-determined routes with a possible limited deviations of routes on demand of passengers, while the routes of shared taxi rides fully depend on passengers (Shibayama and Emberger, 2020).

These positive drivers of ridesharing reside alongside some negative obstacles. Firstly, the sustainability benefits of ridesharing are not guaranteed, they depend on how schemes are implemented, and in some cases can result in less mobility, traffic and emissions through “rebounds” (Axsen and Sovacool, 2019), especially if ridesharing displaces more active walking or cycling. Shams et al. (2020) suggest the contributions of carsharing as a new mode of transportation only add (rather than remove) complexity to the socio-economic system (Shams Esfandabadi et al., 2020). This is troubling given that most forms of mobility are carbon intensive, implying that an increase in ridesharing would merely increase the amount of time petrol and fossil fuelled vehicles remain in use. Saidi and Hammami (2017) calculated greenhouse gas emissions from road transport in South Africa and Lesotho between 2000 and 2009. The authors found that road transport carbon dioxide emissions, estimated at 43.5 million tons in South Africa, increased by approximately 2.6% yearly between 2000 and 2009. And that in South Africa, the motorcars and trucks produced 70.6% of the total road transport emissions (Saidi and Hammami, 2017).

Second, although some norms are emerging in favor of ridesharing, other norms exist against it, and bike-sharing. (Morgan, 2020) notes that in Johannesburg, bike-sharing options have so far only been able to capture about 0.5% of mobility needs (reflected in the latest household travel survey). Then, of those who cycle, it tends to be working class, fairly wealthy men—not exactly a representative sample. (Wood, 2020) argue that bike-sharing in Johannesburg is a failed innovation that has been “non-adopted” especially given that 90% of those cycling are classified as leisure cyclists, and only 10% cycle for commuting to work or taking non-leisure trips.

Thirdly, and in tandem with affordability concerns for automated vehicles and electric mobility, poverty is a barrier to ridesharing and bike-sharing. Even though such options are generally more affordable than cars, the four urban areas still have low affordability levels, especially those households in chronic poverty. Even less capital-intensive bike-sharing schemes would still “require substantial subsidies to work” including adequate remuneration for things like bike storage, staffing, lighting and security (Wood 2020). Consumer behaviours are changing towards adoption of car-sharing, and ride-hailing, cycling and scooters are much more unique and commonly used in Rwanda and South Africa, while light-duty vehicles are used in Kenya. However, in Lagos, Nigeria, the use of petrol fuel transit vehicles, tricycles, and bike-share is widely adopted.

4. Discussion: implications for sustainability transitions research and policy

Even though this study was intended to offer an empirical contribution more than one connecting with theories of mobility and transport or conceptual debates, it still enhances our view of transport planning and policy (making a policy contribution) and connects with emerging thinking about prominent theories.

4.1. Spatial, cultural and historical specificity

First, our review offers insight into the specific regional context of African energy and mobility transitions (or more relevantly its ongoing transition, or lack of it, to electric mobility and low-carbon transport). This is a welcome contribution because it enables other researchers to better connect place-specific notions of geography and space to sustainability transitions, to better comprehend the spatial differentiation of transitions and the power relations they entail (Lawhon and Murphy, 2012; Köhler et al., 2019; Sovacool et al., 2020). Our study facilitates those hoping to analyze the relationships between the “locations, landscapes and territorializations associated with a low-carbon energy transition” (Bridge et al., 2013: 337). It also builds the evidence base for those researchers seeking to grapple with the socio-political regimes present within developing countries that can shape and intertwine with the development or deployment of specific technologies (Swilling et al., 2016). Our results therefore have topical or geographic relevance for indicating how African transitions to mobility are being perceived by different groups of actors. Put another way, there is no uniform set of preferences—we see considerable variation cross demographic, spatial, and political attributes of our selected cities. This enables one to better ground ongoing transport and mobility transitions in Sub-Saharan Africa more properly within its historical and spatial dimensions (Baptista, 2018).
4.2. Understanding African adoption and diffusion patterns

Second, our results can inform approaches attempting to model or predict transport and energy consumption profiles, diffusion patterns, or psychological processes. In developing their own model of sustainability orientated values, Axsen and Kurani (2013) did not look at demographic conceptualizations of identity (such as gender, nationality, or cultural norms), but acknowledge their potential importance in influencing preferences. Our results show how grander, broader technology curves can break into more discrete, heterogeneous classes of users and adopters that cut across spatial scales (neighborhoods, blocks of flats, slums, informal settlements) and household types (large vs. small families, employment patterns that depend on commuting, etc.). Our findings suggest that we must unpack the “individual” or the “adopter” or the “African household” to be more than just an automaton who rationally calculates cost or efficacy in these (and other) models. We open up the complexity of users and the ability for emerging innovations to impact them in complex ways—across space (urban and rural dimensions), time (immediate to distant benefits), and risk (the coupling of drivers and barriers, benefits and costs).

4.3. Deepening sustainability transitions theories and frameworks

Third, and finally, our results deepen ongoing discussions and conceptual debates within sustainability transitions (Loorbach et al., 2017). Within that literature, values and culture are seen as operating across multiple scales (such as niches and regimes) (Schot and Geels, 2008). Social norms, values, and culture are even seen at times to be direct barriers that hinder innovation or create institutional failures (Matthias and Rohracher, 2012; Turnheim and Sovacool, 2020). Instead, our study shows how demographic attributes, culture, and patterns of injustice and inequity can be factors that influence behavioral antecedents or preferences for sustainable forms of mobility.

For instance, African transport systems may have greater degrees of hybridization that blend together forms of mobility or different technologies. As one example, the aboboyaa, a three-wheeled vehicle is locally perceived in Ghana as a hybrid identity, occupying the border of two technological artifacts, the motorbike and the truck (Nur, 2020). Paratransit schemes are also seen by many throughout Sub-Saharan Africa as hybrid infrastructures blending together private and public forms of mobility (Joubert and Venter, 2020).

African transport systems also open up debates about transformation vs. incrementalism. On the one hand, there is a case that the dynamics of innovation and policy design themselves may need harnessed differently, with much more focus on transformation. According to Table 4, one dominant frame promotes innovation for growth. This framing makes an important submission about the consensus which suggests that the state should play an active role in financing scientific research on the premise that new scientific discoveries on urban mobility, in this case in Sub-Saharan Africa that would ripple into practice through applied research and development by the private sector on design and innovation mobility that would be centered on peculiarity of African cities (Pisoni et al., 2019) also see (Dahle, 2007).

But growth alone would not be enough. An argument can be made that transformative innovation policy (TIP) is needed. A TIP would focus on a broad acceptance that public policy should play a more active role in new innovation systems in mobility, and it would also suggest research that is more responsive to social and environmental challenges, alongside economic growth objectives (Schot and Steinmueller, 2018; Daniels et al., 2020). Our analysis therefore offers insight on the need to strengthen the research and development complex within Sub-Saharan African countries, since the present methods for delivering its science, technology and innovation policy cannot offer the required drivers for addressing its environmental and social challenges, this includes green mobility.

On the other hand, transport systems in the Global South, especially within informal settlements, may have greater degrees of oscillation between disruption and incrementalism, a focus on smaller, cumulative minor modifications resulting from the continuous input of commuters or travellers. In many Sub-Saharan African planning contexts including South Africa, incrementalism and minimalism are pivotal principles, not transformation (Geyer et al., 2011). Indeed, Loor and Evans (2021: 5) even write that “incrementalism epitomises the capacity of informal settlements dwellers to make use of their abilities and resources to maintain their space functional” via creative forms of mobility.

A third and final example relates to leapfrogging, skipping over a stage of technical development or a particular problem to pursue instead a more advanced option. The classic example relevant in an African context is their ability to leapfrog landline telephone systems by investing in mobile phone and wireless systems instead; an energy relevant example is leapfrogging past fossil fuels or centralized diesel power plants to solar panels or wind farms (Szabo et al., 2013). Such leapfrogging, at least in the domain of energy systems, has already been shown to significantly reduce the energy intensity of economies, lower pollution, and even create greater economic opportunity (Liddle and Huntington, 2021). Cavoli (2021) suggests that in rapidly growing cities, especially those in the Global South, leapfrogging can involve not only the substitution of technologies (better performing ones to inferior ones) but also cross-sectoral collaboration and system thinking, where communities leapfrog in their planning or their approaches to urban governance. Leapfrogging strategies relevant for transport in such cities can also focus on prioritizing active travel or collective transport modes, rather than merely cars or roads. Leapfrogging can relate to integration at the level of ministries or government action on mobility, and it can also focus on visions and vision-led planning rather than reacting to shorter term political cycles.

Broader social changes and contexts—the prevalence of hybridization, a proclivity for incrementalism, leapfrogging, the ability to afford a car, transient unemployment, living in an area with traffic congestion, having access to an electricity network or the internet—may hold just as much salience as innovation patterns or infrastructure in explaining transition patterns. An implication here is that processes affecting sociotechnical change manifest themselves not only on national and global scales, but at more micro individual, interpersonal, household, and intra-city levels.

5. Conclusion: harnessing innovation for low-carbon mobility

What are we to make of these conflicting drivers, barriers, and overall trends and dynamics? This final section of the paper draws inductively and qualitatively from our results to focus on three insights: one about tradeoffs, one about coupling, and one about innovation.

First, as Table 5 summarizes, the possible benefits of our three innovations exist only juxtaposed next to negative barriers; no innovation is purely positive or negative and all of them have multiple dimensions of positivity and negativity. There are thus (tragically) tensions within

Table 4

<table>
<thead>
<tr>
<th>Framing</th>
<th>Key features</th>
<th>Policy rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation for growth</td>
<td>Science and technology for growth, promoting production and consumption.</td>
<td>Responding to market failure: public good character of innovation necessitates state action.</td>
</tr>
<tr>
<td>National systems of innovation</td>
<td>Importance of knowledge systems in development and uptake of innovations.</td>
<td>Responding to system failure: maintaining competitiveness, coordinating system actors.</td>
</tr>
<tr>
<td>Transformative change</td>
<td>Alignment of social and environmental challenges with innovation objectives.</td>
<td>Responding to transformation failure: pathways, coordination domains, experimentation and learning.</td>
</tr>
</tbody>
</table>

Sources: Schot and Steinmueller, 2018.
each of the innovation options that could see improvements in sustainability or affordability but also the exacerbation of dilemmas and problems. For instance, high car ownership in South Africa could be a precursor for EVs, but also mitigates the potential of ridesharing or AVs because they lead to increased congestion and traffic jams. Two-wheelers could be electrified and thus better for the climate and environment than fossil-fueled ones, but would also contribute to motorized transport (rather than walking or cycling) and the risk of accidents. Walking and cycling may be the most affordable options for low-income households and residents but would preclude those households from accessing many of the benefits to motorized transport or the ability to commute for longer distances (Campbell et al., 2019). If access to transport modes is limited by income, then a first order condition might be for more equitable access to all three of our innovations.

Second, although we have treated each of the three innovations as fairly isolated from one another, there are emergent (and potentially strong) couplings or entanglements between them, such as the energy system (for EVs) and the mass transit system (for ridesharing), or digital networks (for automated mobility or some of the apps needed for ridesharing) or the housing system (which determines where people reside and thus their travel and commuting needs). As Fig. 7 also depicts, each of the three innovations can catalyze or enhance the adoption of the other two innovations, e.g. automated vehicles can also be electrified; ridesharing can rely on electrified vehicles and both can in turn influence automation (Sovacool et al., 2020). There is even a term used in some of the literature to describe coupling all three innovations together: Autonomous, connected, electric shared vehicles (ACES) (Adler et al., 2019).

However, if such coupling and future innovation is to reshape the transition into low-emission technology in an African context, despite decades of bearing the brunt of costly policy failure, then the three particular innovations of automation, electrification, and ridesharing need to be steered towards growth and transformation. Overall, the literature offers a sober critique of failed policy transfer and of policy transfer agents who are at times seen as cynical sellers of transport solutions without enough understanding of context and appropriateness.

International best practice will not work if local context and culture are not respected and incorporated, if bicycle lanes are to avoid being “empty” (Gota et al., 2019), if electric vehicle charging stations are to avoid sitting derelict and abandoned. More insight will be needed to evaluate how technology transfer happens, in what context, under what conditions, and to what degree of success, especially in conditions of

Table 5
The positive drivers and negative barriers facing automated mobility, electrification, and ridesharing in Sub-Saharan Africa.

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Positive drivers</th>
<th>Negative barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated mobility and self-driving cars</td>
<td>• Perceptions of improved safety</td>
<td>• Nonexistent or expensive digital infrastructure</td>
</tr>
<tr>
<td></td>
<td>• Ability for aerial drones to bypass congestion (esp. for medical drones)</td>
<td>• Lack of paved roads and poor maintenance of existing road networks</td>
</tr>
<tr>
<td></td>
<td>• New forms of economic activity (e.g., enhanced efficiency of freight delivery, expanded tourism)</td>
<td></td>
</tr>
<tr>
<td>Electrification and electric mobility</td>
<td>• Ability to leapfrog into EV infrastructure or incorporate African design principles</td>
<td>• Contribution of EVs to traffic congestion</td>
</tr>
<tr>
<td></td>
<td>• Compatibility with autocentric lifestyles</td>
<td>• Lack of reliable electricity supply or distribution</td>
</tr>
<tr>
<td></td>
<td>• Attractive niche markets for e-bikes and two-wheelers (for walkers or cyclists), e-buses (for mass transit) or fleets (for churches)</td>
<td>• Higher capital costs of vehicles and affordability concerns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased accident risks for two-wheelers and scooters</td>
</tr>
<tr>
<td>Ridesharing and bike-sharing</td>
<td>• Familiarity with ridesharing via existing mass or public transit schemes and taxis</td>
<td>• Possible rebounds and increases in travel use and associated impacts</td>
</tr>
<tr>
<td></td>
<td>• Can supplement walking</td>
<td>• Strong norms in some areas against cycling or bike-sharing</td>
</tr>
<tr>
<td></td>
<td>• Far more affordable than owning a private vehicle</td>
<td>• Affordability concerns for those in chronic poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lack of safety for cyclists (and two-wheelers when shared)</td>
</tr>
</tbody>
</table>

Source: Authors.

![Fig. 7. Positive interconnections and couplings between electrification, automation, and ridesharing. Source: Authors. AV = automated vehicle.](image-url)
poverty and limited resources such as those facing our four urban areas. Such an evidence base could link policy outcomes with learning, paying greater attention to collaborative research efforts, joint learning, and community acceptance (Dlugosch et al., 2020). There also remains a need for evidence-based programs to make the case for high-volume, low-carbon transport in Sub-Saharan African countries to show that a context-appropriate shift can reduce emissions as well as meet development and mobility needs.

Perhaps researchers and planners must begin to reject the tacit assumption that innovations and socio-technical transitions will necessarily come from the Global North (Alessandrini et al., 2015). In some contexts, hybridization, transformation, incrementalism and leapfrogging are seen as positive attributes and desirable characteristics of contexts, hybridization, transformation, incrementalism and leapfrogging are seen as positive attributes and desirable characteristics of change that will bring salient lessons to the Global North—enhancing a potential for deep mutual learning where the benefits of low-carbon mobility more inclusively and accountably shared among all of us.

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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