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Prospects for Implementation of Autonomous Vehicles and Associated Infrastructure in Developing Countries

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Abstract: This study explores the implementation and impact of autonomous vehicle (AV) systems, particularly in developing countries. While AVs promise enhanced road safety by reducing crashes, injuries, and fatalities, their adoption faces significant challenges, including public acceptance and infrastructure readiness. A mixed methods approach was employed, combining quantitative data from surveys of approximately 1500 randomly selected individuals and qualitative insights from in-depth interviews with policymakers, traffic engineers, and industry representatives. The quantitative analysis revealed high levels of perceived usefulness (78.8%), positive attitudes (87.78%), and expected benefits (86.09%) among respondents, indicating optimism about AVs' potential to improve traffic efficiency and safety. However, concerns about technical reliability, cybersecurity, and the cost of infrastructure upgrades persist. Comparative analysis of physical and digital infrastructure highlighted significant gaps, particularly in road quality, markings, and internet connectivity. Policy implications emphasize the need for targeted public education to build trust and address safety concerns, regulatory reforms to ensure cybersecurity and ethical compliance, and strategic investments in infrastructure to meet AV requirements. Drawing on lessons from international contexts, the study recommends proactive stakeholder engagement and community outreach to align technological advancements with societal needs. These findings provide a roadmap for policymakers to navigate the challenges of AV adoption in Ethiopia and similar contexts, ensuring the integration of automation into sustainable and efficient transportation systems.

Keywords: autonomous vehicles; impact; infrastructure; transportation; developing countries

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1. Introduction

In future society autonomous components and operating systems are expected to replace manpower smoothly and efficiently. Among the machine systems needed to support modern society, autonomous vehicles (AVs) are likely to play a significant role. Urban residents worldwide are facing increasing traffic-related safety and environmental issues, such as high levels of noise, air pollution, traffic-related injuries and deaths, rising fuel costs, and long commuting times. Acceptance studies of autonomous transportation focus on examining public perceptions and attitudes toward technologies such as automated buses and autonomous vehicles. These studies aim to uncover the factors that significantly influence public acceptance, which is essential for the successful integration and widespread use of these systems. Collectively, these studies highlight the importance of addressing both behavioral and demographic factors through tailored strategies that align with the specific demands and expectations of different technological implementations.

According to the world bank, in 2016 transport accounted for an estimated 23% of global energy-related CO_2 emissions and is likely to account for 33% of greenhouse gas (GHG) emissions by 2050 [1]. There is thus an argued need for innovative solutions to make the transportation sector safer, less polluted, less congested, more fuel efficient and cheaper to use. One such solution is to implement systems involving AVs, which are autonomous in the sense that they do not require human inputs and operate by sensing and reacting to the surrounding conditions [2]. Autonomous vehicles can replace passenger cars and delivery vehicles entirely, reducing local environmental pollution. Self-driving vehicles also have the potential to make roads safer by eliminating the crashes, injuries, and fatalities associated with conventional vehicles, but some safety concerns need to be addressed. Developing countries, with their fast-rising economies, expanding middle classes, and increasing urbanization, are a huge potential market for AVs. However, various hurdles must be overcome before AVs are broadly utilized in developing countries.

It is important to note that while AVs focus on automation and safety, autonomous vehicles (AVs) address environmental concerns by reducing emissions. Also, AVs which are powered by electricity rather than fossil fuels, emit no tailpipe emissions, resulting in cleaner air and better publish health. The integration of both AV and EV technology could provide a comprehensive solution to the current transportation challenges by combining the benefits of automation with those of sustainable energy. The study aimed to evaluate the sustainability of AV systems for developing countries, focusing on societal awareness, reliability, safety, convenience, and comfort from the perspectives of both the general public and specialists. Particular attention was given to the distinction between privately used AVs and public-use AVs, such as autonomous buses, as this differentiation significantly influences societal factors and infrastructure requirements. The research primarily concentrated on autonomous vehicles for public transportation, while also exploring future implications for private use. Ethiopia was selected as the study area, representing a developing country context.

1.1. Potential Benefits of AV Systems

Improved traffic efficiency [3]: AVs and connected vehicles (CVs) can interact with one another and with infrastructure to optimize traffic flow and decrease congestion and trip times.

Reduced Environmental Impact: Electric vehicles (EVs) emit no tailpipe emissions, resulting in cleaner air and better public health.

Economic growth and job creation [4]: The development and implementation of these technologies will result in the creation of new industries and employment, enhancing economic growth.

Improved mobility for all [5]: AVs can transport those with disabilities, the elderly, and those living in underserved regions.

Large and expanding markets: Emerging markets, characterized by their large and growing populations, present significant opportunities for the adoption of autonomous vehicles. For instance, India is projected to have the world's largest population by 2027, which could drive substantial demand for AVs. Similarly, China, with the world's largest middle class, represents a vast market potential for AV technology [6].

Rapid infrastructure development [7,8]: Many developing countries are investing extensively in infrastructure, such as roads, bridges, and telecommunications networks. This will improve the local environment for the development of AVs.

Government backing: Emerging-market governments are increasingly recognizing the potential of AVs to improve transportation efficiency and safety and are providing financial and regulatory assistance for AV development and testing.

1.2. Challenges in Implementation of AV Systems

In many developing countries, the infrastructure is not yet sufficiently mature to facilitate the safe operation of AVs. For example, lane lines, traffic signs, and high-speed internet access may be lacking. Compared with other African countries, Ethiopia has extremely sparse road infrastructure (21 km road per 1000 km^2), and the existing road infrastructure is very congested, leading to high transport costs. These costs are at unaffordable levels for the majority of the disadvantaged population, while also penalizing producers. High transfer costs, mostly owing to high transport costs, act as an important barrier by raising the important parity price (IPP) level [9]. Further investment in infrastructure is needed to address these shortcomings.

Safety concerns [10,11]: There are still some unresolved safeties with AV systems. These need to be addressed at the technical and implementation levels.

Public acceptance [12]: In many emerging countries, public acceptance of AV systems is low because of privacy, job displacement, and safety concerns. Education and public outreach programs are needed to improve acceptance.

Here is the summary of the state-of-the-art autonomous vehicle (AV) systems, along with their benefits and challenges (Table 1).

Table 1. State-of-the-art of autonomous vehicle (AV) systems [13–15].

AV System	Main Benefits	Challenges
System A	Improved safety through advanced sensors. (Reduced traffic congestion)	High cost of implementation (Regulatory hurdles)
System B	Enhanced fuel efficiency (Lower emissions)	Limited infrastructure support (Cybersecurity risks)
System C	Increased accessibility for disabled individuals (Potential for reduced travel time)	Ethical concerns in decision-making (Public acceptance and trust)

Key user-related concerns and expectations about AVs:

Acceptance factors: Relative norms, perceived behavioral control, attitudes, and trust are important variables influencing the desire to utilize autonomous vehicles.

Challenges in development: Researchers are still trying to solve problems with AVs such as occlusion, prediction, and fleet planning and control [16].

Safety and reliability: Optimistic predictions suggest that AVs will be safe and reliable by 2025 and will be commercially available in many developing countries by 2030. These advancements are expected to benefit a wide range of stakeholders, including the general public, governments and municipalities, insurance companies, and businesses. However, there may be situations where human intervention is required [17].

Impact on travel demands: It is uncertain whether AVs will increase or reduce total travel and associated traffic problems [18]. Planning requires predicting future conditions and needs and evaluating the benefits and costs of AVs.

Workplace changes: AV systems are likely to bring enormous changes to the workplace, as jobs primarily involving driving will become obsolete [19].

Communication with law enforcement: Although we are in 2024, many law enforcement agencies, both in developing and developed countries, are still in the process of addressing issues related to AV use on public roads. It remains crucial for all AVs to conform to existing traffic laws and regulations. Ongoing collaboration between AV developers and law enforcement agencies is essential to ensure the safe and effective integration of AVs into public roadways [20].

Limited personal use: Personal use of vehicles requiring no driver is expected to be very limited within the next five years. Initially, AVs may be more commonly used in ride-share and shuttle programs, and only in a few large cities in developed countries.

2. Methods of the Study

The novel contributions of this paper are to report perceptions and current conditions in developing countries and their AV infrastructure status, compared with that in developed countries. In particular, physical and digital infrastructure and societal perceptions of AV systems were analyzed.

2.1. Literature Review

Relevant scientific publications were located through searches in Scopus-indexed databases, including Frontiers, MDPI, Springer, ResearchGate, SAGE, Elsevier, Google scholar. The selection criteria for these publications were based on their relevance to the topic and their recency, focusing on journal publications and conference papers from the past five years. Among the key themes explored in these studies are the public's perceptions and acceptance of AVs, as well as their potential impact on transportation systems. For example, Ref. [21] a study on automated buses (ABs) in Scotland identified five key factors exposure to AVs, system assessments, travel behaviors, personality traits, and demographic profiles that influence bus use and willingness to adopt automation. Another study in Singapore using the Unified Theory of Acceptance and Use of Technology (UTAUT2) revealed that interaction quality, societal influence, and performance expectancy drive public acceptance, emphasizing the role of consumer-centric strategies [22]. Further, research on automated buses [23] highlights the importance of perceived trust, safety, and usefulness in early adoption, suggesting that public education and safety assurances are critical to building confidence in such technologies. This ensured that the literature review was grounded in the most current and pertinent research available.

2.2. Data Collection

The data collection process involved both quantitative and qualitative methods:

Surveys: Structured questionnaires were distributed to a diverse sample of participants in both developing and developed countries. The survey aimed to capture detailed information on the participants' perceptions of AV systems, their awareness of AV technology, and their views on the current state of AV infrastructure.

Interviews: In-depth interviews were conducted with key stakeholders, such as policymakers, traffic engineers, and representatives from the automotive industry. Interviewees were recruited through a targeted approach, ensuring they were relevant to the study's objectives. This included direct invitations sent to government institutions, traffic management agencies, and automotive companies, as well as referrals from professional networks. The interviews were conducted in person, during which respondents completed questionnaire papers provided in a controlled setting to ensure consistency and reliability. All interviews were held with the respondents' prior consent, enabling the researchers to explore societal perceptions and practical challenges related to AV systems in greater depth.

2.3. Analysis

The analysis focused on comparing the physical and digital infrastructure and societal perceptions of AV systems between developing and developed countries. The following steps were taken:

Quantitative analysis: Survey data were analyzed using statistical methods to identify trends and differences in perceptions and infrastructure status. Measures such as mean, trends, differences in perceptions, and infrastructure status.

Qualitative analysis: Interview transcripts were analyzed using thematic analysis to identify common themes and insights related to AV implementation and societal acceptance.

2.4. Structure of the Paper

The rest of this paper is structured as follows:

Section 3: A summary of studies on the state of AVs, mechanisms or approaches evaluated in publications, and platforms for AV implementation applications.

Section 4: Describes the current status and societal acceptance rate (perception) of AV systems.

Section 5: Compares AV infrastructure in developing countries (with a focus on Ethiopia) with that in developed countries and summarizes the findings made in this study.

Section 6: Presents the conclusions from the work and suggests areas for future research.

3. Expected Platforms for AV Infrastructure

The Automated Vehicle Readiness Index (AVRI) describes the readiness and openness of various countries to AV technology, which can help public authorities (federal, regional, or local) learn from others and accelerate AV adoption, with potential advantages for society [24]. According to previous studies [25,26] and AVRI predictions, the main pillars for the implementation of autonomous vehicles are technology and innovation, infrastructure, policy and legislation, and consumer acceptance from a societal point of view.

At present, the Netherlands is the country best positioned for the implementation of driverless vehicles [25], due to its robust internet and infrastructure systems, well-maintained road networks, and supportive government policies. Based on AV readiness and status in the Netherlands, AV infrastructure must comprise a good road network, a reliable road maintenance system, standards for road construction, and standardized norms for road lanes, telematics, signs, walkway accident barriers, and curbs. Expensive changes are required before driverless vehicle systems can become a reality. The physical infrastructure required for AVs includes paved roads, road furniture, road markings, speed range, traffic signs, and a road shoulder or curb (static infrastructure), plus the maintenance of these in a dynamic process discussed in Table 2.

The digital infrastructure required comprises traffic management systems, information systems, fleet supervision, communication, digital twinning of the road network, satellite positioning, and a high-definition (HD) map as mandatory components [27,28]. In general, factors determining the availability and development of AVs include the existence of regulations and policies supporting AVs, the level of investment in AV technology and research, the presence of advanced road infrastructure and connectivity, the adoption and implementation of smart city initiatives, and the accessibility and availability of charging infrastructure for electric AVs.

Table 2. Physical Infrastructure required for autonomous vehicle (AV) systems [29].

Status (Dynamic/Static)	Physical Infrastructure Features	Secondary Attributes
Static	Road	Road types (highways, roads, streets, etc.)
		Separation of AVs
		Special road sections (tunnels, bridges, toll plazas, etc.)
		Pavement alongside road (ease of detection of roadways)
		Bearing capacity (lanes, shoulders, bridges-critical for platoons)
	Road furniture	Landmarks
		Gates and barriers (lanes, roads, or areas of concern)
		Gantries for road signs
		Road lighting (for support of AV vision system)
		Game fences (availability and condition)
	Road markings	Visibility, machine-readability (to vehicle sensors)
		Existence of lane markings (lateral positioning)
		Markings indicating use by AVs
	Speed range	Speed limit or recommendation
	Traffic signs	Signs indicating use by AVs
		Visibility, machine-readability
	Shoulder or curb	Wide shoulder
		Lay-bys or parking areas
		Passenger pick-up/drop-off areas

Table 2. *Cont.*

Status (Dynamic/Static)	Physical Infrastructure Features	Secondary Attributes
Dynamic	Infrastructure maintenance	Inspections of infrastructure
		Winter maintenance (for visibility of road markings)
		Road maintenance including road marking painting, and clearing of vegetation.

3.1. Physical Infrastructure

Physical infrastructure acts as the backbone for the digital environment supporting AV systems, see Table 2.

Data for Table 2 were sourced from the European ITS Platform's report on 'Physical and Digital Infrastructure Attributes for Automated Driving'. The presence of physical infrastructures is essential for AVs system components such as smart applications for traffic management, maintenance and charging facilities, mobility hubs that help bring together multiple modes of transportation, and smart parking meters with positioning systems, see Figure 1.

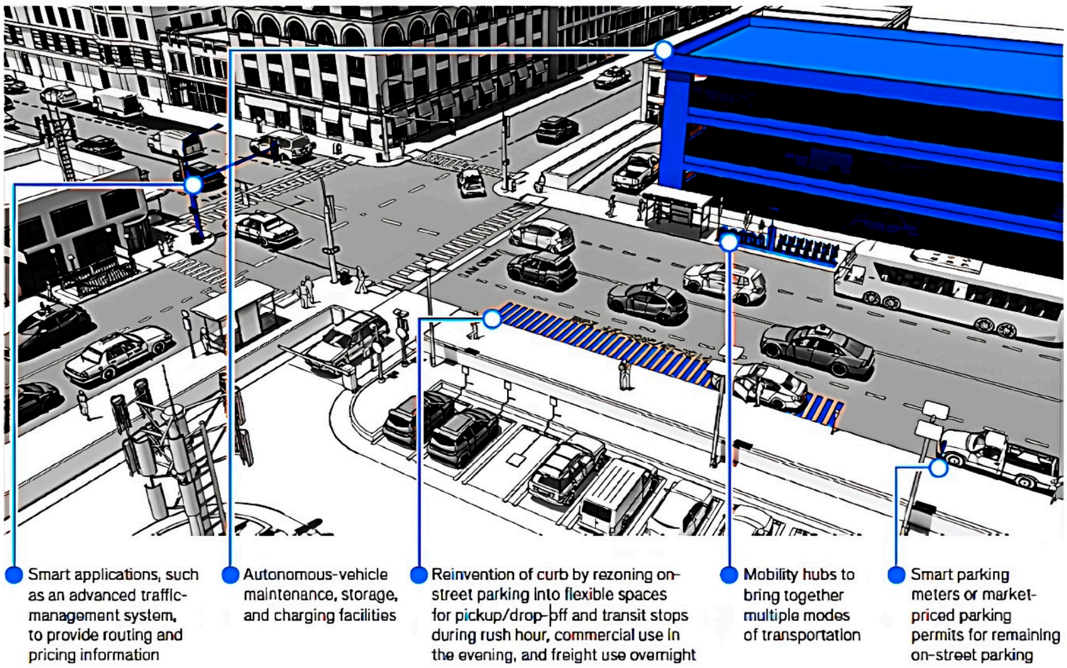

Figure 1. Physical infrastructure components required by an autonomous vehicle (AV) system [30].

3.2. Digital Infrastructure

Software-based infrastructure is necessary to move goods, products, and people in a modern transportation system. Software for traffic management, information systems, fleet supervision, communication, digital twinning of road networks, satellite positioning (GPS), and HD mapping is essential for transportation systems. Attributes of existing software solutions and current gaps are listed in Table 3.

Figure 2 illustrates different components of digital infrastructure that are mandatory for applications. Those components are mostly under development in developing countries which are essentially safe, promoting wider deployment of AVs.

Table 3. Basic digital infrastructure required for autonomous vehicle (AV) systems [29,31].

Status (Dynamic/Static)	Digital Infrastructure	Secondary Attributes	Gaps
Dynamic	**Traffic management**	Incident control	Edge/Cloud systems for managing large volumes of connected and automated vehicle (CAV) data require standardized governance, including maximum latency specifications for real-time signal transmission. Roadside unit coordinated messaging for advanced CAV movements in junction crossings and lane merging/change operations is not standardized, but falls under Society of Automotive Engineering (SAE's) Cooperative Driving Automation Committee. Automated driving system (ADS) technology relies on precise geo-location data from GNSS and GPS, but GPS signals have difficulty penetrating into urban canyons, tunnels, and densely vegetated highways. CAVs can compensate with inertial sensors, but these accumulate errors over time, making them unreliable in areas with GPS signal obscuration. Physical features and road segment's ability to adjust need to be assessed.
		Road works	
		Operational Design Domain (ODD) control	
Static	**Information system**	Digital traffic rules and regulations	
		Geofencing information	
		Realtime events and availability of road infrastructure	
Dynamic	**Fleet supervision**	Fleet supervision and monitoring centers	
Static	**Communication**	Medium and long-range V2I with low latency and wide bandwidth	
		Medium and long range V2I	
		Short range V2I	
Dynamic	**Digital twinning of road networks**	Traffic status on network	
		Real-time management, including traffic flows	
Static	**GPS**	Land stations	
		Positioning support in tunnels	
	HD map	Maps of road environment (landmarks, camera, radar, and Ultrasound sensors) Landmarks for LIDAR sensor	

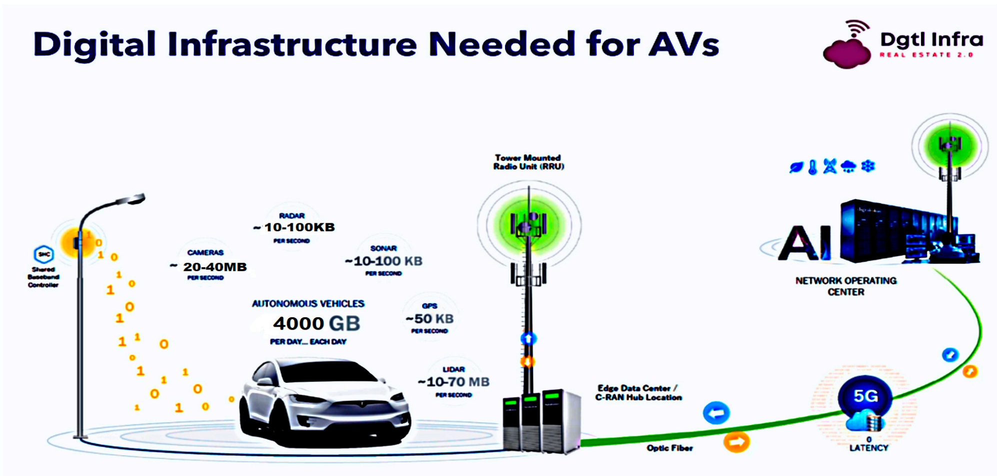

Figure 2. Digital infrastructure components required by an autonomous vehicle (AV) system [32]. Note: (~ indicates to show nearer values).

3.3. Combined Infrastructure Requirement

Highly developed digital infrastructure in the absence of adequate physical infrastructure cannot meet the mobility demands of both manually driven and autonomous vehicles. Investments in physical infrastructure must be made in order to realize the potential of digitization and meet the requirements of future vehicles with varying degrees of automation.

According to 2018 data collated by KPMG, today's digital and physical infrastructure construction was comparatively functional and almost complete in many developed countries (Netherlands, Singapore, Japan, South Korea, UAE, Sweden, USA, Austria, Australia, UK, Canada, Germany, France, Spain, China, New Zealand, Mexico, India, Brazil, and Russia) at that time. Infrastructure was also good in Denmark, Taiwan, and Hungary in 2018. By 2020, Norway, the USA, Finland, Sweden, Denmark, and Israel, were among the top 20 countries in terms of digital and physical infrastructures for AVs [33].

4. Current Status of AV Infrastructure in Developing Countries and Public Acceptance of AVs

Ethiopia has an estimated population of around 100 million, of which around 80% live in rural areas and 20% (21 million) are urban residents [34]. The population is expected to grow to 122 million by 2030 [35]. As Ethiopia's cities and urban centers grow, they face increasing challenges in serving the growing demand for mobility, along with rising levels of traffic congestion, deaths from traffic crashes, and local air pollution. Evidence worldwide shows that street designs focused on vehicle movement rather than mobility for people, undermine the quality of life and the character of public spaces [36,37]. Greater emphasis on walking, cycling, and public transport in the planning, design, construction, and management of transport systems is needed to achieve a more equitable allocation of road space. From an economic point of view, Ethiopia currently has food security problems, with 20.1 million people facing low food security in various parts of the country for different reasons [38]. Therefore, the construction of infrastructure for autonomous vehicles similar to that in the Netherlands is unachievable in the present conditions in Ethiopia and other developing countries. According to Internet-world-stats 2023, Africa has 11.2% internet coverage and 17.6% of the global population, while Asia has 54.2% and 54.9%, respectively, and Europe has 13.9% and 10.6%, respectively [39]. Internet penetration rates in different continents worldwide are shown in Figure 3.

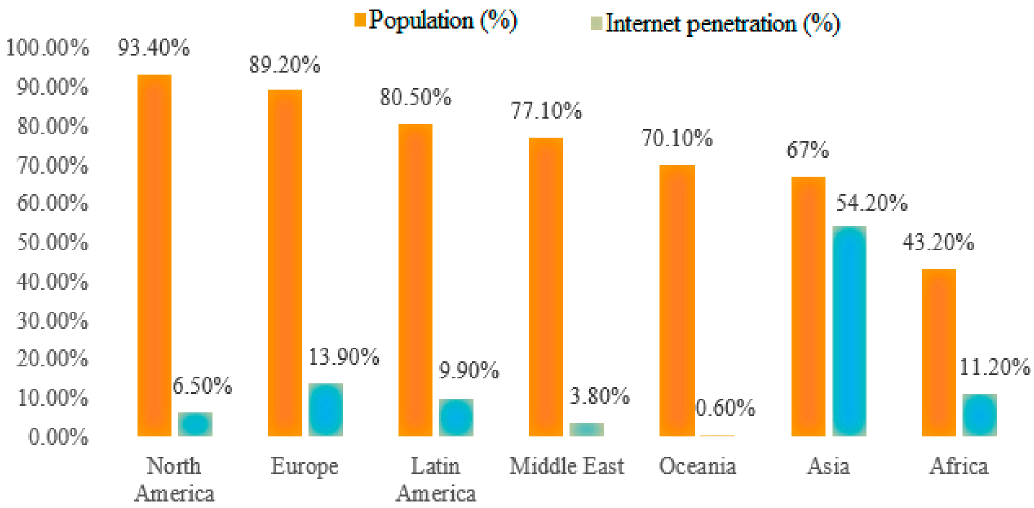

Figure 3. Population and Internet penetration rates in different continents worldwide [39].

In emerging nations, societal attitudes to AVs are largely positive, but there is considerable skepticism and anxiety. According to a KMPG poll, 62% of respondents in emerging nations are interested in AVs, but only 20% believe AVs are safe [26]. There are a number of reasons for this, one of which is that many individuals in developing nations have had bad experiences with public transport and may believe that AVs are no safer than conventional vehicles. Another reason is the lack of knowledge regarding AV technology. Many individuals in developing countries may not understand how autonomous cars function or how they vary from ordinary automobiles. Despite these reservations, there is much enthusiasm for the possibilities of AVs. People in developing countries are eager to reap the benefits of AVs, which include decreased traffic congestion, enhanced safety, and increased accessibility. Considering all those conditions, let us understand the context of one country by picking from a developing country, Ethiopia.

5. Ethiopian Context for AV Systems

Ethiopia, like most of the continent of Africa, is currently not technologically advanced and it has no AVs in testing or in use. Thus, short- and long-term training needs to be provided by relevant government bodies in order to familiarize Ethiopian society with the AV concept. A problem is that Ethiopia is a low-income country and its road network, vehicle density, and vehicle systems are all in their infancy. A much larger road network would be required to enable the introduction of AVs in Ethiopia, but there are a number of factors that might make a viable market for this technology. These include a huge and increasing population, a rapidly expanding economy, and an innovative administration. Furthermore, inadequate infrastructure for conventional vehicles may make autonomous vehicles more appealing than ordinary automobiles. The main hurdles that need to be overcome are road conditions and traffic patterns, as AVs must be capable of dealing with the country's peculiar driving circumstances, such as dirt roads, aggressive driving, and unpredictable traffic. Ethiopians are becoming more and more interested in AVs in spite of these obstacles. The government is investing in research and development, and some private companies are working on developing AVs for the Ethiopian market [40].

5.1. Road Infrastructure Conditions in Ethiopia

Ethiopia has a rather weak road infrastructure. The country has a massive road network, but many of its roads are in poor condition and pose multiple safety risks from potholes, unmarked obstructions, and a lack of safety barriers. The Ethiopian government is investing in road infrastructure improvements, but progress will take time and money. In the interim, driverless cars will need to be able to cope with Ethiopia's poor road conditions.

Specific Road Infrastructure Problems in Ethiopia

Condition of road surfaces [41]: The state of Ethiopian road surfaces varies greatly. Some roads are in decent condition, while others have potholes and cracks.

Road markings: On Ethiopian roads, road markings are frequently nonexistent or fading. Drivers may find it difficult to see lanes and make turns because of this.

Signage: On Ethiopian highways, signage is sometimes nonexistent or badly maintained. Drivers may find it difficult to maneuver and avoid hazards because of this.

Safety features: On Ethiopian highways, safety elements such as safety barriers and rumble strips are uncommon. This can increase the likelihood of an accident occurring.

Despite these hurdles, there is growing confidence that self-driving cars have the potential to enhance Ethiopian transportation by alleviating traffic congestion, increasing road safety, and expanding mobility alternatives for individuals with impairments.

On the other hand, establishing more physical infrastructure would reduce urban land availability for houses and businesses, fragment and damage the environment and ecosystems, decrease biodiversity, and so on. This creates a risk of impacts on natural rivers, increasing floods and runoff, deteriorating aquifers, and increasing water demand.

5.2. Societal Perceptions of AV Systems in Ethiopia

Perceptions and attitudes of Ethiopian society to AVs were captured in questionnaire-based interviews with approximately 1500 individuals [42], revealing both enthusiasm and concerns. Challenges such as limited infrastructure and public skepticism mirror global trends, where societal factors like perceived safety and enjoyment strongly influence adoption. Broader acceptance studies underscore the importance of targeted education and outreached to build public trust, providing valuable insights for tailoring policies in Ethiopia. By addressing both societal and infrastructural limitations, the findings can guide the development of strategies for AV integration in similar contexts. Their responses are shown in Table 4, while the full questionnaire can be found in Appendix A of this paper.

Table 4. Responses obtained in questionnaire-based interviews (N = 1500) on perceptions and attitudes to autonomous vehicle (AV) systems.

Topic [43]	Statement		Percentage of Respondents in Different Sociodemographic: Male Agree	Male Disagree	Female Agree	Female Disagree	Work	Habitat
Perceived ease of use	Learning how to use AVs would be simpler for me.		29.64%	37.3%	5.76%	27.27%	• 37% unemployed, • 63% employed.	• 54% urban. • 46% rural.
	Using AVs would not need any mental effort.		41.78%	29.17%	28.7%	0.33%		
	I found AVs straightforward to grasp.		49.83%	17.63%	5.42%	27.11%		
	It is simple to operate AVs.		36.12%	25.75%	26%	12.04%		
Perceived usefulness	My driving would be more comfortable if I used AVs.		52.91%	14.26%	28.46%	4.35%		
	Transporting people by AVs would be beneficial.		53.21%	12.85%	21.42%	12.5%		
	AVs would make my driving easier.		53.21%	13.35%	27.4%	6.88%		
Attitude	Using AVs is	A wise idea.	63.97%	2.49%	28.28%	5.25%		
		A good idea.	63.97%	2.69%	28.96%	4.37%		
		A meaningful.	60.25%	6.77%	25.59%	7.38%		
		Advantageous.	58.14%	8.58%	21.95%	11.33%		
Intention	If AVs are available in the future,	I plan to use one	24.24%	No response	12.88%	62.87%		
		I plan to buy one.	10.8%	No response	14.7%	74.49%		
Perceived danger	What would worry me would be,	Technical and system malfunctions.	Almost all considered all these a high risk.				• 37% unemployed. • 63% employed.	• 54% urban. • 46% rural.
		Cyber-attacks(hacks).						
		High initial price.						
		Whether morally correct and ethical.						
		My private information being disclosed.						
		Users' or owners' legal responsibility.						
		Transportation sector jobs would decline as a result of AVs.						
Benefit	AVs would increase,	Traffic safety.	59.16%	5.8%	26.19%	8.85%	• 37% unemployed. • 63% employed.	• 54% urban. • 46% rural.
		Fuel efficiency.	56.86%	9.03%	32.1%	2.0%		
		The mobility of persons unable to drive (disabled and old).	64.85%	2.05%	26.67%	4.44%		
	AVs would reduce,	Vehicle emissions.	60.72%	5.73%	25.91%	7.62%		
		Transport cost.	52.16%	13.9%	27.82%	6.12%		
		Traffic congestion.	Unknown				Unknown	
	It requires less land use.		Unknown				Unknown	

All interviewees were located in Adama city and in rural areas located around the city, which is considered the second capital of Ethiopia, i.e., after Addis Ababa. Figure 4 shows the locations in which data were collected and road traffic conditions in the city.

5.3. Evaluation of Ethiopian AV Infrastructure and Comparison with That in Developed Countries

The current status of both physical and digital AV infrastructure readiness and set-up in Ethiopia was compared with that in different countries around the world [44], to identify the future implications of this technology in developing countries, see Table 5 and Figure 4.

Figure 4. Locations in Adama city, Ethiopia, in which data were collected, and prevailing traffic conditions. (Google map—image @2024 Airbus).

Table 5. Overview of autonomous vehicle (AV) infrastructure in selected countries on different continents worldwide.

Continent	Country	Infrastructure (%) Digital	Infrastructure (%) Physical	Remark
Europe	The Netherlands	80.02	99.3	At the forefront of AV infrastructure. The country has a well-developed road network and has actively promoted smart mobility solutions, including AVs.
Asia	Singapore	63.36	100	One of the leading countries in AV infrastructure. The government has been proactive in creating a conducive environment for AV testing and deployment, including dedicated AV testing centers and regulatory framework.
	South Korea	72.1	83.8	Is investing heavily in AV technology and infrastructure. The government has set up a dedicated AV testing site, K-City, and is actively promoting development and deployment of AVs.
	Japan	59.08	89.4	Has been making steady progress in AV infrastructure. The government has been promoting AV technology as part of its Society 5.0 initiative and has conducted several AV trials on public roads.
America (North and South)	Mexico	22.52	43.4	AV infrastructure is still in the early stages of development. However, the government has shown interest in AV technology and has conducted a few AV trials.
	Brazil	19.76	<5	AV infrastructure is still in the early stages of development. The country has conducted a few AV trials, but widespread deployment of AV is still a long way off.
Africa	Ethiopia	0	<5	AV infrastructure in Ethiopia is currently very limited. The country is still grappling with basic road infrastructure issues, which makes the deployment of AVs a challenging prospect.
	South Africa	0	16	South Africa has shown interest in AV technology, but its AV infrastructure is still in the early stages of development.

The comparisons and assessments in Figure 5 were based on the basic infrastructure pillars analyzed and reported by [30], which are a compilation of EV charging stations, 4G coverage, technology infrastructure change readiness, mobile connection speed (0.5 weight), and broadband (0.5 weight) for digital infrastructure, and road quality for physical infrastructure. Based on the comparisons, it will clearly be difficult for developing countries to introduce AVs in the near future or even for them to become familiar with the concept in comparison with current conditions in developed countries.

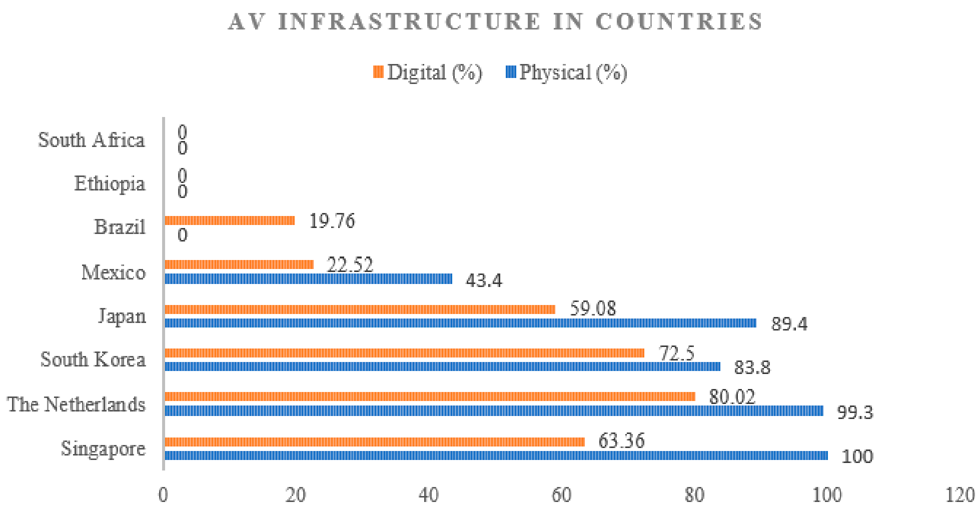

Figure 5. Comparison of autonomous vehicle (AV) digital and physical infrastructure by country.

5.4. Perceptions of AV Systems Among the Interviewees

Analysis of societal perceptions was based on interviews conducted by researchers. There are many difficulties with conducting research concerning AVs and societal readiness, and also concerning the impact of autonomous technology on developing countries by either providing functions or damaging existing resources. The results indicated that more training is needed in developing countries to improve awareness and perceptions of the system. Previous studies have shown that safety is a primary concern in regards to AVs. [45–47]. Table 6 presents perceptions and rates of acceptance among respondents in this study.

Table 6. Rates of acceptance of autonomous vehicle (AV) systems and perceived impacts on existing infrastructure.

1. Perceived advantages		
Advantage	**Percentage of Interviewees in Agreement**	**Remark**
Perceived ease of use	55.82	All questions raised by interviewers were answered but to different degrees.
Perceived usefulness	78.58	
Attitude	87.78	
Benefits	86.09	
2. Perceived risks		
Safety	99.9% viewed AVs as risky and would be afraid of using them.	

Overall, the results indicated that AVs will be very difficult to implement in Ethiopia without comprehensive public information and training. Many interviewees were in favor of the system, but most were afraid of using it, see Table 4.

6. Discussions and Policy Implications

The adoption of AV systems is heavily reliant on public acceptance. Acceptance studies of autonomous transportation underscore the importance of addressing behavioral, attitudinal, and demographic factors to build trust. Insights from other studies reveal the potential for tailored strategies, such as enhancing interaction quality and conducting public awareness campaigns, to mitigate safety concerns and promote favorable perceptions.

For Ethiopia, the alignment of these strategies with local infrastructure and societal needs can play a pivotal role in overcoming public resistance and ensuring the successful integration of AV systems. Lessons from international contexts suggest that proactive engagement with stakeholders and communities can accelerate the societal acceptance of these transformative technologies.

7. Conclusions and Future Research Needs

Autonomous vehicles are being promoted in developed countries to simplify work tasks and reduce human effort. However, attention should also be given to their use in developing countries. Based on the findings in this study, using Ethiopia as a representative case, it is evident that road infrastructure in developing countries is currently insufficient even for regular traffic. Therefore, effort should be focused on this infrastructure before considering the implementation of autonomous systems. According to the Automated Vehicle Index (AVRI), Singapore currently has the best AV infrastructure provision with 100% physical infrastructure and 63.36% digital infrastructure among the 30 countries assessed. In contrast, Brazil, despite being the 10th-ranked country in terms of GDP according to the International Monetary Fund, is ranked 30th in AV readiness, with 0% physical infrastructure and 19.76% digital infrastructure. This highlights the disparity in AV readiness between different regions. Continents like Africa, which are rich in raw resources but poor in infrastructure, need more attention because their economic backbone is primarily in agricultural systems. In the present study, a significant proportion of Ethiopian respondents agreed that AVs are easy to use. A total of 55.82%, 78.58%, 87.78%, and 86.09% of Ethiopian respondents interviewed agreed that AVs are easy to use, useful, viewed positively (Attitude), and provide benefits, respectively. However, there were some questions to which interviewees did not respond. Overall, 77% of respondents gave a largely positive response to AV systems, while 23% expressed negative views.

In general, developing countries have the potential to be a major market for AVs, but several challenges need to be addressed before AVs can be widely adopted. These challenges include limited infrastructure, safety concerns, and low public acceptance. Education and public outreach are essential to overcome these challenges and ensure that AVs can be safely and widely adopted in emerging economies.

This study examined the current state of AV systems in a developing country, people's perceptions, and infrastructure preparations. Future research should focus on developing training programs to introduce AVs to wider society and assess the impacts of AVs on land users in poor nations, such as the need to evict people from agricultural land. Better public awareness of the system and providing compensation to those affected by implementation would assist in the uptake of AV systems.

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Appendix A

Questionnaire used in interviews with local residents in Adama city and surrounding areas, and key workers

The principal objective of this key informant study is to explore the extent to which autonomous vehicles can be implemented in Ethiopia and its implications in the future. The study is being performed purely for academic (research) purposes. All responses will be treated as confidential and cannot be traced back to the individuals who provided them.

RESPONDENT'S PROFILE

AGE:______________ SEX:_______________ MARITAL STATUS________________

LEVEL OF EDUCATION:______________________________ WORK:__________________________________

Thank you for your response. Please read the following statements carefully and indicate whether you agree, disagree, or do not know by making a tick (√) or cross (**X**) in the space provided

Topic	Statement		Respondents' Feedback from Different Sociodemographic			
			Agree	**Disagree**	**Conceptless**	**Comment**
Perceived ease of use	Learning how to use AVs would be simpler for me.					
	Using AVs would not need any mental effort.					
	I found AVs straightforward to grasp.					
	It's simple to operate AVs.					
Perceived usefulness	My driving would be more comfortable if I used AVs.					
	Transporting people by AVs would be beneficial.					
	AVs would make my driving easier.					
Attitude	Using AVs is	A wise idea.				
		A good idea.				
		A meaningful.				
		Advantageous.				
Intention	If AVs are available in the future,	I plan to use one				
		I plan to buy one.				
Perceived danger	What would worry me would be,	Technical and system malfunctions.				
		Cyber-attacks(hacks).				
		High initial price.				
		Whether morally correct and ethical.				
		My private information being disclosed.				
		Users' or owners' legal responsibility.				
		Transportation sector jobs would decline as a result of AVs.				
Benefit	AVs would increase,	Traffic safety.				
		Fuel efficiency.				
		The mobility of persons unable to drive (disabled and old).				
	AVs would reduce,	Vehicle emissions.				
		Transport cost.				
		Traffic congestion.				
	It requires less land use.					

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