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# AUTONOMOUS VEHICLES: THEORETICAL AND PRACTICAL CHALLENGES FOR EFFICIENT AND INCLUSIVE TRANSPORT IN AFRICA

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## ABSTRACT

Autonomous vehicles otherwise regarded as self-driving vehicles are poised to be the next generation of technological advancement in the transportation sector globally. They offer superior value for money with regard to the cost of operation, excellent safety records, and many other benefits. Cities around the globe have adopted it even as research and development efforts are ongoing. This study investigates the role autonomous vehicles could play in Africa, especially as it relates to transportation inclusivity. The study determined that there are lots of inclusivity issues beguiling African nations ranging from religious, financial, educational, and cultural issues and was able to highlight how the adoption of autonomous vehicles can aid to solve issues relating to stigmatization and social exclusion.

## KEY WORDS

inclusion, autonomous vehicles, Africa, transportation

## CLASSIFICATION

JEL: R42

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## INTRODUCTION

As defined in [1], autonomy is described in the simplest terms as a person's ability to act on his or her values and interest. The key feature of autonomy is the self-awareness of action, which drives a person to act based on an established value of interest. Autonomous vehicles are vehicles that can operate themselves and perform necessary functions without human intervention. Examples of these autonomous vehicles are, flying electric cars which in itself is a personal air vehicle that provides door-to-door transportation by air and ground [2]. They can achieve this through the ability to sense their environment [3]. Human drivers have long been a key part of the transportation systems of communities, from horseback riding to bicycles, motorcycles, and cars. The inefficiency of a human driver was elaborated by [4], who determined that there are five critical issues to a human-operated vehicle namely; driver independence and mobility, driver acceptance and trust, failure management, third-party testing, and political support. The human factor has been identified as a contributor to poor safety issues relating to transport, [5] opined that eliminating the human factor and error from driving will increase safety, mobility, and cost efficiency.

Autonomous vehicles permits a vehicle to manage driving points that otherwise would have been managed by a human driver [6]. As a mode of mainstream transport, autonomous vehicles are still plagued by numerous challenges relating to human interference and behavior, cyber security issues [6] ethical issues, traffic management strategies, and liabilities [7]. This has limited the proliferation of the service around the world, most especially in the African Continent. Autonomous vehicles are self-driving or robotic vehicles incorporated with vehicular automation, which grants them the ability to sense their environment while navigating safely with little to no human input [8]. The allure of self-driving vehicles has been primarily driven by the need to transport humans and goods safely, however, issues relating to transportation in human and business-driven society can create situations where members of the population are disenfranchised from opportunities due to an inefficient and/or classist transportation systems. There also exists a need to elaborate on the social implications of adopting autonomous vehicles as an alternative transport medium. Authors in [9] described the sentiment of people living in the Hungarian capital, Budapest, with respect to the choices they would make when presented with a smart solution (autonomous vehicles as a mode of transport). This study rather thus investigates holistically, using readily available data sources from the internet, the existing challenges facing transport inclusivity amongst the diverse populations on the African continent.

## TRANSPORTATION IN AFRICA

Transport systems in Africa cut across the use of the three major components of transportation as detailed in [10], the primary transportation infrastructure; such as buses, cars, traffic lights, road networks; the transport management system such as regulatory bodies, traffic rules and the integration of information and communication technology, such as the internet, telecommunication networks and the global positioning systems. The existence and usage of each identified mode of transport are spread across the entire continent as evidenced by [11], who also established a link between urbanization and transport accessibility by stating that current urban transportation is not up to the demand of the African population, where colonial impacts can still be found to impact transportation accessibility, due to low quality of vehicles and poor road safety. A majority of nations/cities within the African continent are connected by roads as seen in Figure 1.



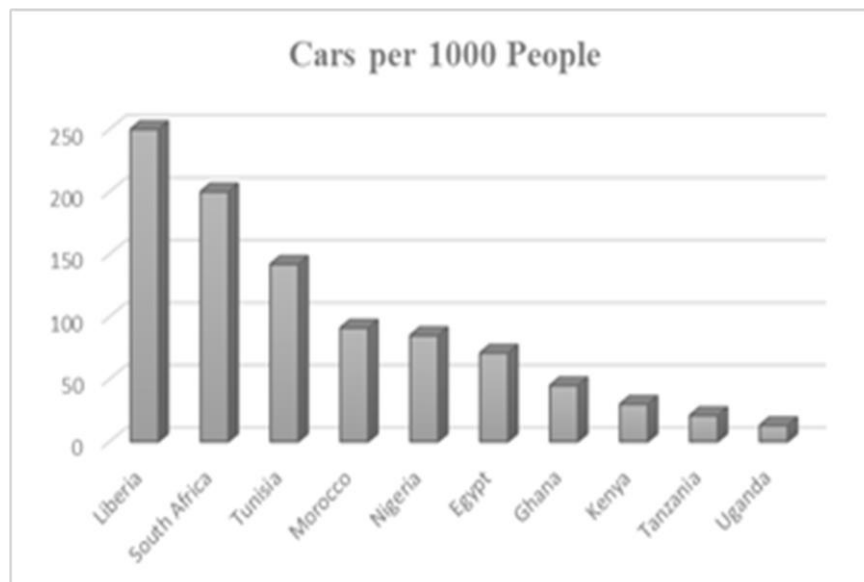
Figure 1. Trans African Highways [12].

The road connectivity ensures that cities within the African continent are interlinked, forming a basis for trade and cultural exchange access between Africans. Road transport is deemed to be the most dominant mode of motorized transport in Africa [13], accounting for 80 % of the goods traffic and 90 % of the passenger traffic on the continent. To further foster the development of road networks within the African continent, intervention efforts from banks as detailed in [14] showed that African Development Bank's (AfDB's) commitment to the transport sector increased more than six-fold from \$150million in 2000 to over 1 billion dollars in 2011, where this level of financial commitment represented nearly a quarter of the bank's total portfolio at the time. This is a testament to the need to have increased mobility amongst Africans regionally.

Road accidents kill 1,2 million people globally every year, with 19 % of the deaths occurring in Africa, thus ensuring that Africa has the highest number of road accidents per capita [13]. The need to have robust transportation systems across Africa has been long identified and has thus enjoyed high investments in transport networks with funding currently at high levels, yet there are poor numbers of cars per 1000 people within the population in different countries within Africa as evidenced in Table 1 and Figure 2, where the highest number of cars per 1000 people was found to be highest in Liberia with 250 cars and least in Uganda with 13 cars, this number is dwarfed by the lowest number of 272 for Denmark as seen in Figure 3b).

**Table 1.** Passenger car availability for Africa [15].

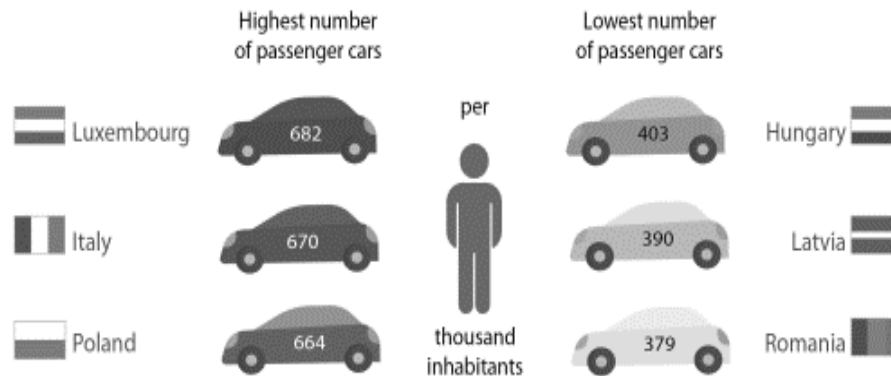
| Country      | Cars per 1000 people |
|--------------|----------------------|
| Liberia      | 250                  |
| South Africa | 200                  |
| Tunisia      | 142                  |
| Morocco      | 91                   |
| Nigeria      | 85                   |
| Egypt        | 71                   |
| Ghana        | 45                   |
| Kenya        | 30                   |
| Tanzania     | 21                   |
| Uganda       | 13                   |

**Figure 2.** Passenger car availability for Africa [15].

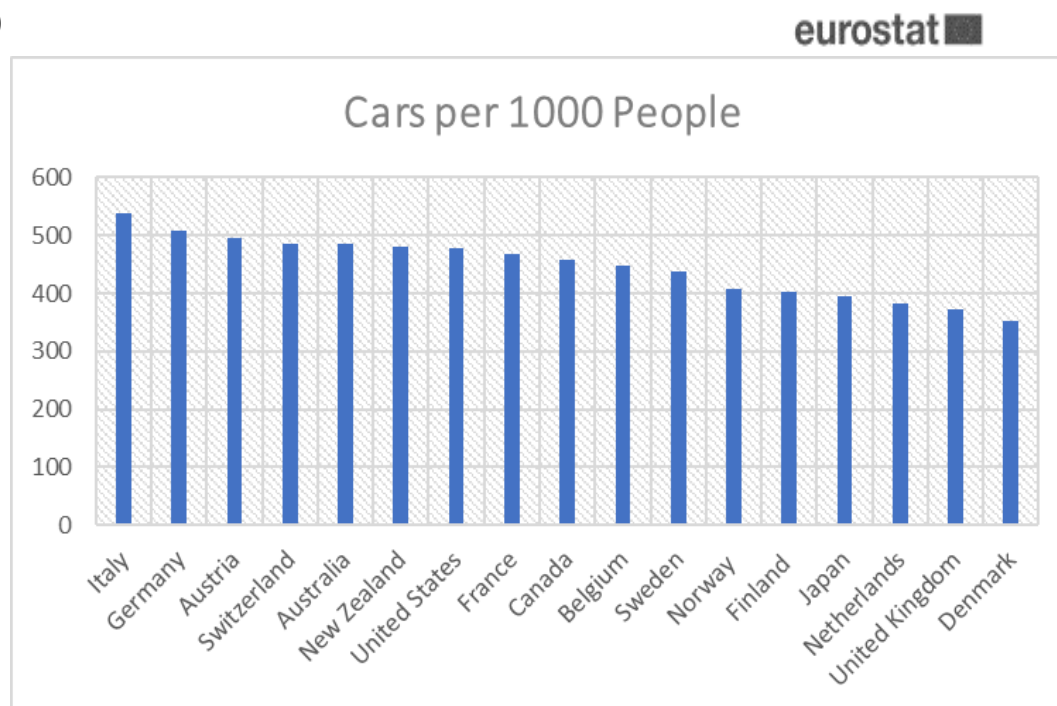
The significance of having lower vehicles per population in Africa as opposed to European and Asian cities might have a negative impact concerning accessibility and ease of trade, but it also has a positive impact concerning pollution, as transport systems generally hurt the environment and human health thanks to their contribution to air pollution. Africa still has a low impact on health due to air pollution, compared to other developing and developed countries [13], even though it is estimated that the cost of air pollution in Africa is almost 2,5 % of its gross domestic product. Other challenges identified with transportation systems include; destruction of flora and fauna, destruction of forests and associated ecosystems, soil erosion, and congestion of cities amongst others.

Transportation policies on-road use in Africa as discussed in [16] were articulated around four blocks namely; responsibility; which pertained to the need to create a coherent organizational structure for network management, with relevant institutions having assigned roles and responsibilities, Ownership; which pertains to the need for constituent representation of road users through oversight boards, Sound business practices; which pertained to the establishment of commercially oriented management practices to derive value for money from road investments and spending, and sable and secure financing; which pertains to the need to establish an adequate

a) **EU Member States with the highest and lowest number of passenger cars per thousand inhabitants, 2020**



b)



**Figure 3.** Passenger Car availability for Europe [17].

flow of funds from created road funding apparatus which are in themselves independent. The possibility of sustenance of the transport sector in Africa is highly dependent on highly scalable policies, made by forward-thinking policymakers with a resolve for consistent funding on not only the road networks, but all other transport networks within the region, to ensure that mobility and connectivity within the African continent are seamless is highly desirable.

Logistic performance as a strategic factor for indicating the competitiveness of economies was widely explored in [18]. Artificial intelligence and other related smart technologies, such as autonomous vehicles have a big role to play in achieving any economic competitiveness. The current transportation networks in Africa does not support high logistic performance and this in turn has a negative effect on African economies.

## **AUTONOMOUS VEHICLES FOR INCLUSIVITY**

Inclusion or inclusivity can be described as the policy or practice that encourages equal access to resources and opportunities for all people, irrespective of their gender, social class, religious leaning, sexuality, or physical and mental disabilities. Safe and inclusive transport is described in [19] report as being key to participation in society as it provides access to life-enhancing and socioeconomic opportunities through the navigation of an environment, for a predetermined destination safely and reliably, while being considerate of individual needs is a key pillar for safety and inclusivity in transport systems. Ease of mobility is highly linked to social development and poverty reduction, as people can access opportunities for commerce and skill acquisition in locations other than their base location (country, cities, towns, etc.). Goal 11 of the United Nation's sustainable development goals encourages members to provide accessible, safe, and affordable transport for everyone, most especially for vulnerable people.

The world bank reports that 62 % of jobs in the informal sector have been lost post-COVID in regions like Togo, Benin, Burkina Faso, Cote d'Ivoire, Guinea, and Niger [20], where informal workers represented 80 % of that figure, for which 90 % of them were women. The increase in poverty amongst African nations was also established in [21], which reports that less than half of all African countries have experienced inclusive growth between 200 and 2020, with 17 out of 49 countries showing trends of poverty-reducing outcomes, however, inequality increased in 18 countries, and non-inclusive growth on other dimensions occurring in 14 African countries.

Autonomous vehicles offer an opportunity to create inclusive mobility [22], by designs that suit the requirements of those who need them most. Challenges against mobility which autonomous systems aim to provide solutions to are; street design and traffic complexities, children's independent mobility, elderly mobility, physically disabled people with mobility issues, cognitively disabled people, visually impaired people, etc. the mobility challenges issues faced by diverse groups of people can be looked at from various perspectives.

### **PHYSICAL INCLUSIVE CHALLENGES**

Physical inclusive mobility challenges relate to people with physical limitations that affect their ability to move about safely. This can be considered from the perspective of children and seniors who are limited in size, strength, and cognition to be able to navigate unaided, to people with physical challenges who are not mobile, due to being unable to do so effectively and safely. Autonomous vehicles play a critical role for seniors and for those with a physical disability as discussed in [23], who estimated that poor mobility access amongst seniors and people with physical disabilities can be a huge barrier to independence and quality of life. The study submits that autonomous vehicle technology offers a great sense of independence and freedom to people living with physical disabilities. This ensures that the mobility people of this category do not have to depend on family members and caregivers alone, as door-to-door automated transportation services can now be deployed to meet their mobility needs. The existence of a gap in interventions for equitable mobility provisioning for disadvantaged groups was elaborated in [24], whose study investigated autonomous vehicle policies and how they affect equity amongst disadvantaged groups. Although it highlighted that autonomous vehicles had the potential to either improve or harm equity for disadvantaged groups, it agreed with the need to have policies that ensure equitable outcomes for under-represented populations. Generally, autonomous vehicles have to be able to provide succor for people with physical disabilities from pain points by providing a custom design that complies with the specific needs of people with different physical disabilities. In [24] it is suggested that such a provision could lead to a higher price in cost of the vehicles due to the customization needed to satisfy a wider audience.

## **COGNITIVE AND VISUALLY IMPAIRED INCLUSIVE CHALLENGES**

Cognitive impairment implies people with some form of mental dissonance, while visual impairment relates to people with vision problems ranging from poor eyesight to its total lack thereof. Visual and cognitive impairment tend to go together if not always mutually exclusive. People within this category are also faced with similar issues as those with physical challenges concerning mobility. They ordinarily need help from family and caregivers for mobility, whereas, for the visually impaired, care can come from guide animals, walking canes, and other assistive technologies deployed to the blind and visually impaired. For effective mobility, autonomous vehicles can also serve as a platform for easy access to transport. The relationship between physical and mentally challenged individuals concerning how autonomous vehicles can serve a purpose was further discussed by [24], who proposed that shared automated vehicles could increase the accessibility levels for people with physical and sensory disabilities, so long as certain bottlenecks such as identification of appropriate boarding spots with minimal obstacles, price of the service can be handled. A further argument that justifies the need for an autonomous vehicle solution for the mentally and visually impaired is highlighted by [25] who determined that paratransit services utilizing public facilities for people with disabilities have proven to be expensive and difficult to coordinate. Therefore, a custom approach to mobility for the visually impaired using autonomous vehicles is an optimal solution for mitigating the observed challenges in that group.

## **ECONOMICALLY INCLUSIVE CHALLENGES**

Economic issues can also cause a lack of inclusivity concerning transportation. People with low income have difficulties in accessing the capital cost of owning a vehicle [26], the cost of owning a vehicle goes beyond the purchase cost, but also to the maintenance cost and the availability of parts. Governments globally have invested a lot in mass transit transport systems to aid inclusivity amongst citizens, however, this has still not captured people with physical, cognitive, and visual impairments within the existing infrastructure. People with low means of income, even when not impaired by disability still find themselves excluded from mass transit systems due to the absence of adequate subsidies within the sector in some countries. This thus implies that more cost-effective solutions to mass transit would help with affordability, thus encouraging more people of low income to use transport systems. Autonomous vehicles offer a cost-effective solution for economic inclusion. The absence of the driver eliminates the cost of salaries, as evidenced in [27] who determined that the cost of the driver represented 88 % of the cost of running a transport taxi service in Zurich. The rigid schedule of operations required with human-operated transport services is also another factor autonomous vehicle can mitigate economically. People of low income are mainly janitors, factory workers, waiters, maids, nannies, small retail business owners, etc. The rigid schedule of operations of transport services mostly does not suit the time movements of people in this category, who have to resume at odd hours of the day and night to carry out their jobs, thus even if many of them could afford the fares of typical mass transit systems, they are simply unavailable during the time they need them. Transit systems using autonomous vehicles with a capacity to run 24 hours a day would solve that bottleneck. Though there are other associated costs to using a shared autonomous vehicle transit system, such as mobile smartphones, internet connectivity, credit/debit cards, bank account, etc as these are needed to implement such a system, these are technologies majority in the population are already using and are conversant with.

## **AUTONOMOUS VEHICLES AND INCLUSIVITY IN AFRICA**

Africa is plagued with three urgent transport challenges according to [28], namely the highest rate of road fatalities in the world, an unprecedented rate of urbanization, and the highest

transport costs in the world. As much as Figure 1 depicts the interconnected road networks on the continent, it is still so fragmented that there is a dearth of transport infrastructure and inefficient transport services. [29] investigated the emission issues relating to transportation in Africa by elaborating on vehicle fuel economy and electromobility, where due to unavailability of proper funding and incomes, the majority within the population are only able to buy cars with outdated technologies and thus advocated for flipping of the script, where Africans learned to adopt cutting-edge vehicle technology. Cutting-edge technology in the transportation domain is currently autonomous vehicle technology, which offers low operational, financial, and emission costs for the transportation of man and goods across the continent. Inclusivity in the African continent can be investigated from the lens of its diversity, centered around culture, ethnicity, gender, and religion [30], where ethnicity was investigated as a major driver of diversity.

Gender issues within the African context also play a key role in diversity as it relates to inclusivity [31], where financial inclusivity for women was identified as one of the four key strategic pillars for gender transformative financing. Inclusivity within the African continent can also be viewed through the lens of urban development and access amongst the general population [32], who highlighted the need for a massive restructuring of the urban spaces, to ameliorate the negativities arising out of apartheid and colonial governments in southern Africa. A lot of related studies have investigated financial inclusivity within Africa, such as [33] which determined that financial inclusion had a significant and positive effect on entrepreneurship in Africa. [34] also argued that financial inclusion breeds growth within the African continent, however, but that education plays a key role in fostering financial inclusion.

Disability inclusion is opposed in African Societies due to cultural and religious issues [35], where some cultural beliefs attribute children and people with disabilities as being cursed by the gods or that such children are suffering disability ailments due to crimes their parents committed or crimes they committed in a past life. Thus, you see a high level of segregation and stigmatization. Parents are willing to leave their children at home, hiding them from the glaring eyes of the public and with some simply abandoning them after birth in hospitals.

Religious inclusion issues also abound in Africa, where women have been the major victims of this practice, due to religious beliefs, the movement of women can be limited to reduce their close contact with people of the opposite sex to whom she is not related to. There is also another religious and cultural practice that which ascribes a class status to a set of individuals and prevents them from interacting with others freely, an example is the Osu Caste System [36]. There are many more inclusion challenges faced by people in Africa, which go beyond those mentioned in this study. However, it still highlights the need for inclusivity within African communities and cultures.

Autonomous vehicles can play a critical role in driving inclusivity in Africa. Just as suggested in [26] that automated vehicles can influence the accessibility of vulnerable social groups in urban and rural areas, thus having a major impact on social exclusion. A major reason why there is a divide between rural and urban city inclusion amongst the African population can be attributed to the cost of transport in itself or the lack of transport infrastructure. Autonomous vehicles offer are more cost-effective solution to transportation as its lower cost of operation could drive down the transportation fares, thus allowing a lot more people in the rural areas to have access to urban centers. The role autonomous vehicles can play to ensure disability inclusion is immense, as it eliminates the human component, which in any case would be a human African driver, who might be culturally and religiously biased against the disabled person. The availability of autonomous vehicles within the African transportation system would improve the quality of life currently enjoyed by people living with disability, as they will have greater access to mobility as they have to engage only with a computerized vehicle

as opposed to a human-operated one. This advantage also applies to people in Africa affected by religious inclusion issues. Women of certain faiths are not allowed to use vehicles in the presence of other men or people who are prejudiced by others. Autonomous vehicles will also aid the mobility of women and people in this category as well by providing around a clock computer-operated transport service that is not prejudiced against them. There are lots of interventions ongoing to promote financial inclusion amongst African women, where investments in their education are currently ongoing to ensure they are educated enough to fully benefit from the interventions, autonomous vehicles can also aid in promoting the education of women and the poor, as it would provide a round the clock, affordable transport alternative to ensure that the divide between people and opportunities are ever being constricted.

## CONCLUSION

This study attempts to establish a link between inclusion in African communities and the impact autonomous vehicles could have in fostering such inclusivity. Existing transport challenges within the continent were identified, with key mention of existing interventions currently underway to provide a solution. Autonomous vehicles are poised to be the transportation method of the future and although it has not yet permeated the African Space, there are lots of advantages to be gleaned if adopted, especially with respect to their impact on fostering inclusion. African transportation systems are in dire need of world-class, modern solutions that could aid its economic development and autonomous vehicles are one of such technologies that can drive social and financial change, thus bridging the gap between the rich and poor.

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