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African e-mobility startups' perceptions and use of information systems, challenges, and opportunities

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Abstract

For a systemic shift towards sustainable transport, a convergence of the mobility, energy, and information systems is vital. An information system is a combination of hardware, software, people and processes that collect, process, and distribute information to support analysis, decision making, monitoring and feedback. Information systems are central to the operation of numerous interconnected electric vehicles and services for passenger and freight transport, intelligent charging and pricing solutions, and energy management systems. This paper investigates the role of information systems in enhancing interoperability across multiple transport modes within the e-mobility value chain in Kenya, Tanzania, Nigeria, Ethiopia, and Senegal. It contributes to the emerging body of knowledge by analyzing how African startups interpret and engage with concepts such as Mobility-as-a-Service (MaaS), Artificial Intelligence, and E-Mobility-as-a-Service, thereby providing insights into the opportunities and challenges shaping digital transformation in African e-mobility systems. The research methodology combines the findings from case studies of MaaS implementations in the EU-funded SOLUTIONSplus Project together with in-depth interviews with African e-mobility startups operating a variety of electric vehicles. Thematic analysis was used to identify consistent patterns and relationships between the recurring themes in the data. The results show that information systems are intrinsically linked to e-mobility, with digital infrastructure underpinning critical functions that make them indispensable to the viability, scalability and sustainability of e-mobility ecosystems. Information Systems contribute to the development of innovative financial models, encourage financial accessibility to achieve carbon certification for sustainability and carbon emission mitigation, drive data-driven decision making and enable customer education and awareness. However, the implementation of information systems in the e-mobility sector remains hindered by challenges such as limited regulatory preparedness, fragmented systems, policy gaps, and financing constraints. In addition, factors including inadequate human resource capacity, insufficient customer and user awareness, and the absence of reliable data to inform decision-making further constrain the effective adoption of information systems.

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Introduction

Africa's cities are rapidly urbanizing, thus increasing the demand for energy and mobility services to facilitate economic development and social participation. Demand-side solutions for mitigating the effects of this rapid urbanization include strategies targeting technology choices, consumption, behavior, lifestyles, coupled production-consumption infrastructures and systems, service provision, and associated socio-technical transitions [1].

In most African countries, used light-duty vehicles constitute 85–100% of the total fleet, and between 2015 and 2018, Africa imported the largest share of used light-duty vehicles among the world's regions, at 40% [2]. Currently, travelers in African cities do not have the same access to a variety of modes of transportation as their counterparts in Europe and Asia, which often leads to a higher share of transport costs for individuals and companies in Africa. In selecting between different transportation modes, travelers consider a number of criteria, such as cost, travel time, flexibility, convenience, such as the location of the pick-up and drop-off points, the ability to listen to music, or privacy, reliability, and the perception of security [3].

A reoccurring feature in many developing economies is that transport systems are affected by high levels of corruption, poor network performance, limited access to data, high rates of poverty, investments focused on appeasing political constituents rather than emphasizing what is needed and prioritizing flagship construction projects (media attractors) rather than maintenance or upkeep [4]. Consequently, African countries lag behind in the adoption of innovations in public transport, such as electric mobility and the digitalization of transport services. However, there are emergent (and potentially strong) couplings of automation, electrification and digitalization or entanglements between them, such as the energy system for electric vehicles (EVs) and the mass transit system (for ridesharing), digital networks (for automated mobility or some of the apps for ridesharing) or the housing system (which determines where people reside and thus their travel and commuting needs) [5].

The literature reveals that technology-enabled initiatives in African cities are critical levers for adopting and exploring the benefits of emerging e-mobility technologies, as African cities are pushing to leverage tools and technology enabled by the fourth industrial revolution [6, 7]. However, many rapidly urbanizing African cities are struggling to meet the demand for public transport, and infrastructure is still a major challenge for governments with limited budgets and competing development interests. Public transit in Africa is dominated by the informal sector commonly referred to as Paratransit that is difficult to regulate and include in planning. Paratransit is an intricate system that involves many different players. These include privately-owned and operated public transport options that include buses, minibuses, vans, motorcycles, bicycles and tricycles.

The need to integrate paratransit as a demand-driven solution while achieving sustainability goals to reduce carbon emissions from the transport sector has created an opportunity for technology-based solutions. In this context, information technology can be used as an important resource for building solutions aimed at overcoming infrastructure and urbanism deficiencies, collecting information in multiple contexts, and constructing tools for management, planning, and other resources necessary for the development of smarter forms of mobility [8].

The increased penetration of mobile phones has led to immense innovation in transportation in response to user needs and demands. New transport services and technologies have been closely linked to the 'as a service' concept, describing a new paradigm where mobility is no longer consumed as an asset (i.e., based on private vehicle ownership) but rather accessed on demand [9]. Within the African context, there is limited research on the coupling of electrification and digitalization in the transport ecosystem, specifically how digital tools and information systems affect the adoption of shared e-mobility services. This paper analyzes the challenges and opportunities of integration and interoperability information systems in African e-mobility startups. It analyzes how stakeholders make decisions on information systems in their operating environments. The objectives of this paper are as follows:

- Identify opportunities for digital technologies that African e-mobility stakeholders can leverage;
- Identify challenges for implementing digital technology solutions in e-mobility companies;
- Identify strategies to support different e-mobility stakeholders in implementing digital technologies to achieve their goals successfully.

The role of information systems in electric mobility

Within the automobile industry, information systems can provide information on trips, driving patterns, and battery conditions [10]. When the multitude of systems are engineered and integrated into even more complex systems for e-mobility, interoperability and complexity handling are vital [11]. Research on the role of information systems in the transition to electric mobility encompasses a variety of topics, such as data management, digital payments, digital platforms, vehicle-to-grid integration, smart charging, and Mobility-as-a-Service (MaaS).

In recent years, many new transport and logistics digital services that address real-life urban mobility challenges have entered the African market, such as demand

delivery, bicycle sharing, car sharing and ride sharing, offering a high level of flexibility and convenience. The COVID-19 pandemic provided an opportunity to reflect on the quality and efficiency of the transport sector and unveiled the potential for innovation by introducing and scaling the use of cashless or contactless payment options within the continent. This would not only reduce the risk of spreading the disease but also increase the efficiency and transparency of the overall transport system.

The use of information systems by e-mobility startups services combined with public transport planning has great potential to catalyze a broader shift toward sustainable transport by renewing approaches to financing, infrastructure and vehicles. Big data analytics, the Internet of Things (IoT), and autonomous vehicles are closely intertwined with the future, which proponents argue will offer more efficient vehicle use, optimize transport networks, better utilize infrastructure and deliver a more seamless customer experience [9].

Mobility as a service (MaaS)

The MaaS proposition can be described as a one-stop, travel management platform with digitally unifying trip creation, purchase and delivery [9]. Common and central elements of MaaS have been proposed as: offering a service with customer/user/traveler transport needs as the main focus; offering mobility rather than transport; and offering the integration of transport services, information, payments and ticketing [12]. The levels of integration of services in the proposed topology of MaaS consist of integrated information services/multimodal travel information, integrated booking or ticketing, integrated payment or invoicing, organizational integration and bundling, which entails, e.g., a subscription to trips with different modes [12].

The literature on MaaS predominantly focuses on implementations in the Global North; however, the SOLUTIONSplus project explored implementations in the Global South. Under the SOLUTIONSplus project, a study on the potential transit accessibility gains and required policies under MaaS in Metro Manilla, Philippines, showed that the integration of informal transport into the transit network could almost triple accessibility from 23.9 to 65%, indicating that there is great potential for including micromobility in MaaS developments [13].

A second study under the project analyzed the implementation barriers of the MaaS concept in Quito, Kathmandu and Kigali [14]. The study revealed that despite some progress toward an intelligent and integrated transport system in the analyzed cities, many conditions present in the Global North, such as the formality and integration of the public transport system, still need to be met in rapidly urbanizing cities in the Global South before MaaS can be realized.

Data needed for information systems in the e-mobility transition

Sustainably transitioning to electric vehicles (EVs) is challenging where transport and electricity systems are poorly defined due to a lack of data, such as those dominated by paratransit [15]. For a sustainable transition to EVs in Africa, planning for power demand and mobility patterns is needed in many regions. To understand the trajectory of EV adoption, the demand for charging infrastructure and the skills needed to support this transition, stakeholders need to examine the tools and information systems used to collect and analyze these data. The literature review reveals that there is limited data on information systems and MaaS implementation in the e-mobility sector in Africa. The lack of organized public passenger transport alternatives in urbanizing cities in Africa has led to the dominance of informal, demand responsive modes that contribute to fragmented operations, lack of registration and oversight, high number of cash based transactions and limited use of technology. As a consequence, the public transport sector suffers from poor visibility of network performance, inaccurate ridership and trip estimates, lack of real-time operational data, difficulty in modelling demand and planning interventions.

The state of e-mobility in Africa

Over the past decade, the number of motorcycle 2 & 3 wheelers has been growing in Sub-Saharan Africa due to the availability of low-cost motorcycles from China and India that are used for informal commercial use for passenger taxis and deliveries [16]. As the conversation on electrification takes shape on the continent, most governments and private sector players target electrification of these vehicles since there is an emerging business case for local manufacture that was not feasible for the Internal Combustion Engine (ICE) vehicles due the maturity of the global ICE market. Furthermore, the cost of the acquisition of an electric 2 & 3 wheeler is lower than that of an electric car or electric bus making it an easier asset to acquire for majority of the average consumers.

The Kenyan transport sector accounts for approximately 12% of Kenya's total GHG emissions as of 2015, and an increased uptake of electric energy has the second highest mitigation potential [17]. This is largely due to a relatively low grid emission factor in the country's electric grid. In August 2023, the Ministry of Transport established the e-Mobility Taskforce to develop a National Electric Mobility Policy to create an enabling environment for the development, growth and adoption of electric vehicles in Kenya [18]. Launched in 2024, the draft National E-mobility Policy illustrates a comprehensive, multi-modal strategy to transition the country toward sustainable transport by reducing reliance on fossil fuels and cutting greenhouse gas emissions. As of December

2023, 2,694 EVs were registered in Kenya, bringing the cumulative number of registered EVs to 3,753 [19].

Nigeria's approach to e-mobility is anchored in its broader Energy Transition Plan (ETP) and commitments to decarbonize transportation. Unveiled in 2021, Nigeria's Energy Transition Plan (ETP) highlights the effort required to achieve the 2060 net zero target whilst also meeting the nation's energy needs [20]. Nigeria has a large fleet of 2 & 3 wheelers. Among the 13 e-mobility companies in the country, only 5 deal with 2&3 wheelers; the current EV fleet in Nigeria consists of at least 348 vehicles, representing a mere 0.002% of the total vehicle fleet of 18 million [21]. The national grid suffers from major weaknesses along the entire value chain, from generation and transmission to distribution, which have been difficult to address [22].

The Ethiopian government has an aggressive and fast-paced plan to fully transition to EVs, one of the most ambitious globally. Ethiopia's 10-year Perspective Development Plan calls on the government to import 4,800 electric buses and 148,000 electric cars, and in 2024, Ethiopia banned the import of non-electric cars and offered a new tax exemption for the import of electric cars as part of a green legacy project [23]. However, it's policy framework is still evolving, with efforts to establish incentives for local EV manufacturing and assembly.

Senegal's climate change strategy for e-mobility centers on decarbonizing urban transport through electric public transit, supportive regulation, and incorporating renewable energy sources. The government is developing a national EV framework to support the adoption of electric vehicles [24]. In 2024, Senegal launched Africa's first all-electric bus rapid transit (BRT) network in Dakar, marking a significant increase in sustainable urban transportation in the region [25]. The electric BRT is supported by a digital ticketing system that provides a check-in, check-out solution that offers access to services across 23 stations [26]. However, informal transport remains a major mobility mode in Dakar, and policy fragmentation challenges comprehensive sector regulation.

Tanzania is working to develop a comprehensive climate-aligned strategy to scale up e-mobility as part of it strategy to transition to decarbonize transport with the National Transport Policy (2003) currently undergoing review. The Tanzania National Climate Change Response Strategy (2021–2026) was developed to combat the negative impacts of climate change, and the National Transport Policy (2003) guides the development of efficient, well-integrated transport infrastructure and operations. Launched in 2024, Tanzania's electric Standard Gauge Railway (SGR) represents a landmark shift toward large-scale electric mobility in East Africa [27]. However, developments in the electrification of other modes has been much slower. Significant work was done through the SOLUTIONSplus Project, which introduced electric three-wheelers (tuk tuks) and electric bicycle feeder vehicles in the city.

Across the African countries described above, implementations on EV adoption have been driven by private sector players, specifically startups and have mainly focused on paratransit solutions with the exception of Senegal and Tanzania where the governments have made strategic investments through the electric BRT and the electric SGR. Even with these investments, the governments of Senegal and Tanzania are still lagging behind with regards to regulation that would support the growth of the e-mobility value chain in their respective countries. It is noted that the private sector is driving the evolution of e-mobility in most African countries, even as government regulation is struggling to catch up with this shift in mobility requirements.

Research methodology

In this paper, inductive reasoning was used to draw broader insights about the implementation of information systems in the e-mobility space, based on specific observations from case studies and stakeholder perspectives. The research combined findings from MaaS case studies in Dar es Salaam and Kigali, undertaken as part of the EU-funded SOLUTIONSplus Project, with primary data collected through semi-structured interviews with selected African e-mobility startups.

The interviews followed a semi-structured format, allowing for both guided discussion and open-ended responses. An interview guide was developed covering key themes such as: the role of information systems in operations, perceived technical and institutional barriers, capacity building barriers, impact on business models, integration with national policies and platforms, and the potential for data-driven service innovation. The interviews were conducted via online platforms, selected based on participant preference. The interviews aimed to validate findings from the SOLUTIONSplus Demonstration and Scale-up Concepts that were carried out for all partner cities in the framework of Living Labs. Living Labs are inclusive, real-world innovation environments where diverse actors—startups, governments, local communities, research institutions, and industry stakeholders—co-create and test e-mobility prototypes under actual operating conditions [28]. They help bridge sectoral and actor disconnects by fostering iterative learning and adaptation, thus improving the likelihood that digital solutions for fleet management, battery analytics, or MaaS platforms respond to local realities.

A total of 15 startups drawn from Kenya (5), Tanzania (3), Ethiopia (2), Senegal (2), Nigeria (2) and Italy (1) were selected through purposive sampling. The Italian company supported the MaaS case studies in Dar es Salaam

and Kigali. The respondents included founders, directors, and product or technology leads, offering insight into both strategic and technical perspectives within the startups. These startups varied in size, market focus, and stage of growth; working on Electric 2 & 3 wheelers (9), Electric Cars (3), Electric buses (2), and Information Systems Providers within the MaaS ecosystem (2).

Data from the interviews was analyzed using thematic analysis, following Braun and Clarke's approach that includes (1) familiarization with the data, (2) initial coding, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report [29]. Transcripts were coded manually to identify recurring patterns. Key themes included: data integration and interoperability, information system adoption and usage, digital infrastructure readiness, talent gaps, customer and partner relations, business models and regulatory fragmentation. Relationships between themes were then mapped to understand how various social, technical and policy factors influence the adoption of information systems in African e-mobility startups.

Findings and analysis

Perceptions of information systems

> *Our mobile app enables users to book accessible transport on-demand or in advance, improving convenience and transparency for persons with reduced mobility.Respondent, Kenya.*

The e-mobility startups leverage digital tools and information systems in their operations in the following ways: communication and collaboration tools, data storage, project management, business process automation, customer relationship management, trip booking, fleet management and digital payments. Information systems are also used in IoT integration with EV technology and enable data-driven decision-making. The startups specifically use them in managing charging infrastructure, fleet monitoring through centralized dashboards, telematics to track vehicle usage and driver behavior, reduce financial risk, route optimization, and ultimately contribute to carbon mitigation.

For persons with reduced mobility, e-mobility information systems enhance accessibility and inclusivity by connecting users to mobility options in real time. By digitizing the process, it fosters greater transparency, efficiency, and data-driven service improvements in accessible transport.

The respondents measured the successful implementation of these digital tools and information systems via usage metrics, user feedback and complaints, time saved from the reduction in manual work, revenue generated, process improvements, system reliability and compatibility, customizable solutions to meet business needs, smooth customer onboarding, system integration with government systems and standardization of data formats across partners.

Strategic technology partnerships

> *We explore strategic partnerships to access technical expertise, reduce development costs and test scalable digital solutions without heavy upfront investment," respondent, Kenya.*

For e-mobility startups, the question of using third-party technology solutions versus developing information systems in-house is a balance of cost efficiency, expertise, and scalability while ensuring alignment with the startup's core business goals.

Among the startups interviewed, 31% of the startups preferred in-house development, citing internal team capacity and expertise. These respondents viewed in-house development as an opportunity to build specialized digital applications that can be repurposed as white label solutions, thus creating independent revenue-generating spin-offs with long-term scalability potential in the e-mobility sector. A further 46% adopted a hybrid approach; combining in-house development to maintain control of select system functions with third-party applications for fast integrations, reliability and to increase cost efficiency. Meanwhile, 23% of the respondents opted for a fully third-party development model, often using white label solutions, due to lack of in-house expertise. These startups emphasized the need to focus on growing their core business, vehicle manufacturing, while leveraging technology partnerships to support their information system's needs.

Challenges of implementing information systems

> *We tried using a payment gateway but customers were not aware or digitally savvy, the transaction cost was too high, and customers were not comfortable making larger transactions (on the digital platform), respondent, Ethiopia.*

Human resource challenges Some startups noted that limited technical experience among employees often led to resistance in adopting new systems, resulting in slower onboarding, requiring significant time and effort to train and gain buy-in. This created potential knowledge gaps within teams. Additionally the high cost of getting skilled talent to build and maintain information systems led many startups to pursue external partnerships or engage with broader ecosystems for specialized tasks.

Technological development and customization The startups emphasized that evolving business models within the emerging e-mobility industry require tools that are both simple for users and robust enough to adapt to shifting operational and market demands. A notable example is telematic systems originally designed for fossil-fuel vehicles, often require extensive customization for EVs to track charging levels, costs, and battery health. A related challenge is the lack of standardization and interoperability across information systems. Customers increasingly expect seamless integration into existing digital platforms instead of learning to adopt new standalone tools.

Technology integration cost The high cost of onboarding technology partners, particularly due to high per-user costs, limits integration with certain information systems, especially for resource constrained startups. Furthermore, pricing for some of these third-party software is not transparent, therefore driving up implementation costs for developing, customizing, and maintaining information systems.

Customer and partner adoption Respondents noted that many customers and driver partners are often hesitant to download or use new apps, citing a preference for consolidated platforms or minimal interaction with digital tools due to application fatigue. Digital adoption among users, e.g., bus operators and riders, requires significant user education and user support. Additionally, customers' unfamiliarity with digital payment gateways and discomfort in carrying out high-value transactions online further impedes the adoption of information systems. A fundamental barrier to the adoption of digital solutions by customers is the low-level of digital literacy, which continues to challenge the effective implementation of these technologies.

User accessibility needs A startup focused on users with reduced mobility needs emphasized that designing inclusive electric vehicle systems for users with diverse disabilities, such as visual, mobility, cognitive impairments, requires extra testing and refinement to ensure adequate accessibility and usability.

Table 1 Internet penetration and mobile phone connections per country [31–35]

Country	Internet Penetration	Mobile Phone Connections
Senegal	60.0	121.8
Nigeria	45.5	90.7
Kenya	40.8	118.7
Tanzania	31.9	99.0
Ethiopia	19.4	60.4

Lack of reliable data Predictive tools depend on accurate and comprehensive datasets, which may be unavailable in many African cities due to poor recording and data collection practices. Moreover, challenges in validating customer information can lead to system inefficiencies and potential risks in decision-making.

Policy and regulatory barriers The rapidly evolving regulatory landscape for e-mobility presents challenges in terms of compliance. This was highlighted as a challenge in Kenya and Nigeria. Compliance with government regulations, particularly changing tax requirements can introduce significant complexities in system integrations. Startups often face challenges integrating these evolving regulations into third-party software, since doing so requires ongoing coordination with international partners to modify proprietary information systems. In addition, outdated Know Your Customer (KYC) protocols coupled with asymmetric information in financial transactions, where one party, usually a microfinance institution, has more information on a product than the buyer, contributes to predatory lending practices and hinders seamless integration of financing tools.

While the challenges discussed have been generalized at a continental level, country-specific factors, such as internet penetration and digital literacy, play a critical role in shaping outcomes. These factors influence the skill level of the available workforce, user readiness to adopt information systems, and the accessibility of digital solutions. Respondents from countries with lower internet penetration (Tanzania, Ethiopia) reported greater difficulties in raising user awareness, delivering adequate training, and sourcing qualified local talent. Additionally, the success of digital payment systems, which are vital for widespread adoption of e-mobility information systems, depends on foundational enablers such as a large customer base, robust technology infrastructure, and a supportive regulatory and institutional environment [30]. Table 1 summarizes the internet penetration and mobile connection rates as a percentage of the country population.

Opportunities for implementing information systems

> *People are just tired of apps, how many apps do I have to have on my phone?...What will happen (since people are tired of having many apps)? Consolidation. If an app already exists, can you put my services on that app, respondent, Nigeria.*

While the adoption of information systems in Africa's e-mobility sector faces complex challenges, these systems present a significant opportunity to address critical

gaps and support a wide range of stakeholders across the e-mobility value chain.

Consolidation of applications A respondent expressed concern over the overwhelming number of mobile apps users, mostly riders, are expected to manage, describing it as inconvenient and unsustainable. This fragmentation could lead to user fatigue and diminished engagement. As a result, the startup anticipates a shift towards consolidation: fewer, more integrated platforms that bundle multiple services into a single, user-friendly app. Additionally, there is a growing interest in many EV players to leverage existing solutions rather than reinvent the wheel, particularly as the adoption of ridesharing and vehicle-sharing apps increase. As startups specialize on their core value proposition, there is growing openness to integrate with established information systems providers. These consolidation of digital solutions contributes to the development of a robust ecosystem that supports multimodal integration of EV services and creates an enabling environment for the adoption of MaaS.

Financial models and accessibility By leveraging digital payments and transaction data, e-mobility startups are able to offer flexible leasing models that promote EV ownership. This approach enables them to lower upfront deposit requirements and structure manageable recurring payments (e.g. daily, monthly), thereby reducing financial barriers and improving accessibility for a broader range of users.

Carbon certification E-mobility startups can leverage data generated by the information systems for telematics, route optimization, and carbon tracking to achieve carbon certification. Carbon certification verifies that an e-mobility startup reduces and avoids greenhouse gas by switching from diesel, enabling it to generate carbon credits that can be sold on voluntary or compliance carbon markets.

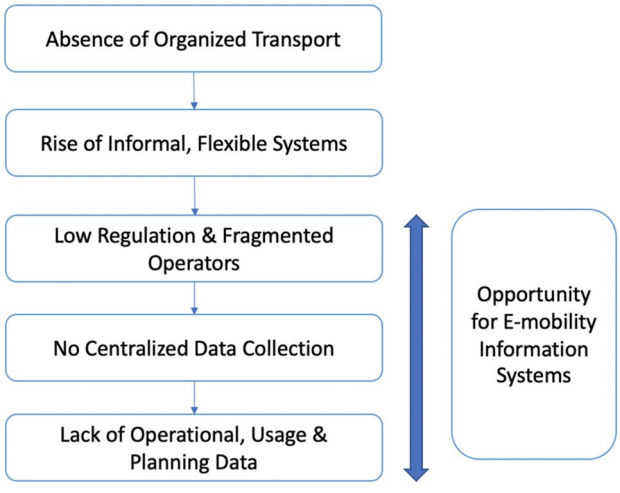

Fig. 1 Opportunity for e-mobility Information Systems in the Rapidly Urbanizing African Cities [36]

Education and awareness Digital tools and information systems create valuable opportunities for stakeholder engagement, user training and awareness creation. Platforms such as social media and online forums such as webinars are increasingly used to educate and connect with users, helping to promote understanding and uptake of e-mobility solutions.

Data-driven decision making E-mobility startups strongly emphasize the importance of collecting and analyzing data to inform decisions and monitor performance. The need for data-driven decision-making drives the desire for operational success through the integration of coherent and consistent systems. Information systems in the e-mobility sector in Africa are creating opportunities for predictability and structure in the informal paratransit sector. By enabling public transport stakeholders to collect reliable data through integrated digital platforms, information systems support evidence-based decision making for improved mobility planning and service delivery. Figure 1 illustrates a visual representation of the opportunity for information systems implementation in the paratransit sector.

Digital infrastructure and the evolution of e-mobility business models

> *Digitization, information systems, and digital applications have impacted our business models by transforming how product value is created, delivered, and captured. Respondent, Tanzania.*

Digital infrastructure, through the provision of digital applications, digital payments, and connectivity with electric vehicles via information systems, enables the development of data driven digital products that support innovative business models. These models facilitate the adoption of EVs in resource constrained environments. They incentivize investments toward infrastructure and policy investments that are not fossil-fuel dependent, promoting systems that are sustainable and climate responsive. Respondents consistently emphasized that digitalization, and the associated digital tools, enhances product value by enabling greater scalability and long-term sustainability across the entire value chain of their businesses. The availability of information systems enables startups to integrate with various stakeholders, such as EV charging infrastructure companies and payment gateways, and form strategic partnerships that

support a collaborative approach to infrastructure development. The value of their business models is not only built on economic transactions but also interactions and integrations that take place among stakeholders. Thus reinforcing the proposition that sustainable business models require a system of sustainable value flows among multiple stakeholders, including the natural environment and society as primary stakeholders [37].

The adaptation of digital platforms and the integration of mobile money in business processes have been adopted by players in the e-mobility ecosystem, ranging from asset finance companies to mobile lending platforms. Digital payments have helped to reduce (upfront) costs and improve the speed of collections for asset lenders, while allowing customers to pay anytime, anywhere, and with a system that is already familiar [38]. The availability of flexible mobile payments enables EV riders to access vehicles through a range of revenue models including leasing, lease-to-own or pay-as-you-go schemes, or direct purchase. Table 2 summarizes the revenue models adopted by the startups.

Despite the availability of digital payments, interviewed Ethiopian and Nigerian startups reported low adoption rates with many users preferring cash transactions, posing a barrier to seamless digital integration. It has been shown that regulatory innovation (e.g. Kenya) better enables the success of new technologies and their concomitant behavioural change than bank-led and preemptive (e.g. Nigeria) regulatory styles [30].

Through real-time tracking, startups have the ability to control use of the EVs depending on the repayment status. It is noted that the dominant business model from the respondents have the 'as a service' concept where the asset is accessed on demand. The EV types, whether a 2 & 3 wheeler or a bus, will influence the specifics of the business model due to the investment and the maintenance required. However it should also be noted that for light duty EVs, a few individual customers have purchased the them upfront.

MaaS implementations in the solutionplus project

> *Trust is needed. MaaS has to be built by all stakeholders depending on the needs of the city, respondent, MaaS Provider, Italy.*

Under the SOLUTIONSplus project, despite the possibility of testing a customized white label MaaS app free of charge for the duration of the SOLUTIONSplus project in Tanzania and Rwanda, only the Rwanda case started and continued the process [14]. In Kigali, Rwanda, discussions were held between the SOLUTIONSplus team and the representatives of the City of Kigali to implement a customized MaaS app; however, a joint decision was taken not to pursue it. The government of Rwanda is driving the push to accelerate the adoption of digital payments and electric mobility, there is a local digital payment provider in the transport sector. The government has also introduced zero VAT on EV imports, exemptions on import and excise duties for EV parts, and an industrial tariff for EV charging, making the sector more accessible [41]. However, regulations restricting the storage of transport cloud data outside the country prevented the integration of the MaaS application. In Dar es Salaam, the local transport agency made the decision to develop its own trip planning and ticketing app, since the conditions to implement a MaaS app for BRT buses and integrate paratransit modes were not in place.

These implementations highlight the challenges of obtaining agreement among local and international stakeholders on policies around global third-party integrations. The MaaS company from the project identified access to data as a significant challenge, particularly in areas where information was not digitized. Many

Table 2 Revenue models adopted by the startups [40].

Revenue Model	Ownership	Frequency	Flexibility	EV Type
Leasing	No ownership	Fixed Term (e.g. monthly, weekly)	Low (Structured and predictable payments)	Fleets of all EV types, individual EVs
Battery-as-a-service	No ownership	Recurring payments (e.g. monthly, per swap)	High (pay on usage)	Electric 2 & 3 wheeler, E-buses
Pay-as-You-Go (PAYG)	Ownership not guaranteed	Usage based (e.g. per ride, daily)	High (can stop anytime)	Electric 2 & 3 wheeler
Pay-as-You-Drive (PAYD) [39]	Ownership not guaranteed	Mileage based	High (can stop anytime)	Electric Buses
Lease-to-own	Ownership after full term payment	Fixed installments over a Term	Medium (Structured and with penalties for delay)	Electric 2 & 3 wheeler, E-buses, E-cars
Direct purchase	Ownership after purchase	One-time upfront payment	Low (Structured one-time payment)	All EV Types
Subscription Services	No ownership	Recurring payments (e.g. monthly, weekly)	High (pay on usage)	Information systems, Electric 2 & 3 wheeler (e.g. MaaS, E-mobility-as-a-service, charging infrastructure)

African cities lack standardized GTFS (General Transit Feed Specification) data, making collecting and mapping transport data difficult. Although the adoption of a MaaS application is expected to enhance the public image and level of service of transport operators, many local stakeholders lacked the capacity and resources to invest in the intensive development of such an information system.

Perceptions of MaaS

> *Most (EV) companies are trying to come up with everything and it's really hard to scale, respondent, Tanzania.*

Of the startups interviewed, 67% indicated having knowledge of the concept of MaaS and viewed it as a promising pathway to implement sustainable e-mobility solutions. However, they recognized the complexity of deploying ride hailing and journey planning applications in Africa. Most notably there are significant gaps in infrastructure that affect the integration of existing digital mapping tools; for example, Google Maps struggles with road accuracy in many African cities. Furthermore, many startups face scalability challenges as they attempt to single-handedly manage all operations in-house, leading to significant resource and capacity constraints.

There is a growing interest among resource-constrained startups in blending in-house development with application consolidation, coupled with an openness to collaborate with third-party partners to optimize resources. This is reflected in their preferred development approaches, 31% of the startups preferred in-house information systems development, 46% of startups favored a hybrid model combining in-house with third-party development, while another 23% relied solely on third-party applications. These preferences indicate a favorable environment for the gradual and locally tailored introduction of MaaS applications, aligned with different levels of integration [12].

Two respondents, in Kenya and Senegal, said that they are implementing E-mobility-as-a-Service in their operations. This means the MaaS principles are applied in their e-mobility startups through subscription services for electric motorbikes and EV fleet management solutions. In all the cases analyzed, the startups are exploring integrated features such as digital payments, embedded trackers for vehicles and remote control of batteries to prevent theft or misuse.

Startups recognize the value of collaborating with external partners such as asset finance companies, e-commerce platforms, digital payment gateways and app-hailing companies to streamline resources and scale efficiently. They also recognize the importance of consolidating ride-hailing platforms and digital transport services to increase efficiency and integration.

Perceptions of artificial intelligence and machine learning

> *We work with drivers or owners who don't have much of a digital footprint, people drive in a controlled chaos, AI can only work when there is predictability, respondent, Senegal.*

The perceptions of artificial intelligence (AI) and machine learning (ML) in improving e-mobility development in Africa vary, reflecting both optimism and skepticism about their current applicability. The respondents highlighted the strategic potential of AI and ML in the African E-mobility space. Among EV technologies, AI and ML can optimize battery usage. Within the EV manufacturing sector, AI leverages opportunities to automate and monitor local assembly lines, identify production bottlenecks, and ensure the smooth flow of materials and parts to enhance continuous production. AI tools can also be used to streamline processes to reduce inefficiencies in charging infrastructure, business models, and vehicle routing.

However, many e-mobility companies lack meaningful data to exploit AI and ML. Without robust datasets, AI and ML models remain limited and theoretical in most cases. They also noted that implementing AI and ML systems requires significant time, money, and technical training. Driving and transportation in some regions in Africa operate in an environment of "controlled chaos," making it challenging for AI and ML systems, which rely on predictability, to deliver meaningful results. The resounding response from the startups was that they believed that AI and ML should address the "last 5% efficiency challenges" rather than foundational challenges such as lack of data, talent gaps, and standardizing operations.

Discussion

> *"Information systems are at the heart of everything we do," respondent, Kenya.*

From the discussions with the startups, it is clear that information systems are necessary to streamline and increase efficiency of their operations and service delivery. In the African context, a nuanced approach is required to meet the needs of the innovators leading the charge of EV adoption in complex operating environments. These insights, illustrated in Table 3, highlight how different types of EV startups are leveraging information systems to overcome operational, infrastructural,

Table 3 Overview of challenges EV startups face and their corresponding digital integration strategies [42]

EV type	Key challenges	Digital integration
E-buses	- Onboarding and adoption of digital tools -Access to reliable data sets - Prioritisation and speed of delivery in a fast evolving business - Charging infrastructure planning	- Passenger (commuter) management -Centralized Fleet management - Digital Payments -Manufacturing process management - Enterprise Resource Planning
E-2 wheeler & E-3 wheeler motorcycles	- Trust and awareness of digital payment systems - Hidden costs with digital integrations - Financing of EVs - Talent acquisition - Regulatory compliance - Data asymmetry -Charging infrastructure availability	- IoT based Asset tracking -Digital Payments - Enterprise Resource Planning -Fleet Management -Ride Hailing
E-cargo bicycles	- Dynamic customer requirements - Data harmonization - Application fatigue - Talent Cost and acquisition	- Bike sharing - Route optimization - Digital Payments - Fleet management - IoT based Asset tracking
E-cars	- Financing of EVs - Charging infrastructure availability - Customizing telematics for EVs - User Accessibility Needs - Talent acquisition	- Digital Payments - Fleet Management - Ride Hailing - Telematics - Booking application

and market-related barriers in a rapidly evolving mobility ecosystem.

Two overarching themes have emerged as critical enablers for the effective implementation of information systems in e-mobility companies: capacity building and developing strategic partnerships.

Capacity building gaps

The capacity-building needs of African e-mobility startups in terms of information systems reflect a mix of technical, organizational, and cultural challenges. As the uptake of low-carbon mobility solutions has lagged behind its potential, an integrated multimodal, multilevel sustainable transport package should address all aspects of the mobility system and seek alignment and complementarity between national and local policies as well as between public and private sector actions [43]. As electric mobility transforms traditional transport systems, it also introduces a significant skills gap that could lead to the economic displacement of many blue-collar and non-technical workers. To mitigate the potential job losses, it is imperative to partner with local education institutions to develop a skilled workforce equipped to implement and scale these e-mobility technologies. Furthermore, offering training materials and resources in locally relevant languages enhances inclusivity and accessibility. In addition, raising awareness of the practical benefits of digital tools in professional workflows can help shift user preferences from traditional methods (e.g., phone calls) to digital communication and collaboration tools.

Building on the need for inclusive skills development, startups play a pivotal role in advancing the e-mobility transition across Africa. As drivers of innovation, they are catalyzing the digital shift by optimizing operational processes and integrating information systems into their business models. Their role is especially critical in promoting the incremental adoption of digital tools and cultivating in-house capacity that supports both growth and long-term sustainability. To bridge internal skills gaps, particularly in emerging technologies, startups can collaborate with academic institutions and innovation hubs to deliver targeted bootcamps and foster peer-to-peer learning, thereby accelerating knowledge exchange and workforce readiness.

Taking a longer term view of the wider e-mobility information systems ecosystem, it is essential to invest in foundational skills by promoting Science, Technology, Engineering and Math (STEM) education at all levels of learning. Strengthening STEM pathways will future proof the E-mobility ecosystem in Africa by cultivating a workforce capable of sustaining and advancing the digital infrastructure required for E-mobility. In parallel, fostering developer communities focused on the digital integrations in the E-mobility space can serve as Innovation Hubs and Living Labs, driving local solutions, enabling collaboration, and ensuring that technological progress remains inclusive, accessible, contextually relevant, and scalable across the region.

Partnership gaps

Given that most of the EV hardware technology development for the startups interviewed is currently carried out in China, fostering strategic collaboration with Chinese vehicle developers and hardware providers is essential to ensure seamless integration of hardware and software prior to implementation in Africa markets. To drive local innovation and customization, startups emphasized the role of national and regional e-mobility associations in supporting them to contextualize e-mobility technologies and information systems. In addition to this, there is a need for these startups, supported by their respective national e-mobility associations, to forge stronger alliances with government, regulators and academic institutions. Such partnerships are essential for addressing

the policy and regulatory challenges affecting their businesses.

The startups highlighted the critical importance of partnering with information system providers that offer access to third-party integration platforms, enabling them to optimize operations and increase service delivery efficiency. To support a more enabling environment, continuous engagement with government and policy stakeholders is essential to shape policies, standards, and regulatory frameworks that facilitate the adoption of e-mobility solutions. Additionally, fostering collaboration through the sharing of resources, data, and best practices between startups and public institutions can accelerate sector-wide learning and innovation. Developing regional Application Program Interfaces (APIs) and centralized mobility data platforms will be key to ensuring interoperability and fostering a more connected, efficient, and scalable e-mobility ecosystem across the continent.

Strengthening integration through living labs and scale-up frameworks

In addition to the highlighted capacity- and partnership-building gaps, it is increasingly evident that harnessing Living Labs can accelerate the development and deployment of information systems within African e-mobility startups. A key insight from the SOLUTIONSplus demonstrations, is that Living Labs offer a structured way to gather data for impact assessments and scale-up concepts [44]. By embedding telematics solutions and IoT-driven data collection mechanisms in pilot fleets, startups can refine business models and evidence-based policies. These pilot stages lower the risk of rolling out large-scale information systems by generating feedback on battery health, driver/customer adoption, and payment gateway integration. Furthermore, Living Labs streamline coordination with policymakers, enabling quicker adaptation to new government regulations, one of the recurring startup pain points identified in this study.

Critically, drawing from "safe system" approaches to sustainable transport governance [45] shows that embedding e-mobility innovations in multi-actor coalitions reduces the pressure on individual startups to single-handedly bear the costs and risks of advanced technology solutions. Such coalitions can yield standardized data-exchange protocols, consolidated procurement strategies, and common platforms for user education. These elements not only enhance the interoperability of digital platforms across different vehicle classes—motorbikes, three-wheelers, and buses—but also help localize solutions to socio-technical contexts. Previous experiences in the SOLUTIONSplus Living Labs confirm that when startups collaborate under shared guidelines for testing, policy alignment, and resource-sharing, they more readily attract both private and public investment [46].

Institutionalizing the insights from Living Labs within scale-up roadmaps and impact assessment frameworks fosters long-term viability. For instance, building on a city- or region-wide e-mobility information system pilot can pave the way for replicating standardized IoT architectures across neighboring markets [47]. Startups can thus evolve from ad hoc software deployments to robust, integrated, city-level platforms for charging, payments, and operational analytics. This institutionalization ensures that local stakeholders and regulators remain actively involved and jointly committed to continuously refining the digital ecosystem that underpins African e-mobility's growth.

Limitations of the study

One notable limitation is the restricted generalizability of the results across the broader African E-mobility landscape. The startups interviewed represent the nascent and uneven development of the e-mobility ecosystem across the continent. Furthermore, empirical research on the influence of information systems in facilitating e-mobility adoption within the African context remains scarce. This gap constrains the ability to establish robust benchmarks, conduct comparative analyses, or triangulate findings across different studies. As the e-mobility sector grows, future research can focus on specific subregions within the continent and specific vehicle types to build a nuanced understanding of the sector.

Secondly, the adoption of interconnected and integrated e-mobility information systems is highly context dependent. On the policy level, a respective country's energy mix, energy policies and digital transformation strategy significantly influence whether there is a supportive environment for the successful implementation of e-mobility information systems. It underscores the need for further research that clusters ecosystems based on context-specific factors such as transport demand profiles, energy infrastructure, and digital strategy frameworks.

Future research

This study on e-mobility in Africa has highlighted the need to strategically focus on the integration of mobility, digitalization, energy, infrastructure, financing and governance. From the discussions it can be seen that there is a growing demand for data analytics and telematics for real-time tracking of vehicles and driver behavior. Telematics can be used to quantify carbon reductions, support access to carbon credits and appeal to banks and investors seeking green portfolios. More research is needed to look at how data analytics and telematics can be used to demonstrate the sustainability of electric vehicles and build impactful business models for carbon reduction.

Through the encouragement of open data in the e-mobility sector, data can be used to support governments to model demand for charging infrastructure and make energy investments. This is especially important for planning and deploying EV charging infrastructure, where the availability and reliability of charging stations is a major determinant of adoption. Investments in commercial-grade charging infrastructure must be paired with careful planning around power stability, site selection, and grid access, with an emphasis on government coordination and long-term land-use planning. More research is needed to inform the location of micro-charging hubs for electric 2 & 3 wheeler operators, low-cost, high-impact interventions that expand access and visibility. Local governments can use this data to map suitable public land to set up charging infrastructure and inform the framework for public and private sector deployment.

The African landscape requires information systems and e-mobility interventions that are tailored to the dominant, fast-growing, demand-responsive informal transit modes. By modelling travel demand and combining this with artificial intelligence an interdisciplinary approach can be adapted to address the complexities and uncertainty of mobility in African cities. This holistic approach brings an understanding to individual travel behavior and the systems that shape mobility patterns in rapidly urbanizing cities. To further support planning and integration of paratransit with the more regulated public transit service providers, such an approach offers a dynamic, adaptive and context sensitive model for leveraging e-mobility information systems in the paratransit sector.

Conclusion

African e-mobility startups are navigating a complex mobility landscape as they integrate information systems into their operations. In exploring use cases from various African cities, the paper highlights the tension between innovation and informality. E-mobility startups are operating in environments with weak integration of paratransit modes, low interoperability between digital platforms, and limited access to public transport data, all of which are crucial for successful implementation of e-mobility information systems. Moreover, the ability of startups to scale depends on strengthened digital and e-mobility regulatory conditions, access to digital infrastructure, and human capital development, particularly in digital literacy and system design.

Without digitalization, e-mobility cannot achieve its full potential. Digital systems support real-time data flows, predictive maintenance, and user interface systems, thereby enabling the operational efficiency, scalability and sustainability of e-mobility initiatives. All the startups interviewed acknowledge the role information systems integration plays in their path to growth and scale. Information systems are a critical lever for optimizing business models in dynamic, cost-sensitive and infrastructure-constrained environments. Going forward, investments in information systems, cross-sector partnerships, and policy alignment will be critical to ensuring that e-mobility in Africa is scalable, sustainable, and locally embedded.

Author contributions
Judith Adem Owigar wrote the main manuscript text, carried out the interviews and the analysis. Oliver Lah contributed to the manuscript integrating the SOLUTIONSplus Living Labs and Scale Up concepts perspectives. Both authors substantially revised and reviewed the manuscript.

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Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Competing interests
The authors declare no competing interests.

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