Towards Inclusive Intelligent Transportation in Africa

Initial Lessons from Rwanda

Ahmed Biyabani, Andrea Denzinger (Eds.)

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Editors:

Dr. Ahmed Biyabani, CMU-Africa
Andrea Denzinger, GIZ

Acknowledgement:

With thanks to the participants of the Afretec Inclusive Digital Transformation Workshop on Intelligent Transportation held on 20.10.2022, discussions from which lay the foundation for this document. Apologies for any omissions.

Dr. Ismail Berrada, UM6P
Prof. Vijayakumar Bhagavatula, CMU
Dr. Khaled Harras, CMU-Qatar
Alphonse Kanyandekwe, RSB
Marvin Manzi, Volkswagen-Rwanda
Elie Mberabagabo, RNP Traffic Dept.
Alain Murara, RURA
Dr. Emmanuel Ndashimye, CMU-Africa
Dr. Alphonse Nkurunziza, UR
Dr. Louis Sibomana, NCST
Prof. Ozan Tonguz, CMU
Dr. Eric Umuhoza, CMU-Africa
Clovis Wanziguya, GIZ
Lisa Werkmeister, GIZ
Prof. Moustafa Youssef, AUC

Special thanks for reviewing:

Mateo Gomez, GIZ
Dr. Barry Rawn, CMU-Africa

Funded in part by the Mastercard Foundation via the Afretec Network.

Table of Contents

Abbreviations

ADAS.. Advanced Driver Assistance Systems
Afretec .... African Engineering and Technology Network
AI... Artificial Intelligence
AUC .... American University in Cairo
CCTV .... Closed Circuit Television
CMU..Carnegie Mellon University
CSRS ....Coordinated Smart Road Safety
CO2...Carbon dioxide
DSRC... Dedicated Short-Range Communications
EFTS.. Electronic Funds Transfer System
E-mobility ....Electric mobility
ETA.. Expected Time of Arrival
EV .... Electric Vehicle
GTFS .... General Transit Feed Specification
ICE... Internal Combustion Engine
ICFM... Intelligent Connected Fare Meter
IDT.. Inclusive Digital Transformation
ITS... Intelligent Transportation System(s)
ITMS .... Intelligent Traffic Management Systems
LDCs .... Less Developed Countries
LMICs.. Low- and Middle-Income Countries
NCST .... National Council for Science and Technology
NGO.. Non-Governmental Organization
PMHS .... Performance Monitoring Hub System
PPP... Public-Private-Partnership
QoS .... Quality of Service
RNP... Rwanda National Police
RSB .... Rwanda Standards Board
RURA .... Rwanda Utilities Regulatory Authority
R&D .... Research and Development
V2I... Vehicle-to-Infrastructure
V2V .... Vehicle-to-Vehicle
V2X .... Vehicle-to-Anything
VICS... Vehicle Information and Communication System
UM6P.. Mohammed VI Polytechnic University
UN... United Nations
UR .... University of Rwanda
VMS .... Variable Message Signs
WHO .... World Health Organization

Executive Summary

This whitepaper stems from a workshop on Intelligent Transportation [1] held in late 2022 as part of the Mastercard Foundation funded Afretec initiative on Inclusive Digital Transformation. The initiative aims to support research and innovation for positive social and economic impact in Africa via Carnegie Mellon University Africa and its partner institutions across the continent and overseas. The workshop brought together stakeholders from academia, government, business as well as non-governmental organizations to solicit their knowledge, insight, and advice. This follows a recent UN report on sustainable transport for sustainable development [2] and other efforts to develop sustainable urban mobility plans [3].

This paper takes a digital approach to identifying and addressing transportation issues with the objective of pointing the way towards developing a sustainable transportation ecosystem. It suggests the use of intelligent transportation systems (ITS) built on information systems, communications, and sensors, to improve the efficiency and safety of road transport. Using ITS can lead to a greener, more productive future based on safer and more reliable travel.

In order to apply technology solutions in the region, stakeholders have already started activities to help address some essential questions:
Have we developed a clear understanding of the transportation ecosystem? Work is underway. [4]
How do we address the key issue of acquiring data for these ITS applications to work? Researchers have already produced some local prototypes with available resources [5].
Will ITS be useful when most vehicles in Africa are second hand without advanced technologies in place? Studies suggest that even with fractional adoption, high tech solutions can lead to improved safety and efficiency [6].

Regarding the role of government, the public-private partnership (PPP) model will remain the predominant way of doing things, where most of the analytics and operation and provision of technologies are externalized and contracted to the private sector. So, in the context of ITS applications in the continent, it would be critical that the authorities build and retain the capacities necessary for understanding the local circumstances, specifying the service, technology and contractual requirements and specifications to work with the private sector, and to request the right information needed for decision-making. It would be especially important to acquire the capacities to act upon the information provided by the private sector to make the right planning, regulatory and policy decisions.

The paper is structured as nine sections reflecting the discussions and presentations from the workshop. The sections are grouped into three parts by theme: (A) global motivation for smart mobility and intelligent transportation and its applicability in LDCs, (B) use cases and examples from Rwanda, and (C) design principles and the requirements for telecoms to support ITS.

Introduction

This whitepaper stems from a workshop on Intelligent Transportation [1] held in late 2022 as part of the Mastercard Foundation funded AFRETEC initiative on Inclusive Digital Transformation (IDT). The initiative aims to support research and innovation for positive social and economic impact in Africa via Carnegie Mellon University Africa and its partner institutions across the continent and overseas. The workshop brought together stakeholders from academia, government, business as well as non-governmental organizations to solicit their knowledge, insight, and advice. This follows a recent UN report on sustainable transport for sustainable development [2] and other efforts to develop sustainable urban mobility plans [3].

The aim of the workshop was to help shape an agenda for applied research, development and deployment of various new digital technologies to improve mobility and transportation in Rwanda and later in Africa more broadly. Participants motivated the need for smart mobility and suggested practices, standards and policies with inclusivity and decarbonization as two important goals. They reported on certain aspects of transportation in Rwanda informed by local traffic and regulatory authorities, on work at universities, related to smart cities, as well as the collaborative projects of international development organizations. From the associated discussions, it became clear that the priorities and desired eventual outcomes are improved safety, reduced pollution, better quality of life and increased economic activity.

The workshop spawned subsequent discussions between academic, development and commercial partners which in turn led to preparation for the establishment of a Smart Mobility Lab in Kigali in early 2024. It is hoped that the Lab will serve as a model that can help generate more comprehensive mobility plans here and which can be scaled up to larger countries and regions in Africa and elsewhere.

Approach and Application

This paper takes a digital approach to identifying and addressing transportation issues with the objective of pointing the way towards developing a sustainable transportation ecosystem. Figure 1 depicts a preliminary view of the interaction among the various sectors. The paper also suggests the use of intelligent transportation systems (ITS) built on information systems, communications, and sensors, to improve the efficiency and safety of road transport. Using ITS can lead to a greener, more productive future based on safer and more reliable travel.

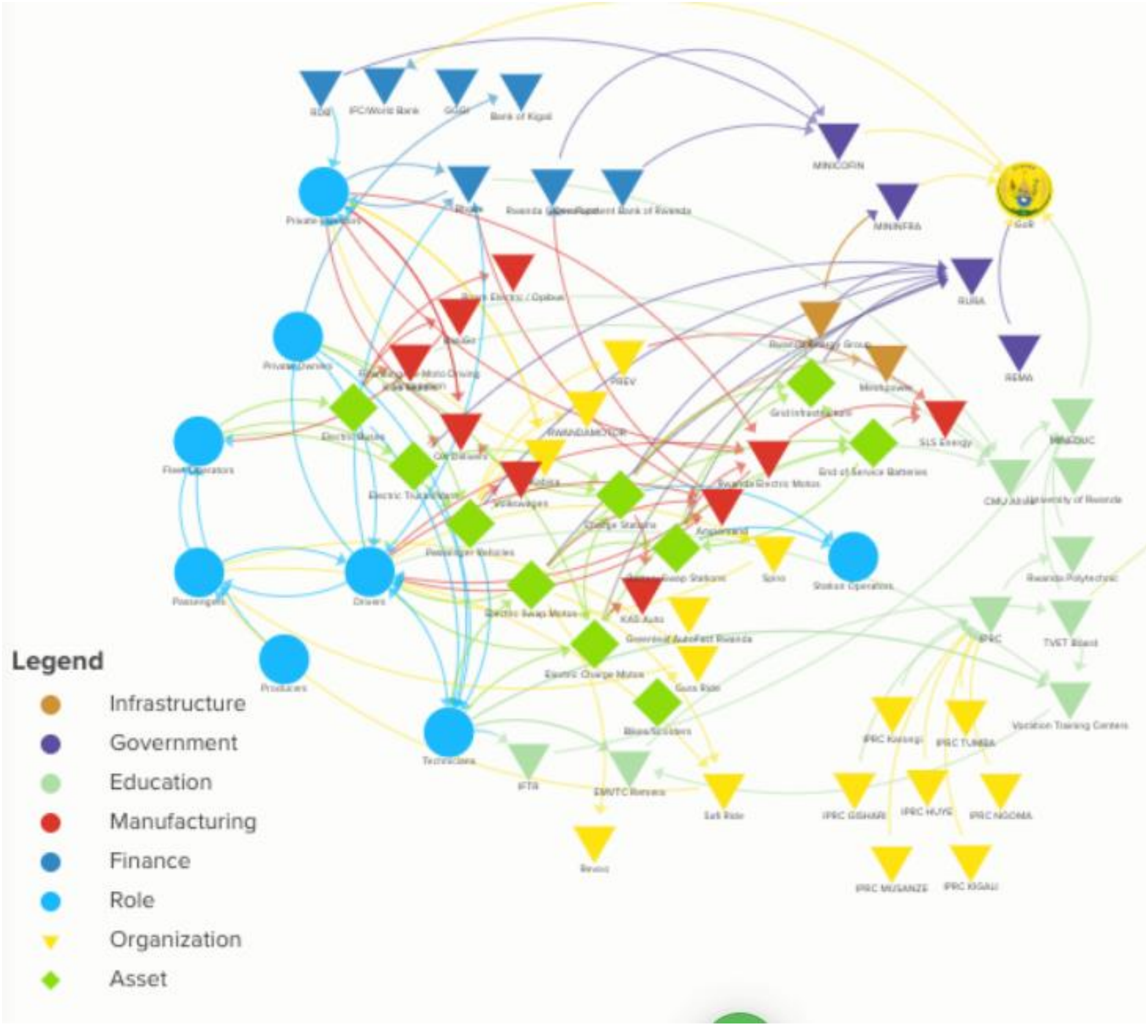

Fig.1: Ecosystem map showing interaction of sectors via organizations, roles, and assets.

However, while digital technologies impacting transportation can be deployed relatively quickly, the design, construction or modification of the physical transport infrastructure has an inherently longer time scale and falls in the domain of civil engineering, urban planning, and public policy. Further, any suggested transportation solutions will have associated costs both for the individual users as well as for the taxpayers who support the public works budget. Hence, any real-world solution will have at least three layers: technology, policy and finance.

In order to apply technology solutions in the region, stakeholders have already started activities to help address some essential questions:

Have we developed a clear understanding of the transportation ecosystem. [4]

How do we address the key issue of acquiring data for these applications to work. For example, in the context of sustainable urban mobility planning, the most expensive and time-consuming activities are gathering the necessary data, mostly through traditional surveys, for the status quo assessment and scenario building and modelling. ITS can solve these issues, but these systems need to be permanent and well regulated. This is required in order to be able to move towards real digital and smart cities. Researchers have already produced some local prototypes [5].

How do we deal with the fact that still most vehicles in Africa are second hand without advanced technologies in place? Studies suggest that even with fractional adoption, high tech solutions can lead to improved safety and efficiency [6].

Looking at ITS technologies in Africa, which have the potential to be scaled now? and which need to wait for other developments to happen (e.g. electrification, phasing out of old vehicles, etc.)?

What capacities are critical that need to be developed by governments?

Regarding the role of government, the public-private partnership (PPP) model will still remain the predominant way of doing things, where most of the analytics and operation and provision of technologies are externalized and contracted to the private sector. So, in the context of ITS applications in the continent, it would be critical that the authorities build and retain the capacities necessary for understanding the local circumstances, specifying the service, technology and contractual requirements and specifications to work with the private sector, and to request the right information needed for decision-making. It would be especially important to acquire the capacities to act upon the information provided by the private sector to make the right planning, regulatory and policy decisions.

Structure of the Paper

The sections below reflect discussions and presentations from the workshop and are grouped into three main parts by theme: (A) global motivation for smart mobility and intelligent transportation and its applicability in LDCs, (B) use cases and examples from Rwanda, and (C) design principles and the requirements for telecoms to support ITS.

Part A on motivation includes section 1 which describes how ITS can potentially have a big impact in the long term, section 2 which speaks to smart mobility and carbon neutrality, and section 3 on ITS and EVs in in LDCs.

Part B on examples from Rwanda includes section 4 on ITS and Traffic Management, section 5 on using ICT for regulation enforcement, and section 6 on Green Smart City Development.

Part C on design includes section 7 on Inclusive Digital Solutions and Design for Transport, section 8 on Urban Mobility Design using AI, and section 9 describing vehicle communication technologies and the role of telecom providers in supporting ITS.

There is an overlap between some sections. For example, inclusivity appears in discussions on ITS design principles as well as in Smart Cities. Similarly, EVs appear in discussions on impact and carbon neutrality while issues around their adoption in LMICs are treated separately. This is a result of the focus of the workshop discussions where participants' underlying concerns gave rise to recurring themes. It also serves as a marker of potential importance.

Part A

1.0 ITS impact on air pollution and climate change

Air pollution is a major cause of Africa's chronic respiratory illnesses and premature deaths. The World Health Organization (WHO) records 176,000 deaths per year in Africa are due to outdoor air pollution alone representing about 2% of annual deaths, while 90% of urban air pollution is caused by vehicle emissions and road traffic is among the key contributors to air pollution [7]. This may be reduced by cutting back the time spent in traffic and by using alternative fuels. Other approaches that have been suggested include car free zones, air quality monitoring systems, improved road infrastructure, and dedicated bus lanes or prioritized public transport vehicles where possible. Efforts towards making a city more liveable include using AI and connected sensors to predict traffic flows and make it more efficient.

Climate change is a worldwide challenge and while Rwandan CO2 emissions, for example, are not a big contributing factor globally, they are expected to rise to 12.3 million tons annually by 2030. This represents more than a doubling since 2015 when they were 5.3 million tons annually [8]. Suggestions to reduce the carbon footprint include phasing out older vehicles and machinery, and simultaneously creating fiscal and non-fiscal incentives for e-vehicles and hybrids, something that Rwanda is pursuing via tax incentives and preferential electricity tariffs for commercial charge stations.

With this backdrop, a fundamental question for proponents of ITS is whether such systems can actually have a meaningful long-term impact on reducing air pollution and mitigating climate change, and if so, how exactly.

Workshop participants agreed with the proposition and described a number of potential mechanisms for the effect to become apparent. These can be grouped under the five categories of emissions, modes of transport, logistics, infrastructure, and equity [9].

In terms of reducing emissions and pollution, there are three main ways by which the positive effects of ITS could be felt [10, 11]. The first of these is the facilitation of EVs whose adoption is promoted by integrating charging infrastructure and incentivizing their use. Since EVs produce fewer greenhouse gas emissions compared to traditional internal combustion engine vehicles, increasing adoption rates will lead to a drop in emissions and pollution. Another way is via efficient traffic management. Smart traffic management systems optimize traffic flow, reducing congestion and idling time. This leads to lower emissions and less air pollution also. Finally, there is eco-driving assistance wherein AI provides real-time feedback to drivers, encouraging cost-saving fuel-efficient driving behaviours. This minimizes user operational costs and vehicle emissions and reduces the carbon footprint.

In terms of promoting sustainable modes of transport [10], it would be important to encourage the use of public transport as well as cycling and walking. In many LMICs such as Rwanda, the latter two are already prevalent while public transport can vary considerably in different regions. AI techniques can be used to enhance public transit systems, by making them more reliable, efficient, and accessible. With the increased use of mass transit options such as buses and trains, individual car emissions would drop in relative proportion. Similarly, if urban planners were to encourage cycling and walking by, for example, introducing dedicated cycling lanes and pedestrian-friendly pathways, fossil-fuel powered vehicle use would drop.

As for freight and logistics, freight efficiency and last mile delivery solutions are critical. By optimizing freight routes, reducing the proportion of empty truck trips, and enhancing supply chain efficiency, overall emissions from freight transport could be minimized. Similarly, electric delivery vans and the innovative use of drones could reduce emissions during the final leg of product delivery.

Climate-resilient infrastructure is another important area where ITS could be of use. One of the effects of climate change is more frequent extreme weather events. Using insights from ITS, it may be possible to adapt to extreme weather events such as floods, storms, and rising sea-levels. ITS data could be used to identify critical infrastructure that should be upgraded or designed afresh on priority. Along the same lines, investing in climate-resilient ports and airports would ensure continuity of trade and travel despite changing weather patterns [12].

Finally, ITS can be used to provide more equitable access to transport and thus have a large social impact. The primary mechanism would be to support affordable mobility that would mitigate economic disparities. Also, ITS technologies could be used to target pollution reduction thus improving public health because cleaner air leads to fewer respiratory illnesses and better overall well-being.

Taken together, a picture emerges of ITS as a tool for mitigating climate change and building resilience in public infrastructure. This would lead to a more sustainable and equitable future.

2.0 Smart mobility and carbon neutrality

Another issue that was discussed by workshop participants was about applying smart mobility to attain carbon neutrality, defined as net-zero CO2 emissions.

Smart mobility and ITS are sometimes used interchangeably. So, there are some opportunities which overlap with the discussion in Section 1. These include transitioning to electric vehicles (EVs) and promoting low-emission alternatives; encouraging a shift from private cars to public transport, cycling, and walking; optimizing routes, reducing congestion, and minimizing idling time; using AI for optimized freight transport through smart logistics; and building green infrastructure to enhance urban air quality [13].

There are several other specific opportunities. First among them is the ability to scale carbon neutrality at a granular level where individual e-commuters are incentivized. A commercial opportunity for providers is to create a new revenue stream incentive where the EV-network components can earn a transaction fee. In terms of financing, there can also be improved result-based products for e-buses where rewards for "green" miles are easily verified. There can also be an improved asset base line of credit for e-bus owners. Another opportunity lies in advancing transactional security, ensuring e-wallet and carbon credit trades. Also, intelligent carbon tracking can be aligned with targeted sustainable development goals.

In terms of challenges [14, 15], at the macro-level, moving from fossil fuel-based transport to cleaner alternatives requires time and investment and overcoming resistance to change. Such behavioural change is tricky as encouraging people to adopt sustainable modes of transport involves changing habits. Along the way, it will be crucial to ensure that smart mobility solutions are accessible to all socioeconomic groups. In terms of physical infrastructure, developing charging stations, bike lanes, and efficient public transit networks will require substantial investment. Funding and coordination will be key. Lastly, in order to achieve mobility carbon neutrality, it will be necessary to harmonize standards, emissions reduction targets, and policies across borders. This is non-trivial and likely to be quite complex.

Turning to the specifics of implementation, it can be a challenge to digitize and standardize e-commuter profiles. Also, there will be high capital costs in procuring e-buses, setting up charging stations and infrastructure. In the monetary space, there will have to be some mechanism or tolerance for adapting to decentralized financial transactions.

3.0 ITS and EVs in LDCs

Less developed countries (LDCs) can benefit from ITS and EVs in several major ways. These revolve around health and well-being, cost savings and energy security as well as economic inclusion and job creation [16].

In terms of health and well-being, the use of EVs will mitigate air pollution while ITS can also reduce emissions by improving traffic efficiency thus reducing congestion and idling. Many vehicles on the continent are older or not well maintained and are notorious polluters. Replacing them or having them on the roads less often, would contribute to better public health. This would also lower healthcare costs or the cost of days off, thus increasing overall productivity.

In the area of cost savings and energy security, while EVs may cost more initially, their operating costs can be much lower than ICE vehicles. The most common mode of powered transportation is the motorcycle, which has a shorter lifetime and thus potential for rapid fleet renewal. So over time, there can be significant savings for businesses and individuals. However, this also depends on the availability of parts, mechanics and financing to support maintenance and ownership. Also, if EVs are powered by locally generated energy sources such as solar or hydropower or even local hydrocarbons, the dependence on imported fuels will decline. This not only saves often scarce hard currency but also improves national energy security.

As for economic inclusion and job creation, by adopting ITS and EVs in their transport sector, LDCs can leapfrog historic patterns of development in the global north. This would allow them to skip expensive investment in systems that are soon to be outdated. Simultaneously, LDCs could plan for jobs in newer technologies whether in manufacturing or infrastructure development. Finally, the use of ITS can itself improve access to transportation services for previously underserved communities. This can lead to social and economic inclusion.

Finally, by switching to EVs, LDCs can reduce their greenhouse gas emissions and more easily meet their climate commitments. This is a lower priority for countries that have not contributed significantly to global warming but may have a big impact as their economies grow over the coming decades.

However, LDCs face some challenges centred around initial investment costs for infrastructure development as well as regulatory frameworks. Lack of public awareness is also an issue but may be easily overcome if the right financial incentives are offered. International cooperation, financial assistance, and technology transfer can play crucial roles in supporting the adoption of ITS and EVs. In Rwanda, the upskilling of mechanics and creation of financing packages for drivers are active areas of development.

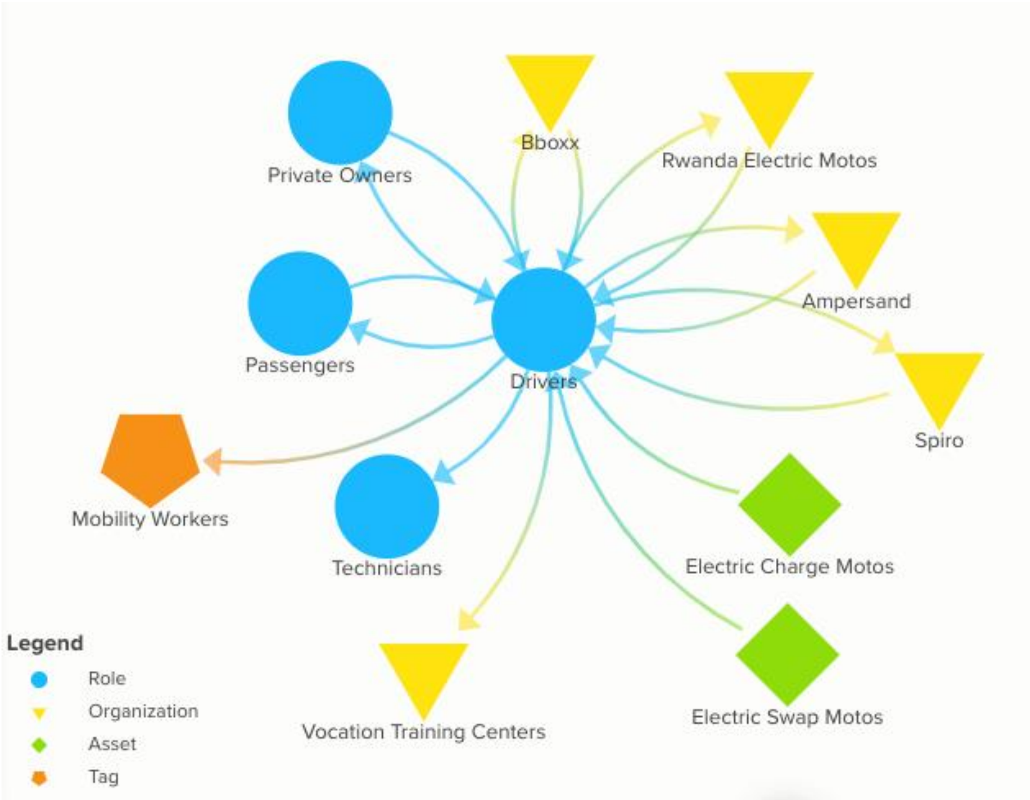

Fig. 2: Excerpt of Rwandan electric mobility ecosystem map: focus on motorcycle driver relationships.

Similar exercises are feasible outside Rwanda. At the time of writing, researchers from CMU Africa and the American University in Cairo were starting on a project to build the digital foundations for sustainable transport in Africa more broadly. A core part of their work would focus on the necessary preconditions for an EV ecosystem including the financial component and the topic of battery recycling.

Part B

4.0 ITS and traffic management

Many traffic departments in different jurisdictions worldwide use ITS to streamline traffic flow, prevent accidents and enhance overall road safety [17]. This is done by using sensors, digital communication, and computing resources to monitor, manage, and optimize transportation networks' efficiency. Requirements for such systems include real-time data collection, predictive analytics, communication infrastructure, and smart control systems. Improvements in traffic safety, efficiency and access can lead to a more sustainable transportation ecosystem.

Using ITS for Real-Time Traffic Monitoring and Management

Traffic authorities can gather real-time data on traffic patterns, congestion levels, and potential hazards by using sensors, cameras, and other surveillance equipment. The acquired data allows for the quick identification of emerging safety threats, such as accidents, and the impact of road closures, or of adverse weather conditions. With this information at their disposal, the authorities can launch the appropriate public safety activities. Additionally, the gathered data can be processed using predictive data analytics algorithms and used to anticipate traffic bottlenecks and flow patterns. This in turn permits the dynamic adjustment of signal timings, lane configurations, and speed limits to optimize traffic flow and minimize the risk of collisions.

Authorities can also decide on resource allocation, such as proactively deploying emergency response teams to areas with heightened accident probabilities. Going a step further, by analysing historical traffic data, weather patterns, and population trends, traffic departments can identify high-risk areas, predict recurrent safety issues, and plan for longer term targeted interventions to mitigate risks. Overall, ITS has the potential to transform safety planning and intervention strategies. This will ultimately save lives and reduce the societal impact of accidents and congested roads.

Traffic management in Rwanda

Traffic management is generally understood as handling traffic flow and volume throughout the day. The country is seeing emerging growth from two lane to four lane roads while at the same time the number of motorized vehicles is also increasing rapidly and competing with pedestrian and non-motorized bicycle traffic. Given the limitations of the hilly terrain, and the high population density, traffic management is a highly challenging task requiring a mixture of temporary and permanent solutions. Smart or intelligent systems are being considered for addressing the situation.

The main challenges fall into several categories: a. Institutional capacity to effectively manage change. b. Educating staff and the public on the new traffic landscape. c. Enforcement capabilities. d. The financial burden of acquiring and implementing new technological solutions.

The latter includes means to monitor road conditions, deploy both mobile and stationary speed cameras as well as speed governors on buses, enforce red light violations at intersections, maintain automobile inspection stations, facilitate testing and licensing for qualified drivers, and deploy a radio network for country-level coordination.

Some of the traffic initiatives underway at varying levels in Rwanda include the introduction of dedicated bus lanes where possible, smart parking, a Passenger Information Management System (PIMS), an electronic road payment system, bus management systems, and smart traffic control signals.

A central Traffic Control centre has been designed. Its assigned role is to create safe and efficient traffic flows and manage traffic in emergencies. Operators at the centre will be able to utilize traffic information from CCTV Cameras, vehicle detectors, and from police cars. The centre also has a general public safety role. For example, it can make announcements for large areas using general radio broadcasts, update traffic information signs using messages and graphic images, infrared beacons and other devices in Vehicle Information and Communication System (VICS)-compatible car navigation systems.

It is apparent that there will be a tremendous volume of traffic information available for analysis. At a high level, the traffic authorities intend to use such information to enhance road safety by inculcating a new road use culture. This will be built on an education layer where road users are shown the consequences of the choices that they make. The legal foundations of this endeavour will have to keep abreast of the latest technological solutions deployed.

Building Intelligent traffic management systems will be a long journey. Fortunately, there is an institutional willingness to expedite projects and to put the relevant public infrastructure in place. There is also an openness to partnering between government, industry, and academia as the key enablers for efficient traffic management.

5.0 ICT for regulation enforcement

Regulatory authorities are another critical actor in the creation of an inclusive mobility environment [18]. By viewing transport as a public utility, five main concerns arise: a. Ensuring that transport services are available throughout the country. b. Issuing and renewing licenses and authorizations. c. Planning of routes and terminals. d. Monitoring of service levels. e. Enforcing transport service regulations.

In the case of the Rwandan regulated transport sector, the Rwanda Utilities Regulatory Authority (RURA) has a three-part remit:

Table 1: RURA remit.

Road transport of persons	Road transport of goods	Waterways transport
Public bus transport services **Cross border buses** **Motorcycles transport services** **School buses transport services** **Taxi cabs transport services** Rental vehicles transport services	**Goods transportation services** Freight forwarders services	Goods transportation services

The instruments that the regulator has access to include Presidential directives, government policies, national laws and regulations, as well as public codes of conduct for companies and operators.

Digital and ICT technologies can be used to enable each of the domains of action listed above. RURA is actively using ICT in public transport to facilitate: 1. An Electronic Fund Transfer System (EFTS) for ride fare payment. 2. A digital speed governor for public buses. 3. An Intelligent Connected Fare Meter (ICFM) for taxis. 4. Internet on board buses. 5. Driver vocational cards. 6. Various online services.

Future plans include building a data warehouse, and a Performance Monitoring Hub System (PMHS). Other projects being planned include public transport demand estimation categorized by modes of transport, algorithms for estimated times of arrival (ETA) for carriers, making transport data available in GTFS format. RURA is also developing a data sharing policy/guide, updating its regulations for E-ticketing, speed governors, and ITS.

There are also several transport data maps being developed by public, commercial and academic actors involved in transportation in Rwanda. Some of these will be open access. Together with RURA's data warehouse, these will be key enablers for not just transport regulation but also the design of an inclusive transportation ecosystem.

6.0 Green smart city development

When considering human activity that has an impact on health and well-being as well as the climate, transportation is just one component. It is intricately tied to the physical environment where people live. So, if society aims for a sustainable, greener future, urban planning will play a critical role and ICT can help enable better outcomes. In this context, one of the topics discussed at the Afretec workshop was about how governments can facilitate the development of green smart cities [19].

Chief among the suggestions was for governments to develop a policy framework, whereby sustainable practices would be encouraged. These include instituting green building standards and imposing renewable energy mandates and requiring more efficient transportation systems.

Another recommendation was for governments to allocate funds for infrastructure projects such as power plants relying on renewable energy sources, and waste management. Investment in smart grids and efficient public transport was also encouraged.

Turning to implementation, public-private partnerships (PPPs) were recommended as they allow for a faster development and deployment of leading technological solutions. The public interest should be kept paramount in such partnerships.

In order to make policy and project decisions based on empirical evidence, a data gathering and management strategy would also be necessary. For example, implementing systems to collect and analyze IoT and surveillance sensor data to augment people-driven surveys. The processed data could be used to enhance municipal operations, by among other things, planning inclusive public transport and improving traffic flow.

Alongside policy work, it would be important to engage the community via educational workshops and public awareness campaigns, to highlight these initiatives. The long-term goal would be to encourage sustainable practices and eco-friendly behaviour.

Lastly, governments should invest in R&D in renewable energy, urban planning and other innovations that can have a positive environmental impact. Simultaneously, collaboration should be encouraged between municipalities, industry, academics, and NGOs so that lessons and best practices can be shared.

It is notable that Rwanda has already started implementing these strategies [20] and appears committed to fostering the development of smart cities that prioritize sustainability and contribute to a greener future [21].

An example: Towards a Coordinated Smart Road Safety Platform

Researchers at the University of Rwanda have proposed a Coordinated Smart Road Safety (CSRS) Platform [22]. The system will rely on a database providing quick and centralized access to actionable road safety information. It would pull together and make available existing road safety anonymized data. The data would come from relevant road safety stakeholders and from implementation agencies (police, transportation authorities, the city administration, and regulators), post-crash actors (hospitals, insurers), researchers, civil society organizations and private sector actors (operators, manufacturers, IT companies). The CSRS platform informs how to build road safety resilience in cities so that when human error occurs on the road it no longer leads to serious or fatal outcomes.

Part C

7.0 Inclusive digital solutions and design for transport

ICT and digital technology can play a central role in helping decision makers and regulators to meet the transportation needs of as many users as possible and to improve access in poorly served communities.

Among the digital approaches [23] are data-driven decision making and the use of digital platforms. For example, data analytics tools can be used to glean insights into transportation patterns, user behaviour, and service gaps in poorly served communities. This can assist decision makers to make policies and allocate resources. Also, digital platforms can help improve access by providing real-time information, booking options, and payment solutions to users. Examples of such platforms include ride-sharing apps, public transit apps, and on-demand transportation services.

The low cost per capita, widespread availability and reconfigurability of digital solutions inherently support accessibility and inclusivity. To do so in practice, however, requires planners to consciously address the needs of all segments of society including those with disabilities, seniors, and low-income individuals, by for example, providing alternate modes of access. Examples include phone-based booking systems or community outreach programs.

Other innovative transportation technologies such as electric vehicles, autonomous vehicles, and micro-mobility solutions can be used to enhance accessibility. They can also help reduce costs and minimize environmental impact.

Reliable digital infrastructure is essential for accessing and utilizing transportation services effectively. Related policy recommendations mentioned above include public-private partnerships (PPP) for quick deployment of supporting digital technologies, and investment in digital infrastructure to bring connectivity to poorly served communities.

Finally, it is important to have clear and flexible regulatory frameworks. They are essential not only to enable digital transportation services but also to ensure safety, security, and consumer protection. It would also be in the public interest to encourage innovation and competition in this space while addressing potential risks and concerns.

Design Principles

Based on discussions involving stakeholders and practitioners, as well as standard best practices [24], a few guiding principles for fostering inclusivity in the mobility space come into focus. These include affordability, accessibility, universal design, user feedback, multimodality, and information availability. While no one principle is sufficient, application of multiple principles can lead to a transportation system that is more inclusive overall.

Perhaps the most important principle in LMICs is affordability for all socio-economic groups and families. Application of this principle will impinge on topics of financial inclusion and of subsidy policy.

A very important principle is that of accessibility for people with disabilities. By employing features such as ramps and elevators, as well as priority seating, public transport vehicles and facilities can be made more accessible.

Related to the above but distinct is the approach of universal design. Under the associated principes, the mobility solution is designed to cater to people of all ages, abilities, and backgrounds. The mobility product should be easy to use for anyone without the need for special accommodation.

Closely tied to universality is safety and security. It is important to create mobility environments that are safe and secure for all users.

Another principle is that of user feedback. By soliciting opinion and input from diverse groups of users, their needs and preferences will be better understood. This feedback can then be incorporated into the design and planning process to create a more inclusive transportation system. A related principle is community engagement to ensure that their needs and perspectives are considered.

The multimodality principle is essential to developing a system that can accommodate different travel preferences and mobility needs. Simply stated, it is the provision of different options where possible. For example, buses, trains, bike lanes. Or the availability of different classes of service within a mode of transport. Application of this principle is dependent on the socioeconomic and infrastructural ground realities.

It is also important to provide information about the transportation services in multiple languages or formats so that people with different linguistic backgrounds, literacy levels or handicaps can access them. Examples of formats include signage, audio announcements and digital platforms, each of which could possibly have text in multiple languages.

Finally, in a digital world, it is important to consider universal access to data. A lot of extremely valuable data is gathered in siloed systems, for example, by telecom companies, that is out of reach to everybody else. If regulators cannot facilitate open access data without infringing on commercial interests or privacy, it might still be possible to use synthetic data for planning purposes.

8.0 Urban mobility and design using AI

Artificial Intelligence (AI) carries the potential to enhance urban mobility design by providing insights and optimizing resources [25]. The primary application areas would be traffic flow optimization and demand prediction. But AI can also be used for public transportation routing, infrastructure planning, and urban development simulation. The result would be to facilitate the creation of more sustainable and efficient transportation systems.

Generative AI models can simulate traffic patterns and explore scenarios with changed configurations. By simulating proposed changes to road networks and transportation routes, as well as traffic signal location and timing, it would be possible to predict the resulting congestion. So, by selecting from the best of several options at the traffic managers' disposal, the overall traffic flow efficiency could be optimized.

Similar algorithms could also be applied to the task of optimizing public transportation routes and schedules. The inputs to such an exercise would be factors like passenger demand, traffic conditions, and environmental considerations. The expected output would be a more efficient and reliable transit system.

AI algorithms can also aid urban planners to design and optimize the infrastructure itself by, for example, proposing new layouts for bike lanes, pedestrian walkways, and parking spaces. This would present different options for the planners to create a more accessible and sustainable environment.

When historic data is available, data science techniques can also be applied to analyse past traffic patterns. If coupled with public transportation usage, and demographic trends, future demand for transportation services could be predicted. Related to the above, it is also possible to simulate the impact of urban development projects on transportation networks. This would help city planners make decisions about land use and zoning regulations, as well as infrastructure investments.

AI for ITS

Apart from the traffic management, infrastructure and demand prediction cases outlined above, AI can be applied to ITS at the vehicle-level. Two major application areas are predictive maintenance and driver assistance. Although most cars on the African continent are not equipped with features that would be amenable to such AI assistance, the number of new cars and public transportation vehicles with those features is increasing rapidly.

Predictive maintenance systems within vehicles, at inspection stations or distributed elsewhere in the larger transportation eco-system, can be used to predict potential failures and avert breakdowns. This would reduce downtime not just for individual vehicles but also for infrastructure components. The overall result would be improved transportation system reliability.

Many newer vehicles are equipped with or can be retrofitted with driver assistance systems built on a hardware layer consisting of such devices as proximity sensors, cameras and vehicle-to-vehicle communications. These assistance systems can be extended to automated safety features such as collision avoidance based in part on AI tools like image understanding. AI algorithms are also being used to develop vehicle autonomy under certain constraints.

AI Risks

The use of AI for urban mobility planning and in ITS also poses certain risks and challenges centered around safety concerns, privacy and security, ethical considerations and regulatory challenges.

In terms of safety, the reliability of transportation systems controlled or affected by software is a critical issue. As with any complex digital system, it is possible that not all failure scenarios are tested before deployment. With the inclusion of AI components to the digital system, additional failure modes may have to be tested. In case of an unforeseen operational environment, algorithmic errors could lead to increased risks for vehicle passengers, pedestrians, and other road users.

The collection and analysis of large amounts of transportation data also raises concerns about privacy and data security. There is a real possibility of leakage of privileged information, unauthorized access and cyber-attacks. Different jurisdictions have started requiring digital and AI systems to adhere to their privacy regulations and to employ security measures.

AI algorithms can be very sensitive to the data sets they are trained on. Hence, human biases may be exacerbated in decision support systems. It would be important to test for such potential ethical violations such that the smart mobility system in question treats all users fairly and equitably.

Another challenge is that, given the rapid advances in AI, regulations governing mobility and transport systems quickly lose their applicability and effectiveness, even becoming redundant. To mitigate these risks, procurers should include requirements for safety, privacy, transparency, and ethical considerations in the system specifications. The same requirements should be tested at all phases of product development and deployment. This includes testing, validation, and certification processes, as well as ongoing monitoring and evaluation in real-world settings. Additionally, collaboration between governments, industry stakeholders, academia, and civil society should be encouraged in order to address any gaps. These steps may foster innovation and ensure responsible use of AI in ITS.

9.0 Vehicle communications and telecom support for ITS

Various vehicle communications standards were developed to allow traffic safety information to be passed to vehicles but have been slow to be adopted [26]. Newer ITS and smart mobility systems for providing driver assistance often contain features that rely on the underlying vehicle communication technologies. Regardless, telecom networks have emerged as a critical link in the chain of actors in the modern transportation ecosystem. We summarize a few relevant safety features and the broad requirements for telecom providers in this space [27].

Vehicle communications can be split into two or three categories: Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), or more generally, Vehicle-to-Anything (V2X). V2V communication facilitates direct communication between vehicles, allowing them to share data pertaining to speed, position, and proximity. Some collision avoidance systems rely on such communication. V2I technology enables vehicles to communicate with roadside infrastructure, such as traffic signals, signage, and central control centers. Traffic incident alerts can be sent via such communication. Both V2V and V2I allow for the exchange of critical information in real-time. This can enhance drivers' situational awareness thus reducing the likelihood of accidents.

ITS may include Advanced Driver Assistance Systems (ADAS). These refer to features such as cruise control, lane departure warning systems, blind-spot monitoring, and automatic emergency braking. The features rely upon sensors, cameras and onboard computing and are a building block for other automated systems and, ultimately, autonomous vehicles.

Dynamic Variable Message Signs (VMS) and Intelligent Traffic Management Systems (ITMS) are also used to broadcast traffic safety information and guide drivers through difficult and evolving traffic conditions. Examples include timely updates on traffic congestion, accidents, construction zones, and alternative routes.

Such traffic safety and management systems depend on reliable communications links. Radio systems such as DSRC can be a viable option in some cases. However, a public telecommunications network is often more affordable and more likely to be available to all road users. In order for telecom providers to effectively support the deployment and operation of ITS and connected vehicles, a few broad requirements arise including high-speed connectivity with low latency and adequate QoS, wide coverage, data security, scalability and interoperability. These are shown in Table 2 below.

Finally, telecom operators in a particular jurisdiction operate under technical standards set by national bodies. The national standards often match or are adopted from international standards. Interoperability across standards or the ability to support different standards would be required in the case of a regional ITS across borders.

Table 2: Requirements for telecom support of ITS.

Requirement: high-speed, reliable connectivity. **Reason: to enable real-time communication between vehicles, infrastructure, and other devices.**	**Requirement: low latency.** **Reason: to ensure quick response times essential for safety-critical applications.**
Requirement: wide geographic coverage. **Reason: to support connected vehicles regardless of their location in urban, suburban, and rural areas.**	Requirement: security. Reason: to protect data transmitted between vehicles and infrastructure from cyber threats and ensure the integrity and privacy of the data exchanged.
Requirement: scalability. **Reason: to accommodate the growing number of connected vehicles and increasing data traffic generated by ITS applications.**	Requirement: Quality of Service (QoS). Reason: to support various ITS applications, without compromising performance.
Requirement: interoperability. **Reason: to enable seamless communication among vehicles and infrastructure from different manufacturers and service providers.**	Requirement: compliance with regulations. Reason: to adhere to spectrum allocation, data privacy, and cybersecurity requirements.

Conclusion

This whitepaper presented the outcome of discussions among parties from academia, government, business as well as non-governmental organizations about the opportunities and challenges of bringing smart mobility solutions to Rwanda and the African continent more broadly. The topics spanned the long-term impact of the use of ITS, carbon neutrality, green smart city development, inclusive design principles and the use of AI, as well as requirements for telecoms to support ITS.

Stakeholders in Rwanda have already started using ITS to improve traffic safety and implementing data driven policies to provide access to more users in the country. Researchers have demonstrated the use of advanced digital technology for transport in the local context and some are studying the technology, policy and financial requirements for the introduction of EVs at a national level.

It is hoped that these initial efforts will inspire the development of other smart mobility solutions in Africa and elsewhere. One of the first outcomes is the launch of a Smart Mobility Lab in Kigali which seeks to bring together diverse partners to tackle different issues in intelligent transportation and e-mobility and serve as a focal point for research and development. Building inclusive intelligent transportation offers many potential environmental, health, economic and social benefits and Africa is no exception in standing to benefit.

References

1. Afretec IDT workshop, at CMU Africa, Oct. 2022.
2. Sustainable Transport, Sustainable Development, Ed. Kathryn Platzer, UN, 2021. https://www.un-ilibrary.org/content/books/9789210010788
3. Developing Sustainable Urban Mobility Plans, Marie Cleuet and Aurelie Jehanno, Systra, *Changing Transport*, 2023.
4. Paiva, Sara, et al. "Enabling technologies for urban smart mobility: Recent trends, opportunities and challenges." *Sensors* 21.6 (2021): 2143.
5. de Oliveira, Gabriel Gomes, et al. "Data collection and analysis applied to intelligent transportation systems: a case study on public transportation." *Discover Artificial Intelligence* 3.1 (2023): 13.
6. Hill, Colton, and Philip N. Brown. "The Trade-off Between Altruism and Anarchy in Transportation Networks." *2023 IEEE 26th International Conference on Intelligent Transportation Systems (ITSC)*. IEEE, 2023.
7. Fisher, Samantha, et al. "Air pollution and development in Africa: impacts on health, the economy, and human capital." *The Lancet Planetary Health* 5.10 (2021): e681-e688.
8. https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=RW.
9. 5 ways to reduce emissions from global transport systems, WEF, 2023. https://www.weforum.org/agenda/2023/03/5-ways-the-world-can-reduce-emissions-from-global-transport-systems/.
10. Transport transformation critical to address climate change and universal access to safe, affordable, resilient mobility, UN, 2021. https://www.un.org/sustainabledevelopment/blog/2021/10/transport-transformation-critical-to-address-climate-change-and-universal-access-to-safe-affordable-resilient-mobility/.
11. Why green transport is vital for meeting global climate targets, WEF, 2022. https://www.weforum.org/agenda/2022/06/green-transport-and-cleaner-mobility-are-key-to-meeting-climate-goals/.
12. Vallejo, Lola, and Michael Mullan. "Climate-resilient infrastructure: Getting the policies right." OECD, (2017). https://www.oecd-ilibrary.org/docserver/02f74d61-en.pdf
13. Sustainable and smart mobility strategy - European Parliament. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/659455/EPRS_BRI%282021%29659455_EN.pdf.
14. Shah, Kinjal J., et al. "Green transportation for sustainability: Review of current barriers, strategies, and innovative technologies." *Journal of Cleaner Production* 326 (2021): 129392.

15. Butler, Luke, Tan Yigitcanlar, and Alexander Paz. "How can smart mobility innovations alleviate transportation disadvantage? Assembling a conceptual framework through a systematic review." *Applied Sciences* 10.18 (2020): 6306.
16. Rajper, Sarmad Zaman, and Johan Albrecht. "Prospects of electric vehicles in the developing countries: a literature review." *Sustainability* 12.5 (2020): 1906.
17. Cheng, Zhi, Min-Seok Pang, and Paul A. Pavlou. "Mitigating traffic congestion: The role of intelligent transportation systems." *Information Systems Research* 31.3 (2020): 653-674.
18. Smith, Göran, and David A. Hensher. "Towards a framework for Mobility-as-a-Service policies." *Transport policy* 89 (2020): 54-65.
19. Razmjoo, Armin, et al. "Effective policies to overcome barriers in the development of smart cities." *Energy Research & Social Science* 79 (2021): 102175.
20. Hudani, Shakirah Esmail. "The green masterplan: Crisis, state transition and urban transformation in post-genocide Rwanda." *International Journal of Urban and Regional Research* 44.4 (2020): 673-690.
21. Gubić, Ilija, et al. "Green Buildings and Green City Strategies for the COVID-19 Pandemic Affected Tourism Industry in Rwanda." *Uncertainty Shocks in Africa: Impact and Equilibrium Strategies for Sound Economic and Social Development*. Cham: Springer International Publishing, 2023. 83-100.
22. GATERA, Antoine. *Towards improved road traffic safety: A modelling and IoT integration approach.* Diss. University of Rwanda (College of science and Technology), 2022.
23. Lee, Juhyun, et al. "Smart city as a social transition towards inclusive development through technology: a tale of four smart cities." *International Journal of Urban Sciences* 27.sup1 (2023): 75-100.
24. Di Ciommo, Floridea, et al. "When an Inclusive Universal Design Starts by the Data Collection Methods." *Transportation Research Procedia* 72 (2023): 2968-2975.
25. Yigitcanlar, Tan, et al. "Contributions and risks of artificial intelligence (AI) in building smarter cities: Insights from a systematic review of the literature." Energies 13.6 (2020): 1473.
26. Zeadally, Sherali, J. Guerrero, and J. Contreras. "A tutorial survey on vehicle-to-vehicle communications." *Telecommunication Systems* 73 (2020): 469-489.
27. Korhonen, Timo, et al. "Selecting telecommunications technologies for intelligent transport system services in helsinki municipality." *IET Intelligent Transport Systems* 6.1 (2012): 18-28.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany
T +49 228 44 60-0 (Bonn)
T +49 61 96 79-0 (Eschborn)

Friedrich-Ebert-Allee 40
53113 Bonn, Germany
T +49 228 44 60-0
F +49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15

E info@giz.de
I www.giz.de
I www.transferproject.org

Author/Responsible/Editor:
Ahmed Biyabani, Andrea Denzinger (Eds.)

Photo credits:
© Sepa Sama

Printed and distributed by:
changing-transport.org