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Equitable Transport Access and Mobility in African Cities: current knowledge and research gaps

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PREFACE

In urban areas in both the Global South and the Global North, many individuals and communities face significant challenges due to inequities in access to essential economic, social and cultural opportunities. Transport-related inequity can manifest itself in many ways, where disparities in access are often systematically linked to socioeconomic or environmental disadvantage. Understanding various forms and dimensions of inequitable access in transport systems, as well as exploring concrete possibilities for strengthening access for all persons, are increasingly viewed as an important priority for both research and policy.

The current study by Gift Dumedah et. al. focuses on issues related to transport-related equity in Sub-Saharan African (SSA) cities. The purpose of the study is three-fold: to provide an overview of current knowledge in this area, to summarize the state of research, and to identify gaps in knowledge that might be addressed by future research in SSA cities.

The authors discuss transport-related equity from three interlinked perspectives, namely universal access, efficiency and health and safety. They explore the ways in which these dimensions impact upon low-income and vulnerable populations, arguing for a holistic approach while also underscoring the need for concerted efforts based on local insights and adaptive strategies. The study also provides annotated lists of work on transport-related accessibility which can be useful for scholars, students and stakeholders with interests in learning more.

This work was commissioned by the Volvo Research and Educational Foundations (VREF) within its "Mobility & Access in African Cities" (MAC) program. The purpose of the MAC program is to support research on issues related to sustainable mobility and equitable access in cities in Sub-Saharan Africa (SSA), as well as contribute to long-term processes of change. An important goal of the program is also to stimulate dialogue among researchers at SSA universities and between researchers and broad groups of stakeholders in these areas.

Specifically in relation to the current study, the MAC program also currently encompasses three African Research Programs in Mobility & Access in African Cities (ARP-MACs) 2025-2027. The current study serves as a scientific point of departure for the ARP-MAC "Equitable Transport Access and Mobility in African Cities" (ETAMAC), which is lead by Gift Dumedah and funded by VREF.

We hope that this study will be a resource for researchers, educators, policymakers, and other stakeholders in their efforts to understand transport-related equity challenges, as well as work to enact change toward universal access.

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EXECUTIVE SUMMARY

Brief and overall objective

The overarching goal of this study is to provide a background and inform researchers of the key priorities towards developing a research agenda on enhancing transport-related equity in African cities. The paper has a specific focus on equitable, affordable and reliable access to livelihoods, services, leisure activities, and opportunities in sub-Saharan African (SSA) cities.

Objectives of this study

- to provide an overview of current knowledge regarding equitable, affordable and reliable access to livelihoods, services, leisure activities, and opportunities.

- to summarize the state of research on the above theme, specifically in SSA cities.

- to synthesize gaps in knowledge that might be addressed by future research in SSA cities.

Key findings and research gaps

Access to essential opportunities in SSA cities is highly unequal and differentiated by several interlinking factors such as socio-demographics, mobility resource constraints, and the capability of individuals, communities, and authorities responsible for the transport sector. These and related conditions make SSA cities exhibit considerable spatial and social inequalities within the context of high population pressures and disparities in political power and access to resources. These challenges underscore the need for concerted research efforts aimed at providing local insight, adaptive strategies, and a holistic perspective on transport-related equity in SSA cities. Accordingly, this study synthesizes transport-related equity from three interlinked perspectives: universal access, efficiency, and health and safety.

Transport-related accessibility focus

- Disparities of access to basic services: Based on the Accessibility as a Human Capability Approach, a minimum level of access to essential opportunities, such as workplace, healthcare, and education, is needed for all populations. However, the accessibility needs and perception of vulnerable populations do not often align with the existing demand and mobility services, where they face significant constraints. Work is needed to examine how disparities of transport-related access impact low-income and vulnerable groups, their perception of these constraints and socioeconomic costs. Specific themes include actual travel practices, constraints, and effective integration of traveler characteristics and

perception with accessibility measures as a means to investigate the disparities between existing service provision and user needs.

- Mobility-based urban morphology and equitable access to opportunities: SSA cities are characterized by low-density sprawl and a high mix of informal urban communities, which create persistent socioeconomic inequities, making it challenging to achieve equitable access to safe and affordable transport and other essential opportunities. These conditions require an in-depth investigation to develop accessibility-informed urban morphology to better characterize equitable access to services.

- Inclusivity of Public Transport (PT) and Non-Motorized Transport (NMT) options: PT and NMT are among the most visible displays of spatial and social inequalities, highlighting disparities of social and economic wealth in SSA. These disparities directly impact participation in valued activities such as jobs, education, and healthcare. Factors such as walking distance, personal safety, and affordability can exclude vulnerable populations from regularly accessing their valued opportunity destinations. Knowledge of these challenges, their perception by vulnerable populations, and implications for their livelihood and well-being are limited in SSA. Opportunities to leverage PT and NMT services to enhance their inclusivity will thereby inform policy action and enhance access to opportunities for vulnerable populations in SSA cities.

Transport-related efficiency focus

- Space-time allocation of PT & NMT: In SSA cities, vulnerable populations resort to various mobility options to achieve access to socioeconomic services such as health care, work, and markets that support their livelihood and well-being. However, the spatial and temporal allocations of PT and NMT in SSA cities are highly inefficient, leading to high-cost burdens and detrimental effects for low-income and vulnerable populations. That is, there is limited knowledge on how variations in the provision of PT services and NMT opportunities across different parts of the city, and across days and hours of the day, affect its access, perception and use by vulnerable populations, as well as how equitable allocation might be achieved to enhance access to opportunities.

- Affordability of PT options: It is widely recognized that travelers' transport expenditure is very high, about 50% in some cases, relative to income in SSA. Limited studies on this pertinent issue make it difficult to assess the full extent of the challenge. Accordingly, there is a need to understand travel fares, pricing patterns and incentives within PT, and to investigate how these patterns affect vulnerable populations' perception and coping strategies towards enhancing equity of travel policies for different PT modes.

- Allocative and productive efficiencies of PT and NMT options: The mobility performance index is often used to evaluate the performance of the transport system, providing a benchmark for assessing the effectiveness and sustainability of transport systems across cities/nations, highlighting areas of strength and areas that may require improvement in terms

of mobility and infrastructure. In the context of SSA cities, concerted research is needed to investigate how allocative and productive performance of PT and NMT can be improved to facilitate access to opportunities for vulnerable populations. There is a need to understand how to adaptively match demand to different PT and NMT modes in the context of operating conditions, user travel practices, infrastructure conditions, network development, and travel markets.

Transport-related health and safety focus

- Traffic crash rates and their impact on vulnerable populations: It is widely recognized that vulnerable road users constitute the largest proportion of victims of transport-related deaths and severe injuries in SSA. Thus, there is a need to understand how and to what extent vulnerable populations are disproportionately burdened by traffic crashes when accessing opportunities, as well as the approaches to minimizing traffic crashes in SSA cities.

- Traffic noise and air pollution: Low-income and vulnerable populations in SSA cities often work in dangerous road environments where they are disproportionately exposed to unhealthy levels of traffic noise and emissions. However, there are limited investigations which examine the extent to which vehicular noise and emissions impact the choices, preferences, socioeconomic costs and health burdens of vulnerable populations in their pursuit of accessing opportunities in SSA cities.

- Personal safety and transport-related crimes: Key health and safety performance factors such as deaths and serious injuries are increasingly understood as being insufficient indicators of transport-related health and safety. Due to their limited capacity and access to resources, low-income and vulnerable populations are often victims of transport-related crimes and incidents that infringe on their personal safety. Thus, critical research is needed to understand how vulnerable populations perceive transport-related crimes and their personal safety, as well as approaches to minimizing these incidents in PT and NMT systems in SSA cities.

1. Introduction

1.1. Brief and objectives

The objectives of this study are:

- to provide an overview of current knowledge on transport-related equity challenges in Sub-Saharan African (SSA) cities, with a particular focus on access to social, economic, and cultural opportunities for all persons.

- to draw attention to gaps in knowledge that might be addressed by future research and education, with a specific focus on sub-themes relating to transport-related access (or accessibility), efficiency, and health and safety.

- to summarize the research gaps and priorities around transport-related equity challenges in SSA cities.

1.2. Scope

Equity is central to universal access, which enables accessibility to opportunities and goes beyond providing access to transport alone. Globally, the shift from mobility-centered transport to an access-focused one is widely accepted. Access to essential opportunities and how socio-economic and environmental disadvantages differentiate them is a keystone of transport-related equity. That is, the disparities of access to opportunities that are systematically linked to socio-economic or environmental disadvantages underpin a cornerstone of transport-related inequity. Conventionally, a narrow focus on mobility - using metrics such as travel speed, congestion, and components such as motorized transport and private vehicles - puts attention on the transport system itself instead of on users of the system. This narrow attention to mobility-centered transport has left gaps in our knowledge and understanding of transport-related equity challenges often faced by individuals and communities who are already burdened by socioeconomic or environmental disadvantages.

Transport-related inequity can manifest itself in several ways. This study focuses on equitable access to opportunities (e.g. work, healthcare, markets, etc.) in SSA cities. Typically, this access can be facilitated by public transport (PT) in combination with non-motorized transport (NMT) systems such as walking and cycling. PT and NMT systems form the primary means of access to socioeconomic and cultural opportunities in SSA cities (Cooke et al., 2022; Lucas et al., 2019a; Luke, 2024; Porter et al., 2020). Essentially, PT and NMT provide the most common means of access to opportunities in SSA, yet they do not receive adequate governance, proper planning, enough investment and financial backing, proper infrastructure, or sufficient research and development activities. Accordingly, this study examines the equity of the transport system (i.e. PT and NMT systems) in facilitating access to opportunities in SSA, where selected sub-themes (a) uni-

versal access to opportunities, (b) efficiency of the transport system and services, and (c) health and safety of using the transport system and services have far-reaching equity implications.

1.3.   Approach and method

This study aims to provide a situational assessment and knowledge synthesis on transport-related equity challenges in SSA cities. It is focused on a thorough situational evaluation and characterization of equity challenges inherent to the transport system across African cities. This evaluation was achieved through a three-step approach: in-depth literature survey, critical stakeholder survey, and synthesis of findings from stakeholder consultations. The approach provided current knowledge and stakeholder perspectives on transport-related equity challenges in SSA cities.

The literature survey initially focused on keywords (and combinations thereof) relating to transport equity, transport access, transport efficiency, transport safety, and SSA. The resulting literature was screened based on the study objectives, where the selected works were critically reviewed and synthesized. The stakeholder survey employed a bottom-up approach where key stakeholders were identified and consulted for their perspectives on transport-related equity challenges in SSA cities. These were followed by a synthesis phase, which summarized the current knowledge from literature and stakeholder views on transport-related equity issues in SSA cities.

Stakeholder consultation workshops were carried out in three cities: Lomé, Togo (3 May 2024), Accra, Ghana (8 May 2024), and Dar es Salaam, Tanzania (10 May 2024). The consultation instrument comprised an interview guide and discussion questions for focus group discussions. To ensure comparative investigation, the same consultation instruments were used in all three cities. The number and the list of stakeholders represented at the three study cities are shown in Table 1.

City– Country	Participants	Stakeholder List
Accra– Ghana	11	Motor Traffic and Transport Directorate (MTTD); Land Use and Spatial Planning Authority (LUSPA); National Road Safety Authority (NRSA); Ghana Road Transport Coordinating Council (GRTCC); Department of Urban Roads (DUR); Ghana Private Road Transport Union (GPRTU); Driver and Vehicle Licensing Authority (DVLA); Ministry of Transport; Accra Metropolitan Assembly (AMA); Kumasi Technical University.
Dar es Salaam– Tanzania	12	Tanzania Roads Associations (TARA); Safi Consultants; Kinondoni Municipal Council; Road Safety Ambassadors of Tanzania (RSA); Bajaji and Motorcycle Owners Association (CMPD); Tanzania Bus Owners Association-TABOA; Land Transport Regulatory Authority (LATRA); Afritrust Holdings Limited; Tanzania Rural and Urban Roads Agency (TARURA); Dar es Salaam Cycling Association (UWABA); Dar es Salaam Commuter Bus Owners Association (DARCOBOA).
Lomé– Togo	7	Autonomous District of Greater Lomé (ADGL); Directorate of Road and Rail Transport DRRT; Lomé Transport Company (SOTRAL); HANDICAP International; Directorate of Road Security; Intercity Taxi Drivers Association; Association for the Development of Women Traders of Togo.

Table 1. Number and list of stakeholders at the three study cities

1.4. Organization of this study

This study consists of six major sections. The preceding section provided an overview of the goals and scope of transport-related equity, focusing on public transport and non-motorized transport systems and services in SSA cities. It also outlined the approach and method used, which mainly followed three steps: in-depth literature survey, critical stakeholder survey, and synthesis of findings from stakeholder consultations.

The subsequent sections, starting with the second section, provide an in-depth description and context of transport-related equity with a specific focus on SSA cities. The second section further outlines the comparative stakeholder consultation workshops carried out in the three study cities, together with a synthesis of their findings. The third section focuses specifically on equity of transport-related access in SSA cities, including a survey of the current state of research on accessibility, approaches to measuring it, and research gaps in this area. Section four focuses on equity of transport-related efficiency in SSA cities, reviewing the current state of research on efficiency, approaches to measuring it, and research gaps. Section five addresses equity of transport-related health and safety in SSA cities, emphasizing the current state of research on health and safety, approaches to measuring it, and research gaps. The final section concludes with a summary of the key research priorities for future studies to enhance transport-related equity in the domain of universal access, efficiency, and health and safety for all persons, especially vulnerable populations, in SSA cities

2. Transport-related Equity

2.1. Overview

Universally, transport systems are shifting from a focus on mobility – i.e. the ease with which one can move around the transport system, towards a focus on equity – i.e. the ability of the system to provide opportunities for access to all persons (Cooke et al., 2022; Weilant et al., 2019). Mobility metrics such as travel speed and congestion examine the transport system itself. In contrast, equity focuses on the core outcomes of system users by examining access, the ability of users to interact with a large number of people and places in a fixed amount of time (Grengs et al., 2013; Guo et al., 2023; Manaugh et al., 2015). Access in this context relates to access/accessibility to both the transport system and activity locations, e.g. access to workplaces, health care, etc. (Brussel et al., 2019; Cooke et al., 2022). Aside from a well-functioning transport infrastructure, equity of access and movement is a key outcome of any transport system worldwide (Karner, 2018; Karner and Niemeier, 2013; Manaugh et al., 2015; Weilant et al., 2019). Litman (2024) categorized transport-related equity into (a) horizontal equity – where people with similar needs and abilities are treated similarly, and (b) vertical equity (or social equity) – where disadvantaged populations, e.g. low-income persons, receive favorable treatment. However, transport-related equity as an ethical concept needs further contextualization.

2.2. Description of transport-related equity

Equity implies social justice, an ethical concept that is grounded in principles of distributive justice (Braveman and Gruskin, 2003; Daniels et al., 1999; Frank and Mustard, 1994). Equity applies to a wide range of domains, including health care, where it "implies that ideally, everyone could attain their full health potential and that no one should be disadvantaged from achieving this potential because of their social position or other socially determined circumstance" (Whitehead, 1992, p. 3; Whitehead and Dahlgren, 2006, p. 7). According to Healthy People (2020, p. 2), health disparity is defined as "a particular type of health difference that is closely linked with economic, social, or environmental disadvantage." The commitment to eliminate these disparities in health and its determinants, including social determinants, has been referred to as the goal of achieving health equity (Braveman, 2014; Braveman and Gruskin, 2003). Health equity and health disparity are interconnected such that the latter is the metric that is used to measure the former, and that greater equity is achieved by improving the health of those who are economically/socially disadvantaged, not by a worsening of the health of those in advantaged groups (Braveman, 2014; Braveman and Gruskin, 2003).

Relating these concepts in the context of transport, access disparity is thus a type of transport access difference that is closely associated with social, economic, or environmental disadvantage. Transport-related access is greatly influenced by social policies, and several social determinants have been identified as affecting transport-related access, including household

living conditions, wealth, and deprivation in the form of the Human Poverty Index and Multidimensional Poverty Index (MPI) (Campbell et al., 2019; Cooke et al., 2022; Klopp and Cavoli, 2017; Lucas, 2022; Venter et al., 2018). Related socioeconomic factors include income levels, economic assets, occupational class, educational level, racial, ethnic or religious affiliation, as well as gender, geography, age, disability, sexual orientation, and other relevant characteristics. Environmental factors include distinct community and/or mobility characteristics (e.g. informal urban communities), urban form, and exposure to relatively higher levels of vehicular emissions and transport-related health and safety (Lucas et al., 2019a; Porter et al., 2020). Accordingly, the ambition of achieving transport-related equity is a commitment to minimize or ultimately eliminate disparities in transport-related access and its determinants, including social, economic and environmental factors.

In line with this description, Lucas et al. (2019b) associated transport-related equity with (a) fair allocation of transport resources, including infrastructures, services, and expenditures; (b) fair opportunity to be mobile in order to gain accessibility to key socioeconomic activities; (c) reduction of adverse effects of transport systems; and (d) widening participation in the decision-making process. Pereira and Karner (2021, p. 271) described transport equity as "a way to frame distributive justice concerns in relation to how social, economic and government institutions shape the distribution of transportation benefits and burdens in society. It focuses on the evaluative standards used to judge the outcomes of policies and plans, asking who benefits from and is burdened by them and to what extent."

Relatedly, the project on Advancing Transportation Equity by the Minnesota Department of Transportation (Minnesota Department of Transportation, 2022, p. 1) described transport-related equity as "(a) transportation systems that support multimodal options that are affordable, sustainable, reliable, efficient, safe and easy to use; (b) quality transportation services that are accessible to all populations for reaching destinations independently if needed; and (c) transportation decision-making processes that incorporate inclusive public engagement to reduce the long-standing socioeconomic disparities experienced by underserved and underrepresented communities."

It is also recognized that proximity and connectivity of transport services will inevitably be unevenly distributed in space, leading to different accessibility levels. However, aside from spatial distribution effects of transport costs and benefits, aspects such as temporal, socioeconomic, cultural, demographic distribution, as well as "reinforcing effects", have crucial implications on transport-related equity (Pyrialakou et al., 2016; van Wee, 2016). For example, process-based and outcome-based measures have been suggested to address transport-related equity, where the former assesses the transport system and services using accessibility-, deprivation-, or mobility-based measures, while the latter examines the actual outcome of the system and services using empirical data (Pyrialakou et al., 2016).

2.3. Transport-related equity and access disparity

Fundamentally, transport-related access to reaching opportunities can be differentiated by social, economic or environmental disadvantages, where access disparities can be minimized through social policies. That is, socioeconomic or environmental disadvantages should not directly give rise to disparities of access to opportunities because they are underpinned by modifiable social policies. Specifically, disparities of access to opportunities can be minimized by social policies, for example, through better integration of transport modes, improving pedestrian facilities, and making transport systems more inclusive, affordable and accessible. However, equity, as in several domains, is an ethical value, inherently normative and grounded in the ethical principle of distributive justice and consonant with human rights principles (Braveman, 2014; Braveman and Gruskin, 2003; Pereira and Karner, 2021; Whitehead, 1992). Transport-related equity, as an ethical concept, cannot be directly measured (Braveman and Gruskin, 2003) but can be operationalized for the purpose of measurement as the absence of disparities in transport-related access and its determinants that are systematically associated with socio-economic and environmental advantage/disadvantage.

In other words, borrowing from health inequity principles (Braveman and Gruskin, 2003), transport-related inequities consistently put population groups that are already vulnerable or disadvantaged (e.g. informal urban communities, persons with disabilities, low-income households, etc.) at a further disadvantage or higher burden in terms of their access to opportunities. Essentially, the metric of access disparity represents the operational means of measuring transport-related equity. That is, through access disparity, the indicators of transport poverty relating to mobility, accessibility, affordability and exposure to transport externalities can be quantified (Lucas, 2022; Lucas et al., 2016a). Thus, equity strategies can address transport poverty dimensions by minimizing or eliminating access disparities. The commitment to minimizing transport-related inequities requires approaches to defining, measuring, and addressing how groups and individuals are disproportionately harmed by transportation or excluded from its benefits (Transportation Research Board and National Academies of Sciences, 2024). It is recognized that not all access disparities imply transport inequity; instead, it is only those that are systematically associated with socioeconomic or environmental disadvantages.

2.4. Transport-related equity in SSA cities

Transport-related inequity can manifest itself in several settings. Here, the focus is on equitable access to opportunities (e.g. work, healthcare, markets, etc.) in SSA cities. Typically, this access can be facilitated by public transport in combination with non-motorized transport systems such as walking and cycling. In SSA cities, these two transport systems (i.e. public transport and non-motorized systems) form the backbone of mobility and primary means of access to socio-economic and cultural opportunities (Cooke et al., 2022; Lucas et al., 2019a; Luke, 2024; Porter et al., 2020). Access to opportunities through public and non-motorized transport increases

people's ability to meet daily needs regardless of travel mode, which in turn reduces traffic congestion, strengthens local economies, and promotes equity (Brenneis et al., 2020).

Public transport in SSA is dominated by paratransit services, coupled with insufficient governance capacity and a lack of proper institutional arrangements (Acheampong and Asabere, 2022a; Behrens et al., 2016; Porter et al., 2020). In simple terms, the public transport in SSA is the paratransit. The paratransit system in SSA cities is largely characterized by private operators who individually own, operate, maintain, and manage their vehicles with minimal coordination (Acheampong and Asabere, 2022b; Behrens et al., 2016; Dumedah et al., 2023a, 2022a; Klopp and Cavoli, 2017; Poku-Boansi, 2022). Typically, it is associated with poor urban planning, inefficient service delivery, inadequate transport services, unregulated traffic, poor personal and road safety measures, increasing congestion, and pollution. It is recognized that the public transport system referred to here includes all modes used to facilitate access to opportunities, including bus and minibus services, taxi, two- and three-wheeler taxis, ride hailing, and related services.

Non-motorized transport (NMT) systems are a crucial mechanism for accessing socioeconomic and cultural opportunities in SSA cities. Walking and cycling are the predominant modes in Africa, where 78% of people walk for transport in Africa every day (Lucas et al., 2019a; Walker et al., 2022). Essentially, public transport and non-motorized transport systems provide the largest means of access to opportunities in SSA, yet they do not receive adequate governance, proper planning, enough investment and financial backing, proper infrastructure, or sufficient research and development activities. Transport policies and traditional transport decision-makers in SSA typically favor automobiles in a way that further burdens or disadvantages vulnerable populations, where the majority with limited mobility options are highly dependent on walking and cycling due to income constraints (Azunre et al., 2022; Cooke et al., 2022; Lucas et al., 2019a; Porter et al., 2020; Vanderschuren et al., 2022).

2.5.   Three major dimensions of transport-related equity

In the context of the transport system (i.e. public transport and non-motorized systems), three interlinked dimensions of equity are examined, which are: (a) universal access to opportunities, (b) efficiency of the transport system and services, and (c) health and safety of using the transport system and services. These three sub-themes have far-reaching impacts on the ability of the transport system to provide opportunities for access to all persons.

By description, accessibility (or access to opportunities) relates to the ability of the transport system and services to connect all people, including persons with disabilities, across geographical locations and communities to economic and social opportunities. Efficiency in this context relates to the ability of the transport system to quickly and predictably move people around, enabling easy switching between different modes of transport, while optimizing the use of resources such as infrastructure, personnel, systems, fuel, time, etc. Transport-related health and safety is the ability of the transport system and services to reduce fatalities, injuries and

crashes from transport mishaps across modes, and transport-related crimes towards averting the public health risks, and social and economic losses associated with unsafe mobility.

2.6.   Stakeholder perspectives on transport-related equity in SSA cities

As mentioned earlier, this study carried out stakeholder consultations regarding transport-related equity in three SSA cities, namely Lomé (Togo), Accra (Ghana), and Dar es Salaam (Tanzania). A summary of stakeholder responses to closed-ended questions is presented in Table 2. The findings show that the stakeholders were quite divided about whether the current transport system and services are serving their purpose well. But it is quite clear that only a fraction, about 18.2%, agree that the transport system and services are adequately serving their communities. Some reasons provided for the ineffective transport system include the following: longer travel times than expected, long queues, lack of equity, lack of inter-modality, low vehicle supply during peak periods, overloading especially during peak periods, undisciplined driving, mixed traffic on the roads, poor road infrastructure, poor regulation and supervision, traffic jams, accidents, and lack of clearly defined authority for managing travel in the city.

Unanimously, all stakeholders indicated that there are transport-related equity challenges or problems in their respective cities. Specific challenges include the following: lack of terminals, inadequate public transport, vehicles not disability friendly, unsafe terminals, poor vehicles and walkways for persons with disabilities (PWDs), poor accessibility at the outskirts, poor fare regulation, too many old vehicles, high transport fares, long waiting times, poor parking lots, lack of sidewalks and cycle lanes, poor lighting, inadequate NMT facilities, exploitation of passengers during peak periods, inadequate pedestrian walkways and zebra crossings, limited access to public space, non-involvement of all stakeholders, too many tricycles, too many motorcycles, and limited roadways.

Some of the factors that contribute to these challenges include the following: poor stakeholder consultations, poor maintenance culture, poor land use planning, usage of old vehicles, limited transport facilities, congestion, poor setting of priorities, low roadway capacity, encroachment of road space, political interference, poor infrastructure designs, high road tolls, poor vehicle allocations, unregulated fares, lack of education, poor government regulations, unlicensed drivers, poor government regulations, lack of political will, poor planning and implementation, poor coordination between stakeholders, unavailability of data, uncontrolled urbanization, lack of coherent mobility policy, and lack of training for road users.

Variable	Category	Accra-Ghana [N=11]	Dar es Salaam-Tanzani a [N=12]	Lomé-Togo [N=7]	Overal l [N=29]
The current transport system and services are serving their purpose well.	Agree	45.1	9.1	0.0	18.2
	Neutral	27.3	54.5	0.0	27.3
	Disagree	27.3	36.4	0.0	21.2
Are there transport-related equity challenges/problems in your city?	Yes	100.0	100.0	100.0	100.0
	No	0.0	0.0	0.0	0.0
Do transport practitioners [or the transport system and services] address transport-related equity challenges in your city?	Yes	55.6	91.7	85.7	77.6
	No	44.4	8.3	14.3	22.4
Transport-related Access / accessibility	Very important	36.4	58.3	28.6	41.1
	Important	45.5	33.3	28.6	35.8
	Less important	18.2	8.3	42.9	41.0
Transport-related Efficiency	Very important	30.0	50.0	42.9	41.0
	Important	40.0	16.7	42.9	33.2
	Less important	30.0	33.3	14.3	25.9
Transport-related Safety	Very important	63.6	58.3	42.9	54.9
	Important	18.2	16.7	28.6	21.1
	Less important	18.2	25.0	28.6	23.9
Are there transport-related access/accessibility challenges/ problems in your city?	Yes	100.0	91.7	100.0	97.2
	No	0.0	8.3	0.0	2.8
Are there transport-related efficiency challenges/problems in your city?	Yes	100.0	100.0	100.0	100.0
	No	0.0	0.0	0.0	0.0
Are there transport-related safety challenges/problems in your city?	Yes	100.0	100.0	100.0	100.0
	0.0	0.0	0.0	0.0	0.0

Are certain population groups (e.g. persons with disability, informal urban communities, women, etc.) that are more vulnerable to lack of transport services in your city?	Yes	100.0	100.0	100.0	100.0
	No	0.0	0.0	0.0	0.0
Are there certain population groups that are more vulnerable to transport-related deaths, injuries, and crimes in your city?	Yes	100.0	100.0	100.0	100.0
	No	0.0	0.0	0.0	0.0

Table 2. Summary of percentage responses to closed-ended questions from the stakeholder consultations in the three study cities.

However, a clear majority, about 78% of participating stakeholders, stated that transport professionals and practitioners address these equity challenges. On this question, there is a clear departure of the findings from Accra, with a lower proportion indicating that equity challenges are addressed compared with those from Dar es Salaam and Lomé. The rationale provided include limited funding to execute policy frameworks and guidelines, that most road designs are not pedestrian-friendly, road networks in the outskirts are not paid attention to, limited facilities, high cost of spare parts, regard for politicians instead of experts, lack of tools for problem solving, poor advocacy for reforming policy, lack of observation and awareness, and no space to construct roads for PWDs.

The stakeholders in each city identified various measures to address these challenges. For example, in Accra, the Driver and Vehicle Licensing Authority (DVLA) is leading PWD-related projects, and most administrative units are investing in public transport facilities in Accra. In Dar es Salaam, the Land Transport Regulatory Authority (LATRA) is offering competitive travel fares to economically disadvantaged individuals. In contrast, in Lomé, the Lomé Transport Company (SOTRAL) is enhancing capacity for its local stakeholders by implementing vehicle renewal, extending traffic routes, and organizing terminals and parking areas. Additionally, the barriers faced by practitioners identified include the following: inadequate funds, low support from government, road accident issues, low prioritization of road safety, inefficient road construction, infrastructure deficits and inadequacy, high interest rates on loans, low level of data for planning and designing, political interference, poor road network, technical and operational challenges, ineffective collaboration, driver indiscipline, lack of awareness and education, lack of political will, lack of expertise, problems of inter-modality, urban sprawl, and high traffic crashes for motorcycles and tricycles.

In addition, the stakeholders were asked to compare selected transport-related themes, specifically access/accessibility, efficiency, and safety. Distinctly, transport-related health and safety was selected consistently as the most important (about 55%) among the three themes

across the three study cities. Overall, health and safety was ranked highest, while transport-related access and efficiency were ranked the same. There are notable disparities between cities. For example, in Accra, the decreasing order of importance is safety, access, and efficiency. In Dar es Salaam, transport-related safety and access are ranked the same as most important, followed by efficiency. In Lomé, transport-related safety and efficiency are ranked the same as the most important, followed by access. These disparities are insightful, and it will be interesting to investigate further the underlying and contextual drivers of these differences.

Concerning whether there are specific transport-related access, efficiency, and safety challenges in the study cities, there was complete agreement among all stakeholders on persistent issues. Relatedly, the stakeholders overwhelmingly agreed that certain population groups are more vulnerable to a lack of transport services, transport-related deaths, injuries, and crimes. In each city, stakeholders identified specific locations and conditions that are best suited for adding or refurbishing transport infrastructure to shift demand toward safe active travel. Some examples include high activity areas such as schools, markets, hospitals, highly populated areas, city centers, high traffic routes, and residential peripheries. Specific population groups that are more vulnerable to transport-related access, efficiency and safety were identified to include low-income groups, PWDs, bicycle, motorcycle and tricycle riders, pedestrians, passengers, women, children, and students. Additional factors identified included harassment of female passengers, a high rate of road robbery, constant harassment from police and law enforcement officers, frequent vehicle breakdowns, unlicensed drivers and vehicles, poor maintenance culture, poor vehicle inspection, poor compliance, flooding issues, accidents, and overloading.

3. Equity of Transport-related Access in SSA cities

3.1. Introduction

Broadly, transport professionals and researchers have recognized the concept of access (or accessibility), the service that people seek/derive from transportation, as a viable equity indicator (Levine et al., 2019a; Martens, 2016; Martens et al., 2019). Accordingly, studies have been carried out to conceptualize it (Levine et al., 2019b; Levinson and Wu, 2020), situate it within theories of distributive justice (Beyazit, 2011; Levine et al., 2019a; Martens, 2016; Pereira et al., 2017; Pereira and Karner, 2021, 2021; Vecchio and Martens, 2021), and provide methodological frameworks to measuring it (Levinson and King, 2020; Lucas et al., 2016b; Martens et al., 2019, 2019; Martens and Bastiaanssen, 2019; Siddiq and D. Taylor, 2021).

3.2. Current state of the art

Accessibility has been fittingly contextualized into theories of justice, particularly in relation to distributive justice of transport benefits and burdens. A study by Pereira et al. (2017) reviewed common theories of justice, namely utilitarianism, libertarianism, intuitionism, Rawls' egalitarianism, and Capability Approaches (CAs) in the context of transport justice and equity. They concluded by proposing a combination of Rawls' egalitarianism and CAs, suggesting that distributive justice in relation to transport disadvantage and social exclusion should focus primarily on accessibility as a human capability. This perspective has been widely supported in the literature (Beyazit, 2011; Cao and Hickman, 2019a; Luz and Portugal, 2022; Vecchio and Martens, 2021; Willberg et al., 2024). Scholars have emphasized the need for minimum standards of access to essential services and the importance of paying attention to the extent to which transport systems respect individuals' rights and prioritize disadvantaged groups, reduce inequalities of opportunities, and mitigate transport externalities (Pereira et al., 2017; Pereira and Karner, 2021).

In particular, the Capability Approach (CA) has been considered a promising perspective to reframe and reimagine the transport system (Cao and Hickman, 2019b, 2019a; Luz and Portugal, 2022; Martens, 2016; Pereira et al., 2017; Pereira and Karner, 2021). The CA is framed to account for a wide diversity of individuals, including the distribution of mobility resources and its influence on a person's opportunities, depending on personal features, aspirations and choices (Luz and Portugal, 2022; Vecchio and Martens, 2021). It has been demonstrated to address transport-related social exclusion (Cao and Hickman, 2019b; Luz and Portugal, 2022) and transport-related inequity (Cao and Hickman, 2019a; Martens and Bastiaanssen, 2019).

The CA is a normative approach to human welfare that concentrates on the actual capability of persons to achieve lives they value, rather than solely having a right or freedom to do so (Robeyns and Byskov, 2023; Sen, 1992). According to Robeyns and Byskov (2023, p. 1), the CA is based on the idea that "the freedom to achieve well-being is of primary moral importance, and that freedom to

achieve well-being is to be understood in terms of people's capabilities, that is, their real opportunities to do and be what they have reason to value" to achieve a person's well-being – based on real opportunities to do and be what an individual has reason to value – key central themes identified by Sen (1992) are: resources, the conversion function, capabilities, and functionings.

- Resources are the commodities and intangible goods available to an individual to pursue the life he/she values. They depend on the individual's characteristics, background, and social-spatial context. That is, resources are the "means to achievement" (Sen, 1992, p. 33).

- Conversion function/factor relates to the personal, social, and environmental conditions that form the individual life experience. It determines the possibilities the individual has for converting resources into freedoms (Sen, 1992, p. 33).

- Capabilities relate to the real freedoms or opportunities available to individuals to lead a life they value, encompassing the range of opportunities and choices available to them (Nussbaum, 2011; Sen, 1992). That is, capabilities are a person's real freedoms or opportunities to achieve functionings. Whereas mobility is a functioning, the real opportunity to travel is the corresponding capability. Capabilities are the set of functionings that a person has effective access to (Luz and Portugal, 2022; Robeyns and Byskov, 2023).

- Functionings are what people actually achieve "to be" or "to do". They represent actual achievements or states of well-being that individuals experience or can undertake, reflecting their capabilities (Sen, 2008, 1992).

3.2.1. Accessibility as Human Capability

To date, the most comprehensive transport-related accessibility framework within the concept of CA, termed Accessibility as Human Capability (AHC), was proposed by Vecchio and Martens (2021) and is presented in Figure 1. In extending the CA, Vecchio and Martens (2021) conceptualized accessibility as a human capability into three categories: (a) mobility as a capability, (b) accessibility as a capability, and (c) transport as a conversion factor. Mobility as a capability is described as the capability to move physically, socially, and financially from one place to another and interact within society. Accessibility as a capability relates to a person's possibility of engaging in a variety of out-of-home activities. Transport as a conversion factor relates to the capability of the transport system to enhance a wide range of capabilities, including employment, education, access, health, and democratic participation (Martens et al., 2019; Vecchio and Martens, 2021).

Regarding the AHC framework by Vecchio and Martens (2021), the key elements are described in the following:

> *Resources* relate to the key 'inputs' that are used to jointly deliver accessibility, namely the transport system and the built environment (or land use system). It is categorized into private mobility resources, publicly available mobility resources, and activity opportunities. Private mobility resources may include an automobile, a bicycle, walking shoes, a private garage, etc. Publicly available mobility resources include roadways, walkways, bicycle paths, parking spaces, public transport services, shared mobility, etc. The activity opportunities relate specifically to the built environment or the land use system, including its design, density, zoning, and the overall land use mix that characterizes the location of activities, their capacity and other characteristics.
>
> *Conversion factors* are the individual and contextual features that allow a person to convert resources into capabilities. That is, they are indicative of the extent to which a person can actually make use of available resources, or the possibilities of a person translating resources into actual freedoms to act, i.e. to travel and access opportunities (Vecchio and Martens, 2021). This may include the person's income, perception and knowledge of the transport system and services, as well as personal safety, physical ability, knowledge of activity opportunities, and related factors.
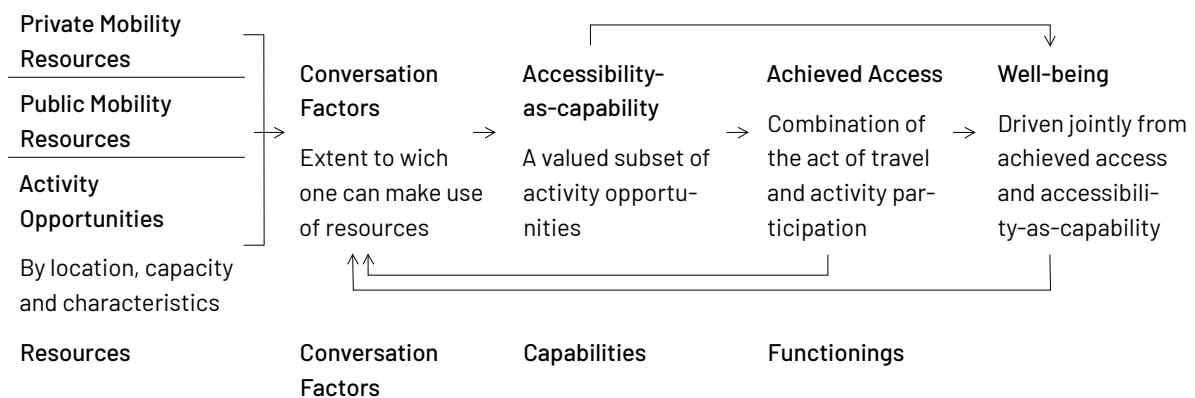
Figure 1. A conceptual framework [author modified] of the Accessibility as a Human Capability (AHC) proposed by Vecchio and Martens (2021, p. 846).

> *Capabilities* are the overall outcome from the combination of resources and conversion factors and translate into a person's level of accessibility. That is, accessibility is the degree to which persons have the possibility to move and access the available opportunities that are of value to them (Martens, 2016; Martens et al., 2019; Vecchio and Martens, 2021). Based on human capability, accessibility is linked to the interplay between relevant, valued, activity opportunities and the person's capacity to overcome spatial friction. Typ-

ically, all available activity opportunities may not be of interest to an individual, so the resulting accessibility as a capability for a person is a subset of the existing ones.

Functionings are the achieved access to activity opportunities, consisting of the dual act of travel and activity participation (Vecchio and Martens, 2021). That is, accessibility is considered a capability, whereas the achieved access is considered its functioning.

Well-being is shaped by an individual's accessibility-as-capability and functionings. Increased accessibility-as-capability and functionings can translate into a person's freedom to choose and participate in activities.

The AHC is a promising prospect as a theoretical framework to examine transport equity and access/accessibility issues, given that it encompasses diverse elements that contribute to an individual's ability to access opportunities. For example, a study by Cao and Hickman (2019b) using the CA framework has shown that people with similar accessibility levels experience statistically significant differences in their travel and activity participation. The capability-based viewpoint of CA is appealing to interrogate how the transport system advantages or disadvantages certain population groups in their ability to participate in socioeconomic opportunities.

3.3. Measuring accessibility

Access to opportunities/destinations can be facilitated by mobility, proximity, and connectivity, but these factors in turn can exhibit trade-offs (Levine et al., 2012; Siddiq and D. Taylor, 2021). Mobility – i.e. the ease with which one can move around the transport system – typically seeks to improve traffic speed, capacity and safety by paving roads, improving roadway design, and minimizing congestion (Levinson and King, 2020). Proximity relates to the spatial arrangement of origins and destinations, with the aim of increasing density and mix, thereby reducing travel distances (Levine et al., 2012; Levinson and King, 2020; Siddiq and D. Taylor, 2021). By connectivity is meant the ease of delivery of goods, services, and information to locations through increasing the density of paths and roads, and the connections between modes (Levinson and King, 2020).

Accessibility, i.e. access to opportunities/destinations, is generally the result of interaction among key components such as land use (or the built environment), the transport system, traveler characteristics, trip characteristics, and temporal factors (Geurs and van Wee, 2004; Levinson and King, 2020; Siddiq and D. Taylor, 2021). The built environment characterizes the makeup, density and mix of land uses, locations of origins and destinations. The transport system relates to the relationships and flows between nodes, networks, and demand facilitated by infrastructures designed to handle and link these flows. Communication systems such as telephone, internet, etc. can act to complement, replace, or enhance the movement of passengers, freight, and information, either as separate or joint components. Traveler or individual characteristics relate to resources and conversion factors from the perspective of the CA. These characteristics include the traveler's income, knowledge of accessibility options, perception and preferences,

safety, comfort, behavior, etc. Trip characteristics relate to the travel attributes and perceptions, such as travel distance and time, travel mode, cost elements, service frequency, wait time, parking, etc. They also include travel satisfaction, safety, comfort, convenience, and externalities such as pollution, noise, crashes, etc.

3.3.1. Categories of accessibility

Broadly, accessibility measures are classified into two categories: primal accessibility and dual accessibility (Cui and Levinson, 2020; Levinson and King, 2020; Levinson and Wu, 2020). Primal measures relate to how many opportunities can be reached in a given amount of time (cost) from an origin, whereas dual accessibility measures the time (cost) required to reach a given number of opportunities (Cui and Levinson, 2020; Levinson and King, 2020). When classified based on principal units of analysis, accessibility is either place- or people-based. Person-based (or people-based) metric disaggregates accessibility estimation to the household or individual level, accounting for personal attributes and constraints (Geurs and van Wee, 2004; Siddiq and D. Taylor, 2021). For example, the number of opportunities an individual can reach in a given amount of time (cost). Place-based or location-based measures relate to the level of access to spatially distributed places or opportunities, accounting for an array of characteristics aggregated to zones, for example, the number of restaurants within 20 minutes travel time from origin locations (Geurs and van Wee, 2004; Siddiq and D. Taylor, 2021).

Further, accessibility can be classified either as normative (i.e. prescriptive) or positive (i.e. descriptive) (Cui and Levinson, 2020; Páez et al., 2012). Normative measures emphasize reasonable or desired costs of travel and are typically insensitive to the heterogeneity of individual travelers and their varied choices (Páez et al., 2012; Siddiq and D. Taylor, 2021). For example, the population within 60-, 90-, and 120-minutes travel time from a given municipality (Ribeiro et al., 2010). Normative measures are useful for evaluating the effectiveness of transport and land use policies in achieving desired accessibility levels, for example, in identifying areas where policy interventions can help improve accessibility and reduce social exclusion (İstillozlu and Doratlı, 2021; Páez et al., 2012). Positive measures are based on people's actual travel behaviours, which explicitly account for the heterogeneity of these behaviours (Páez et al., 2012; Siddiq and D. Taylor, 2021). For example, the number of opportunities within travel distance d from a place of residence, where the travel distance d was estimated based on travel diary survey data (Páez et al., 2010). Thus, positive measures focus on the actual potential for participation in activities, without making value judgments about or prescribing what that accessibility should be (Páez et al., 2012).

In addition, accessibility can be classified as potential, actual (i.e. realized), and perceived (Guagliardo, 2004; Lättman et al., 2018; Levinson and Wu, 2020). Accessibility is potential (i.e. nominal or objective) when a population demand exists in space and time for available service destination(s) and is considered realized (or effective) when all barriers have been overcome to receive or actualize the service (Guagliardo, 2004; Lättman et al., 2018). Accessibility value esti-

mated from spatial data (e.g., land use and transport data) is an example of potential accessibility. In contrast, the actual accessibility value (e.g. travel time) experienced by a person in accessing a destination is the realized (or effective) accessibility. Relatedly, perceived accessibility relates to the perceived potential to participate in spatially dispersed opportunities, influenced by individual perceptions and experiences, which can differ from the actual accessibility provided by the transport and land use systems (Dumedah et al., 2024; Lättman et al., 2018; Pot et al., 2021). The differences between potential and perceived access regarding the performance of land use and transport systems have been widely recognized (Campbell et al., 2019; Carrion and Levinson, 2019; Curl, 2018; Fan et al., 2016; Fried et al., 2020; Lättman et al., 2018, 2016). For example, public transport users were found to perceive waiting times longer than they really are, based on survey-reported waiting time and video-recorded actual waiting time (Fan et al., 2016).

3.3.2. Infrastructure-based measures

Infrastructure-based measures examine the performance or service level of transport infrastructure, e.g. the comparison between observed and predicted/designed travel speed or congestion on a road network (Curl et al., 2011; Geurs and van Wee, 2004). They indicate the performance of the network and may include indicators used in transport modelling, such as capacity, frequency of public transport, etc. Examples include the frequency of bus services passing a certain stop on a travel route; availability of pedestrian or cycling infrastructure; or the traffic congestion across a local administrative area (Curl et al., 2015, 2011).

3.3.3. Cumulative measures (Contour measures, Threshold Measures)

Cumulative measures count the number of potential opportunities that can be reached within a certain distance, time, or other cost elements (Levinson and King, 2020; Siddiq and D. Taylor, 2021). Typically, they represent the accessibility at one location (origin) to another (destination) or set of destinations, where they are described as contour measures, due to the contour maps (i.e. Iso-Area) produced (Curl et al., 2011; Siddiq and D. Taylor, 2021). For example, counting the number of schools that are located within a 30-minute walking distance from the centroid of an administrative unit (e.g. a municipality).

3.3.4. Gravity-based measures (Opportunity measures, Potential measures)

Gravity-based measures are an extension of cumulative measures, but weight opportunities by an impedance factor and the attractiveness of the destination; they may also be called opportunity or potential measures (Curl et al., 2011; Levinson and King, 2020; Siddiq and D. Taylor, 2021). Hence, they may be referred to as weighted cumulative opportunity measures. In the gravity-based approach, easier-to-reach destinations are weighted more heavily than harder-to-reach ones using a distance decay function calibrated by trip purpose that accounts for the

generalized cost of travel, which typically comprises travel time or distance and travel price (El-Geneidy and Levinson, 2011; Siddiq and D. Taylor, 2021). An example is the level of accessibility of public transport terminals to the population, where accessibility is estimated using a function of travel distance, population, and capacity of public transport terminals. Applied gravity-based approaches include the Three-Step Floating Catchment Area (3SFCA) and Rational Agent Access Model (RAAM) (Dumedah et al., 2023c, 2022a; Saxon and Snow, 2020; Wan et al., 2012).

3.3.5. Utility-based measures

Utility-based indicators measure the socioeconomic benefits that people derive from accessing spatially distributed opportunities by incorporating their preferences and constraints (Curl et al., 2011; Geurs and van Wee, 2004). That is, they focus on the value individuals derive from access to activities and destinations, incorporating their preferences and constraints. They relate to the likelihood of an individual making a certain choice, based on socioeconomic attractiveness or the cost of that choice compared to all available options. Typical utility measures incorporate individual preferences and socioeconomic characteristics such as relative attractiveness of destinations and individualized measures of travel impedance (Curl et al., 2011; Siddiq and D. Taylor, 2021). For example, to address equity, utility-based measures can be used to determine the disparities of access between households in informal urban communities and those located at urban outskirts.

3.3.6. Activity-based measures (Time-space measures, Potential Path areas)

These measures provide a comprehensive and realistic assessment of individual accessibility based on daily activity patterns and travel behavior. That is, they relate to an individual's level of access to spatially distributed activities, considering the location of activities and travel through the network and incorporate a behavioral element, usually captured via travel diary data (Curl et al., 2011; Siddiq and D. Taylor, 2021). An example is the Potential Path Area (PPA), which represents the geographic locations where an individual can participate in a flexible activity and return to their destination within a given time budget. The PPA estimates the area that can be visited by an individual, taking into account the location of destinations, the transport network and the individual's scheduling constraints (Curl, 2013; Curl et al., 2011).

3.3.7. Constraint-based measures

Constraint-based indicators evaluate the accessibility of individuals based on the space-time constraints they face in their daily activities and travel patterns. Assessment of these spatial and temporal constraints faced by individuals in participating in activities can help inform more equitable and targeted interventions (El-Geneidy and Levinson, 2006; Siddiq and D. Taylor, 2021).

For example, they can be used to identify areas with limited accessibility for certain populations and to target interventions to specific population groups.

3.4. Access/accessibility research in SSA

A list of transport access/accessibility literature specifically on SSA is summarized in Appendix A, with attention to the study's area and focus, methodology, and key findings. The literature survey showed that most studies used simple accessibility measures, which often capture one aspect of accessibility, such as proximity to opportunities. Some of this lack of comprehensive evaluation is due to inadequate data and data at a coarse scale. Relatedly, most of the accessibility estimates are rarely evaluated in combination with other spatially disaggregated data, such as temporal components, demographic, and socioeconomic variables. This means that a holistic perspective of access to opportunities is almost impossible from most of these studies.

There is a clear focus on access to health care and transport services, e.g. access to transport routes, terminals, central business centers, and health services. While these are part of essential services, other activity destinations, such as access to markets and shopping, education, workplaces, and places of worship, are overwhelmingly limited in the existing literature. For example, market commute in SSA cities is typically carried out by women, whose unique accessibility challenges need to be thoroughly interrogated. Relatedly, workplace commute in SSA cities by informal urban workers does not typically follow the morning-evening travel pattern and receives limited attention in the literature. Rather, these workers often take short-distance travels to several destinations, which can severely impact their travel expenditure and travel fare affordability.

In terms of methodology, the vast majority of the indicated studies employed quantitative approaches with limited application of mixed methods or qualitative approaches. There are opportunities to employ qualitative methods such as embedded ethnographic research with participant observation, in-depth interviews, and Participatory Action Research (PAR) methods, including follow-along methods and mobility biographies (Lucas et al., 2019a; Porter et al., 2020). Ultimately, mixed methods are encouraged to promote a comprehensive view of access to opportunities, e.g. using qualitative findings to validate outputs from quantitative approaches.

Crucially, the evaluation of access to opportunities from the perspective of equity is limited in SSA literature, particularly the interrogation of the linkages between access disparities and their implications on the socioeconomic well-being of populations. Although the quantification of access disparities is widespread in the literature, their systematic linkages to real-life impacts are not well characterized and are understudied in SSA. Relatedly, the current literature on SSA does not entirely cover pertinent aspects of access/accessibility research, such as concurrent evaluation of person-based and place-based accessibility, or a combination of activity-based and constraints-based accessibility. There are opportunities for these challenges to be addressed from a methodological approach using a combination of qualitative and quantitative techniques.

3.5. Research gaps in accessibility in SSA cities

Equity considerations require deliberate accounting of preferences and perceptions of travelers and other factors, such as modal options and disruptions to transport services. These factors are not included in existing accessibility measures even though they have crucial implications on access to opportunities (Siddiq and D. Taylor, 2021; van Wee, 2016). Evaluation of access to opportunities from the perspective of process-based and outcome-based measures has been suggested (Pyrialakou et al., 2016; van Wee, 2016; Wu and Levinson, 2020). However, there are limited studies which systematically address them simultaneously using accessibility-, deprivation-, and mobility-based measures, and validate them against outcome-based measures. That is, the validation of process-based measures against outcome-based ones will facilitate the upscaling of these approaches towards decision-making and better communication of policy actions. Methodologically, comprehensive mixed methods studies are crucially needed with proportionate application of both quantitative and qualitative approaches.

Concerning AHC, both the minimum level of access to opportunities and the level of access for disadvantaged populations should be maximized to promote equity (Boisjoly and El-Geneidy, 2021; Vecchio and Martens, 2021). However, the mapping of access to opportunities and their estimation of minimum levels for different population groups is almost non-existent for most SSA cities. Also, estimating the level of access for vulnerable populations and related frameworks to maximize their levels of access to essential services is mostly unknown for most SSA cities. Thus, comprehensive approaches to mapping of access to opportunities, as well as methodological strategies for maximizing levels of access for vulnerable populations, are crucially needed. Relatedly, the socioeconomic and environmental factors that influence access to transport services, supply of public transport, access to destinations, and connectivity to destinations remain mostly unexplored for SSA cities. It is widely known that accessibility estimations require extensive amounts of data that are often scarce in most SSA cities. That is, estimations of accessibility that require extensive data will be prohibitive to apply in several SSA cities. Accordingly, adaptive and flexible approaches that can make use of fewer data variables and are obtainable from secondary and widely available sources are needed for SSA cities.

4.   Equity of Transport-related Efficiency in SSA cities

4.1.   Introduction

Increasing population growth, urbanization and rapid demand for mobility and access to opportunities mandate the need for efficient utilization of resources to concurrently satisfy these needs at minimum economic, social and environmental costs. The overall objective of efficiency is to optimize the transport system and services to make them predictable, reliable, timely, and cost-effective in their use for accessing activity opportunities. Efficiency thus relates to the optimal allocation of resources in the short term, but also to achieving sustainability in the long term to balance economic, social and environmental goals such as economic productivity, social equity, public health and safety, resource conservation, and environmental protection (Sustainable Mobility for All, 2019a). Thus, a sustainable transport system is efficient in the way it minimizes socioeconomic and environmental resources such as money, land, time, and energy required to access opportunities, is equitable to all users, including the vulnerable, and is safe to use by all persons (Sustainable Mobility for All, 2019a).

Efficiency is measured as the ratio of useful output to total input, to reduce costs and waste, maximize productivity and output, and enhance overall performance. Transport efficiency in this context is viewed as a combination of two key activities: (a) resources expended in making the transport system available for use, and (b) resources expended by users in consuming transport services. That is, an efficient transport system would achieve, among other things: (a) integration across transport modes, (b) optimal traffic volumes that reduce congestion and delays, and (c) minimal use of energy to facilitate mobility and access (Sustainable Mobility for All, 2019a). Evidence suggests that SSA cities as a whole have the lowest levels of transport efficiency of all regions in the world, where 22% of city wealth is spent on passenger mobility, as compared to 14 to 15% in other parts of the global South (Schiller and Kenworthy, 2017, p. 11).

According to the Advisory Council for Aviation Research and Innovation in Europe (ACARE), efficient transport systems relate to the "movement of transport vehicles, of all types, and their passengers and freight, through terminals and transport infrastructure, along various trajectories/routes, either under one mode of transport or a combination of modes, in a timely and least-costly manner to transport providers and users and without undue constraints arising from unreliable and unpredictable operating, administrative, documentary, legal, regulatory and institutional frameworks" (ACARE, 2022, p. 11). This indicates that there are several elements to promoting efficient transport systems, such as factors that address costs, delays, travel times, adequacy of physical mobility resources, including infrastructure creation, maintenance and operation, vehicle and equipment, service delivery, and operation and management practices.

Relatedly, efficiency is categorized into: (a) productive efficiency (also called 'doing things the right way') which relates to the optimal way of producing goods and services at the lowest possible cost, and (b) allocative efficiency (also known as 'doing the right things') which relates to

the optimal way of matching demand and supply that ultimately focuses on the distribution or allocation of resources in society (Sustainable Mobility for All, 2019a). Productive efficiency minimizes production costs and maximizes productivity. This is achieved by focusing on the delivery of transport services and taking into account physical infrastructure requirements and movable assets such as equipment and vehicles, as input costs of providing the services. In this context, resources serving as economic input may include time, energy, technology, land, capital, labor, institutions and regulations. Allocative efficiency has some notions of distributive justice of transport benefits and burdens (Lucas et al., 2016c, 2016a; Pereira et al., 2017). Allocative efficiency is highly dependent on the transport infrastructure network, which influences the extent and spatial distribution of the network, spatial allocation to different modes, and modal and intermodal linkages and connections. The allocative efficiency is also influenced by costs in terms of the price, time, and other non-price costs faced by the travelers when choosing if and when to travel. Aside from infrastructure and cost factors, user demand is crucial in the delivery of transport services.

Relatedly, there is planning efficiency, i.e. the extent to which planning activities are comprehensive and integrated in a way that individual, short-term decisions support strategic, long-term objectives (Litman, 2002; T. A. Litman, 2024). That is, transport systems are most efficient when they are planned, designed, and managed to support strategic goals.

4.2.   Current state of the art

International research on public transport systems' efficiency is extensive. Many methods have been devised to quantify and compare this efficiency. According to Karlaftis (2008) and Karlaftis and Tsamboulas (2012), the transit literature has seen a huge surge in the popularity of efficiency assessment studies due to the strong interest in improving transit operations and evaluating the impact of these changes on performance. Most of these studies concentrated on the developed world, while in the global South, formal bus and train services have received more attention than informal ones in the work that has been done there.

Kavage et al. (2005) noted that transport-efficient development supports using multiple transport modes and reduces the need for car traffic. They evaluated how local land use regulations and development patterns could support transportation efficiency. This study highlighted how long-term efforts to devise transportation-efficient land development regulations can shape new land use development. Nash and Weidmann (2006) defined an efficient public transport system as a system which is fast, reliable and safe, all qualities that make it attractive to customers and improve its productivity. Nash and Weidmann subdivided transport efficiency strategies into the following categories:

- agency-wide, i.e. strategies that address the organization and business practices of public transport agencies (e.g. contracting), as well as programs implemented throughout the network (e.g. GIS vehicle tracking);

- network planning, i.e. strategies that are used to design transit networks, including line routing and modal choice decisions;

- operations, i.e. strategies that include all measures that aim to reduce travel time without significantly changing the route/network and thereby increase the efficiency of transit vehicles operating in revenue or non-revenue service.

It is thus clear that an efficient public transport system is one that offers benefits to travellers in terms of short waiting times between departures, quick travel times, punctuality and clear information (e.g. Kenyon and Lyons (2003). Further, Hrelja et al. (2020) observed that transport and land use planning should be integrated so that planning at all levels strengthens the attractiveness of public transport and its long-term competitiveness vis-à-vis car traffic.

4.3. Measuring transport-related efficiency

Several measures are currently used to measure transport efficiency, including subjective and objective measures and parametric and non-parametric approaches. Subjective measures used to determine the efficiency of a transport system include user opinion and satisfaction surveys. while objective measures include attributes such as load factor (percentage occupancy), travel time, total passenger kilometres covered, passenger waiting time, hold-back time, operating speed, and commercial speed (Eboli and Mazzulla, 2007; Ndibatya and Booysen, 2020; Sampaio et al., 2008).

In terms of analysis methods, quantitative methods are common, including basic statistical descriptions, regression analysis, and other parametric statistical methods. Data used in the research were often obtained from questionnaires, GPS, mobile phones, experiments, observation, and General Transit Feed Specification (GTFS). Some attempts have been made to assess or improve the efficiency of public transport services from operational and financial perspectives, where such studies include those by Nolan et al. (2001) and Fu et al. (2007). Apart from dealing with public transport vehicle routing and scheduling issues, other earlier studies focused on assessing the efficiency of public transport services from an administrative perspective. Another approach for measuring transport efficiency is to estimate parametric cost functions, such as in recent work by Makhlouf and Helali (2024), to determine the efficiency and productivity of the production factors of public transport in Sfax, Tunisia. The approach used an estimation of the trans-logarithmic cost function with different restrictions while relying on the foundations of microeconomic theory.

Data Envelopment Analysis (DEA) is the most commonly used non-parametric approach for measuring the efficiency of transport system components. Dawda et al. (2021) is one of the few examples in the literature on using conventional technical efficiency measures, such as DEA, applied to paratransit modes in India. The study evaluated the operations, route design, and cost efficiency of public transport systems to understand how well the existing set-up catered to demand. The methodology is used to establish the relative efficiencies of a set of comparable

entities (Decision-Making Units) by some specific mathematical programming models. The key advantage of DEA is its ability to handle multiple outputs and inputs. Nikolla et al. (2023) analyzed the efficiency of public transport lines based on citizens' perception of five attributes, namely frequency, cleanliness, possibility to find a seat, punctuality and ticket prices.

Other researchers have used operation time, round-trip distance, and the number of bus stops as inputs to measure operational efficiency, whereas commuters who used buses, populations aged 65 and older, and persons with disabilities were used as inputs to measure spatial effectiveness. Other input variables used include fuel consumption, number of full-time workers, number of operating buses, average travel time per round trip, number of vehicles, operators, and the total number of stops in the round trip. Generally, input variables used depend on the researchers' requirements and the scope of the study (Nikolla et al., 2023).

4.4. Transport-related efficiency research in SSA

Only a handful of studies have explicitly examined aspects of operational efficiency in paratransit systems in SSA. One reason for the dearth of research in this area is the unavailability of any official sources of data, such as what is more commonly available for bus and rail systems. This data gap is increasingly filled by GPS tracking data that are provided by researchers, commercial data companies and NGOs and made available through platforms such as DigitalTransport-4Africa (Klopp et al., 2015). Such data provide detailed route and stop-level data on paratransit operations. As discussed below, in SSA transport inefficiency is manifested by low vehicle travel speeds, variable or long waiting and travel times to passengers, delays and service uncertainties, as well as low vehicle utilization and reduced productivity to operators as a result of congestion, detours, random searching behavior, abandoning the trip before reaching the end of the route, and extended vehicle waiting times at stations.

A summary of research on transport-related efficiency in SSA is provided in Appendix B. The list sheds light on the focus, methodology used, and key findings of each study. The research focus was mainly on paratransit operational efficiency, such as vehicle energy efficiency, air pollution due to operations, travel time, speed, route lengths, number of stops, and number of passengers. Traffic characteristics such as flow, speed, vehicle composition, and travel time under homogeneous and heterogeneous traffic were explored. Other research explored the financial efficiency of the public transport system by studying the vehicle and engine characteristics and the loss of revenue.

In SSA, a common finding has been that informal networks effectively provide good metropolitan area coverage. A comparative study of seven SSA cities found that in most cities, nearly three-quarters of residents live within a 10-minute walk of mapped paratransit routes, making the mode widely available to potential users (Falchetta et al., 2021). Bwire and Zengo (2020) investigated and compared the commuting efficiency between public and private transport modes in Dar es Salaam using an excess commuting framework. They quantified the disparity between

the theoretical minimum and actual commutes, and found that "public transport in Dar es Salaam is very good in terms of providing excellent options to get everywhere in the city as it connects homes and jobs as well as private transport" (Bwire and Zengo, 2020, p. 1).

However, this effectiveness does not necessarily translate into high levels of efficiency. Service patterns are typically very variable across space and time in response to variations in demand density, traffic conditions, and competitor modes (Ferr, 2015). Spatially, many informal routes tend to extend between outlying residential areas and central cities (Falchetta et al., 2021), following major desire lines for radial movements. One implication is that routes tend to become very dense in the city center, contributing to major congestion in already crowded areas and along key corridors. Congestion is a major source of inefficiency, reducing travel speed and productivity for operators and leading to longer travel times for passengers.

In Cape Town, operational parameters such as speed amongst minibus services were found to vary across the three major types of services, namely trunk (or line-haul), intermediate and feeder/distributor services with shorter distances, more frequent stops, and lower commercial speeds (du Preez et al., 2019). Relatedly, Nyaki et al. (2020) analyzed travel time reliability under heterogeneous traffic conditions in Dar es Salaam. The analysis involved buffer time, standard deviation, coefficient of variation, and planning time. The results indicate low service reliability in the outbound directions compared to the inbound directions. Additionally, the study revealed higher travel time variations experienced during off-peak hours than during peak hours.

In terms of routing efficiency, some drivers engage in detours, random searching behavior, and trips abandoned before the end of the route, which impose delays and uncertainty on passengers (Ferr, 2015; Ndibatya and Booysen, 2021, 2020). This is a consequence of the fact that routes and stops are typically selected by drivers under conditions of high uncertainty and are not optimized from a network operational perspective. Also, temporal variations are driven chiefly by a profit motive, as many vehicles are rested during low-demand periods of the day, often leading to long waits for boarding passengers (McCormick et al., 2015). Many vehicles were found to spend the majority of the day waiting or queuing at ranks or stations, leading to low overall utilization (Ndibatya and Booysen, 2020; Saddier et al., 2017).

Concerning NMT, lower-income populations in the SSA find PT to be expensive. Pendakur (2005) carried out a study in Kenya (Nairobi and Eldoret) and Tanzania (Temeke and Morogoro). The study found that increasing the safety and efficiency of NMT would enable lower-income individuals to buy and use bicycles more frequently, as well as develop attitudes toward safe NMT travel, thereby enhancing urban mobility. A related SSATP study by Opiyo et al. (2001) developed specialized infrastructure for cyclists and pedestrians and implemented supply-side interventions and traffic-calming systems to promote bicycle ownership and use. Some of the traffic calming techniques used were redesigning several intersections to improve their NMT safety and efficiency, speed bumps, raised zebra crossings, pedestrian crossing islands, medians, road narrowing with bicycle slips, and bus bays. The study found that poor pavement quality, location, volume, and impediments (e.g. trash, parked cars, potholes, and damaged pavements) that

forced detours and wasted time had a cumulative negative impact on the efficiency of walking. A mix of speed-calming and traffic segregation measures was used to safeguard NMT efficiency and safety. By measuring the average door-to-door travel speeds, the study assessed the efficiency of various modes. Along with creating opportunities for low-income households to acquire bicycles, increasing cycling depends on perceived and actual traffic safety.

4.5.   Research gaps in transport-related efficiency in SSA cities

One key area that deserves more research attention is the role of institutions. The coexistence of diverse urban transport modes, Bus Rapid Transit, minibuses, motorcycle taxis, three-wheelers, bicycle taxis, pick-up trucks, and others, underscores the need for a single, overarching agency to harmonize planning, operations, and fare collection across all major public transport services. The question of institutional planning responsibility also touches on a related issue, namely, road space allocation. The allocation of road capacity between private and public modes is currently heavily skewed towards private modes, and the fact that public transport is stuck in mixed traffic is a major reason for its low efficiency. Though most cities cannot afford to install full-scale BRT, allocating dedicated lanes to formal systems such as BRT is starting to change that paradigm. However, this strategy may only work in some context-specific cases. A recurrent question is whether it is possible to increase the efficiency of public transport by allocating intermediate levels of road space priority to certain modes such as buses and paratransit. According to one study (De Beer and Venter, 2021), operators of minibuses and taxis in South Africa may benefit greatly from priority interventions at junctions in terms of reduced travel times and increased productivity if the proper circumstances are met. The allocation of road space is therefore a technical challenge in that it involves scheme design and involves unknown costs and benefits.

Additionally, there is the institutional and policy dilemma of how to incentivize authorities to work together to achieve such a reallocation of a scarce resource, particularly in the face of opposition from private vehicle users. Also, there is a need to understand how efficiency (or rather inefficiency) and its perception can lead to different equity outcomes, particularly for low-income and vulnerable populations. That is, what are the linkages between efficiency losses in public transport and accessibility for vulnerable populations, these populations' perception of transport-related efficiency, and the approaches to measuring these relationships? These questions underpin the compelling need to assess PT and NMT systems in SSA cities to ascertain their ability to quickly and predictably move all persons with different capabilities, enabling easy switching between different transport modes, while optimizing the use of resources (e.g. infrastructure, personnel, systems, fuel, and time).

Despite the obvious link between operational efficiency and the fare paid by passengers, very little work has been done to better understand this dependency. That is, operational efficiency clearly influences passenger fares, so research is needed to unpack this relationship. For example, how can conceptual frameworks be developed to link key efficiency metrics (e.g., vehicle utilization, headway adherence) to fare-setting mechanisms? It is arguably even more important

to understand the affordability implications of (in)efficiency problems in SSA than elsewhere, given the private, unsubsidized nature of the service (i.e. there is little chance of subsidy mitigating the impact on passengers), as well as the low ability to pay in many user populations. For example, what are the most effective ways to improve paratransit efficiency so that passengers directly benefit in terms of reduced travel costs?

Lastly, it is noteworthy that almost no work has been conducted to explore and understand how efficiency relates to NMT. NMT systems have significant and multifaceted importance in SSA cities where their role extends beyond mobility, impacting economic, social, and environmental dimensions. Integration of NMT and the need to prioritize their infrastructure into mobility options have been widely recognized (Randall et al., 2023; Timpabi et al., 2024; Walker et al., 2022). NMT is the most affordable mode of transport for many in SSA, especially for low-income populations who can save on travel fares. Although research on NMT has largely focused on safety, it would be valuable to investigate its potential to boost network efficiency, such as by providing first- and last-mile connections to public transit, and to reduce travel costs when used instead of motorized modes.

5.   Equity of Transport-related Health and Safety in SSA cities

5.1.   Introduction

The chief objective of transport-related health and safety is to reduce the risk of injuries, fatalities, and damage to property and the environment through noise and air pollution while ensuring the safe and efficient movement of people and goods from origin to destination. Strategies to achieve health and safety in transport systems include prevention, minimization, and protection against crash fatalities, injuries, noise and air pollution. Related measures include education and enforcement of health and safety interventions, as well as rehabilitation. Thus, the ultimate goal of work on transport-related health and safety is to create a safe and sustainable transport system that prioritizes human life and well-being, while promoting economic growth and development.

Vulnerable road users such as pedestrians, cyclists, children, the aged, and motorcyclists are disproportionately affected by road traffic injuries and fatalities (World Health Organization, 2018). The disproportionate burden on these vulnerable groups makes equity of transport-related health and safety a critical issue in SSA cities. Vulnerable road users account for a considerable proportion of road traffic fatalities, with pedestrians alone accounting for up to 50% of all road traffic deaths in some SSA countries (Mitra and Bhalla, 2023; World Road Association - PIARC, 2023). The high fatality rate has been attributed to the lack of pedestrian-friendly infrastructure, poor road designs, and inadequate lighting (Almqvist and Hydén, 1994; Damsere-Derry et al., 2010; Tamakloe et al., 2022; von Beesten and Bresges, 2022; Zegeer and Bushell, 2012). Beyond these factors, limited access to safe transport options, poor road conditions, and inadequate enforcement of traffic regulations are also important factors accounting for high traffic crashes and fatalities (Sam, 2022; Sam et al., 2019).

Relatedly, vehicular emissions and traffic noise in SSA cities have been attributed to respiratory and cardiovascular diseases, sleep disturbance, and hearing impairment (Adepoju et al., 2018; Ajayi et al., 2024b; Clark et al., 2022). Lack of reliable data and poor enforcement of traffic regulations hinder the development of effective and broad transport safety policies and interventions in SSA cities (Aidoo et al., 2021; Akaateba et al., 2015). This challenge presents an opportunity to understand and develop tailored transport-related health and safety interventions in SSA cities within the local context by considering factors such as urbanization, poverty, and limited resources (Meesmann et al., 2022; Mitra and Bhalla, 2023).

5.2.   Current state of the art

Currently, road traffic injuries pose a significant public health concern in SSA. There were an estimated 1.19 million road traffic deaths in 2021, which is equivalent to 15 road traffic deaths per 100,000 population (World Health Organization, 2023). Based on 2019 data on the age distribution of all-cause mortality, road traffic injury remains the leading cause of death for children

and young people aged 5–29 years and is the twelfth leading cause of death when all ages are considered (Mitra and Bhalla, 2023; World Health Organization, 2023). Global road traffic injuries impose an enormous economic cost on societies and are estimated at US$1.8 trillion, roughly equivalent to 10-12% of global gross domestic product (GDP) (Meesmann et al., 2022), rendering it an important health and development challenge.

Road traffic deaths in SSA are projected to more than double from around 243,000 in 2015 to 514,000 by 2030 (Mitra and Bhalla, 2023). Cities like Accra, Dar es Salaam, and Lomé represent typical urban environments in the region, where rapid urbanization and motorization outpace the development of adequate infrastructure (World Road Association - PIARC, 2023). Like others in SSA, these cities face high levels of road traffic crashes, with considerable challenges in ensuring equitable and safe access to opportunities. Vulnerable populations, including low-income groups, pedestrians, cyclists, and public transport users, often bear the burden of road traffic injuries and fatalities. This increases socioeconomic disparities and limits access to safe mobility. In addition, vulnerable populations often lack access to safe mobility infrastructure and resources and are more exposed to high-risk road environments. Informal urban communities and low-income neighbourhoods are typically situated along dangerous roads with inadequate pedestrian crossings and poor road conditions, increasing the risk of traffic crashes and limiting safe mobility options. The socioeconomic and health burden of road traffic injuries is significant for vulnerable populations, as they are also less likely to afford medical care and rehabilitation. The loss of income due to injury or death further aggravates spatial and social inequalities.

Attempts to address transport-related health and safety in SSA cities face numerous challenges, including ineffective traffic law enforcement, poor road conditions, and substandard vehicle maintenance practices. Additionally, the rise of commercial informal and shared transport, including two- and three-wheelers, in SSA has both positive and negative impacts on sustainable development efforts in terms of health and safety. It is widely recognized that strong financial, legal, and regulatory frameworks are needed to support policies and guidelines and the building of institutional capacity.

Two- and three-wheelers in SSA have increased mobility and access to opportunities, improved livelihoods for riders and their families, enhanced economic activity and trade, created employment opportunities, and provided affordable and flexible options in accessing opportunities. Yet two- and three-wheelers also have negative impacts such as high risk of road traffic crashes and injuries, increased congestion, noise and air pollution in urban areas, pronounced roadside friction in urban areas, illegal activities and criminality (e.g., Okada robbery), and blatant disregard for traffic regulations and safety standards (Agyemang et al., 2021; Jones et al., 2022). Additionally, the operations of two- and three-wheelers in SSA face significant challenges such as poor road infrastructure, inadequate safety measures and enforcement, lack of training and licensing for riders, and limited access to finance and maintenance services (Obiri-Yeboah et al., 2021). To improve the current state of equity in transport-related health and safety in SSA cities, strong financial, legal, and regulatory frameworks are needed to support policies and guidelines and the building of institutional capacity.

The global motor vehicle fleet, currently exceeding one billion vehicles, is projected to double by 2030. Many new vehicles being exported to SSA do not meet basic safety standards, as reflected in numerous recalls affecting key components such as airbags and braking systems. Unfortunately, defective vehicles in SSA rarely benefit from these recalls, exacerbating safety risks. This issue is particularly concerning in the informal and shared transport sectors, where such vehicles are commonly found. As vehicle numbers surge and defective models continue to populate roads, road safety professionals face the pressing challenge of protecting pedestrians, cyclists, and other vulnerable road users amidst rapid urbanization and transportation growth. This situation calls for a more equitable and sustainable mix of transport modes that prioritizes safety for all. As motor vehicle fleets and road networks expand, vulnerable road users remain dangerously exposed without concerted efforts to address these challenges (Mitra and Bhalla, 2023; World Road Association - PIARC, 2023).

Ensuring equitable access to safe and affordable transport options is essential for improving the health and safety of transport use and reducing disparities. Investments in infrastructure that protect pedestrians and cyclists, such as wider footpaths, protective bike lanes, PT and NMT infrastructure, are critical. For instance, the United Nations Environment Programme (UNEP) Initiative in 2020 has been instrumental in promoting safer road designs by helping communities across Africa make their streets safer for pedestrians and cyclists (Walker et al., 2022). In addition, initiatives like the Ten Step Plan for Safer Road Infrastructure Pilot Project, funded by the United Nations Road Safety Fund (UNRSF) and co-financed by the Global Road Safety Facility (GRSF) and UKAid, have been crucial in promoting infrastructure safety in SSA countries such as Tanzania (United Nations Road Safety Fund - UNRSF, 2022).

In addition, effective legislation and strict enforcement of traffic laws are vital. This includes laws addressing speeding, helmet use, seat belts, drunk driving, and mobile phone use while driving (i.e. distracted driving). SSA cities have made efforts to integrate road safety into broader urban development plans to create safer environments for all road users. However, the implementation and sustainability of these initiatives remain a challenge due to limited resources, poor strategies and enforcement, and a lack of local capacity building (World Road Association - PIARC, 2023). Building local capacity through training programs and educational initiatives is essential. Programs targeting road safety professionals, law enforcement officers, and community leaders enhance local expertise and promote a culture of health and safety. Community engagement and education campaigns are vital for raising awareness about health and safety and changing behaviors, particularly among young and vulnerable road users.

Relatedly, adequate and readily available data streams are needed to provide evidence and inform action. Comprehensive road safety data systems can help identify high-risk areas and understand crash dynamics to enable better planning and resource allocation for safety interventions. Moreover, improving post-crash response systems, including emergency medical services and trauma care, can significantly reduce fatalities and the severity of injuries (Hafez et al., 2023). Ensuring timely and effective medical intervention is a key component of the Safe System approach.

5.2.1 Traffic noise and emissions

Other major themes in transport-related health and safety include traffic noise and emissions. Traffic noise and emissions pose environmental and public health concerns due to their impact on human health, quality of life, and environmental sustainability. Current research on traffic noise is exploring the health impacts of noise pollution, developing effective mitigation strategies, improving measurement and modelling techniques, and evaluating the adequacy of current policies and regulations (Clark et al., 2022; Kumar, 2019; Roswall et al., 2015; Su et al., 2023; Tiwari et al., 2024). These efforts aim to create quieter and healthier urban environments for residents, particularly those living along transport corridors and activity centers.

Relatedly, research on traffic emissions is characterized by a multi-faceted approach, focusing on understanding, measuring, and mitigating vehicular emissions. Key themes of current research on traffic emissions encompass measurement techniques, health impacts, driving behavior, public perceptions, regulatory frameworks, and future directions (Ayetor et al., 2021; Khreis, 2020; Lu et al., 2021; van Donkelaar et al., 2015). Additional specific themes include on-road emission measurements, high emitter detection, declining fleet-averaged emissions, an understanding of health effects, climate change considerations, and evaluation of regulatory frameworks and policies, including compliance and standards (Bianca et al., 2023; Fabre et al., 2023; Kustar et al., 2022; Sicard et al., 2016; van Donkelaar et al., 2015). Addressing the challenges posed by vehicular traffic emissions will contribute to equitable and sustainable transport solutions.

Accordingly, research should integrate high-resolution noise and emissions modelling with epidemiological and socio-behavioural assessments to map exposure hotspots, quantify health burdens, and uncover community-specific vulnerabilities along urban transport corridors. By rigorously evaluating mitigation strategies, such as noise barriers, green buffers, low-emission zones, and policy interventions, scholars can generate actionable evidence to refine regulations, inform urban design, and promote equitable, sustainable mobility.

5.2.2 Transport-related crimes and personal safety

Another key theme is transport-related crimes and personal safety. Assessment of transport-related crime is vital for enhancing public safety, informing policy, and improving the overall effectiveness of PT and NMT systems. Understanding transport-related crime patterns is critical to identifying crime types such as theft, vandalism, and assaults, as well as their concentration in special areas and times within the transport system (Bernasco et al., 2017; Kruger and Landman, 2007; Smith and Clarke, 2000). This knowledge is fundamental to developing preventive strategies to enhance public safety and positively impact commuter behavior. Crime can deter individuals, particularly vulnerable populations, from using PT and NMT services regularly, thereby affecting their access to opportunities. Also, emerging transport modes such as two- and three-wheelers and ride-sharing services present unique safety challenges that require ongoing

research and adaptation of existing crime prevention strategies (Olaniyan et al., 2023; Smith and Clarke, 2000; Tade and Faisol Olaitan, 2024). Overall, current research in transport-related crime and personal safety emphasizes an in-depth understanding of crime patterns, experiences and perceptions of victims and users, effective prevention measures, and the importance of tailored strategies for different transport systems.

Accordingly, research should combine spatiotemporal crime mapping with qualitative studies of user experiences across both conventional and emerging transport modes, such as two- and three-wheelers and ride-sharing, to pinpoint when, where, and how thefts, vandalism, and assaults occur. By integrating these insights into longitudinal, mode-specific analyses, scholars can develop and evaluate tailored, evidence-based safety interventions that enhance perceived and actual security, boost ridership among vulnerable groups, and promote more equitable, sustainable mobility.

5.3. Measuring transport-related health and safety

Measuring transport-related health and safety involves a combination of proactive measures, continuous training, risk assessments, and systematic evaluations. Traffic safety measurements provide valuable insights into safety performance, helping authorities implement effective interventions and improve overall safety for all road users. These measurement strategies can include crash data analysis, behavioural observations for drivers and pedestrians, and before-and-after studies, traffic conflict techniques for near-miss incidents, statistical analysis, composite road safety index, and road safety audits (Almqvist and Hydén, 1994; Botha, 2005).

The safety of PT and NMT systems in SSA cities plays a crucial role in their adoption as a viable travel alternative. For many road users, this safety is often based on perception (subjective safety) rather than evidence (objective safety). Identifying factors that measure the safety of paratransit operations is essential to understanding the industry's challenges and opportunities for improvement. Generally, studies on transport-related health and safety have used certain indicators to measure transport safety, including fatality, injury and crash rates (i.e. historical crash data), traffic noise, and emissions. Some studies have assessed transport-related health and safety using other indicators, such as the number of road traffic fatalities per 100 million vehicle-kilometres or road traffic injuries per 100 million passenger-kilometres, as well as advanced statistical methods and models to analyze the number of crashes and their outcomes.

However, Sustainable Mobility for All (2019b) have questioned the use of 'fatality, injury and crash rates' as the main indicators (quantitative values) for measuring transport-related health and safety, arguing that a change in the number of deaths and serious injuries in the short term might not accurately represent a lasting change in traffic health and safety. Short-term fluctuations could be influenced by, e.g. weather conditions, enforcement of traffic laws, infrastructure changes, traffic emission and noise level, thus necessitating long-term trends to assess the effectiveness of safety measures. Further, official statistics on crashes and injuries may not

capture the full extent of road incidents, as some traffic crashes might go unreported or under-reported for various reasons, such as lack of witnesses or not involving law enforcement, as in the case in many SSA countries (Jones et al., 2016; Salifu and Ackaah, 2012). This is commonly the case for low-severity crashes. Consequently, relying solely on these statistics may provide an incomplete picture of the actual health and safety situation.

Further, merely counting the total number of deaths and injuries does not fully capture the factors contributing to traffic crashes. To implement effective preventive measures and enhance overall transport health and safety, it is essential to understand the underlying processes and mechanisms that lead to these incidents. For example, even if reported fatalities and injuries are low within a certain period, this does not necessarily indicate that the traffic system is entirely safe. Hazardous conditions or risky behaviors may still be prevalent, increasing the potential for serious or fatal crashes in the future. Therefore, it is crucial to recognize the persistent dangers within traffic systems and work continuously to mitigate them. A comprehensive, long-term approach to assessing traffic safety, one that goes beyond raw numbers and acknowledges the complexities of maintaining safer roads, is urgently needed.

Traffic noise and emissions pose substantial environmental and public health concerns that require comprehensive measurement and management strategies. Their impact on health, quality of life, and environmental sustainability highlights the need for effective policies and practices in urban transport planning. Measuring traffic noise and emission involves various methods and considerations, depending on the specific objectives and constraints of the measurement program (Ibili et al., 2022; Zhou et al., 2024). Strategies for measuring traffic noise include standardized surveys and engineering methods, hand-held sound level meters for quick assessments, static noise testing for individual vehicles, noise mapping for spatial analysis, modelling approaches, hybrid methods, and continuous monitoring systems for long-term data collection (Ibili et al., 2022; Tiwari et al., 2024).

Relatedly, strategies for measuring traffic emissions include laboratory testing using chassis dynamometers, on-road testing with portable systems, remote sensing for quick assessments, advanced modelling techniques that utilize GPS and traffic sensor data, and hybrid methods. These measurement methods for traffic noise and emissions need to be complemented with qualitative interviews, surveys and observations (Ajayi et al., 2024b; Clark et al., 2022; Nyarku et al., 2019).

In addition, transport-related crimes can be measured in various ways to understand their nature, frequency, and impact on passenger safety. Measurements require analyzing the types of crimes, locations, temporal patterns, crime rates, passenger flow data, spatial distribution, and relationship to neighbourhood crime. This multi-faceted approach provides an in-depth understanding of transport-related safety issues.

Overall, a comprehensive approach that considers various metrics, methodologies, and tools is necessary to effectively measure transport-related health and safety. This involves a mul-

ti-dimensional strategy incorporating crash data analysis, monitoring of traffic noise and emission levels, road user behaviour, infrastructure and environmental assessments, vehicle safety evaluations, health outcomes, public policies, economic impacts, and advanced tools and techniques. By combining these methods, policymakers, researchers, and practitioners can develop a thorough understanding of transport-related health and safety issues and implement effective strategies to enhance road safety in SSA cities.

5.4. Transport-related health and safety research in SSA

A summary of research on transport-related health and safety in SSA is provided in Appendix C. These studies have largely focused on themes such as environmental factors, human-induced factors (i.e. driver characteristics, driver behavior and violations such as red-light running) and traffic enforcement and policing on transport safety (i.e. crash) outcomes. Particularly, human-induced risk actors have heavily dominated the transport-related safety research in SSA. Common themes in this area include risk factors associated with fatal road traffic crashes (Ackaah and Aidoo, 2020), injury severity of bus transport (Damsere-Derry et al., 2021) and how risky driving behaviour affects traffic fatalism (Teye-Kwadjo, 2019). Sam et al. (2020) examined the intention to use public bus transport based on passengers' safety evaluations. Also, Teye-Kwadjo (2019) observed that fatalistic beliefs are positively associated with attitudes towards risky driving. In these studies, excessive vehicular speeds among PT operators, use of goods vehicles for passenger transport, excessive loading, and inadequate trauma care have been identified as key contributory risk factors to the high number of traffic fatalities. Essentially, there is a dearth of studies on paratransit (un)safety and invariably transport-related health and safety in SSA cities.

Beyond exploring the crash contributing factors, the use of secondary data (i.e. crash data) dominates safety research in SSA to investigate crash outcomes, where authors largely explored the influence of environmental, vehicular and other road factors on crash severity using advanced statistical methods and approaches. Regarding environmental factors, previous studies, including Tamakloe et al. (2022, 2021), Maldonado et al. (2002), and Sam et al. (2018), revealed that weekends, the absence of a road median, night-time conditions and bad road terrain (e.g. curved, wet and rough roads) are associated with more severe bus/minibus crash outcomes. Other common themes in the literature relate to the relationship between driver knowledge/training and its influence on traffic safety. These studies have focused on drivers' awareness of road situations or other activities like alcohol intake or speeding (Damsere-Derry et al., 2017; du Plessis et al., 2016). As indicated by Akaateba et al. (2015), there is a significant association between, on the one hand, driver education, training and experience, and on the other hand, the frequency of violation of traffic safety laws. Relatedly, Damsere-Derry et al. (2017) reported an increasing level of alcohol intake, where 55% of minibus drivers reported driving a vehicle within an hour of alcohol intake.

Traffic noise levels in SSA cities have been widely reported to be higher than WHO and national guidelines (Clark et al., 2021; Ibili et al., 2023). For example, commercial, business, and industrial areas and areas near major roads were found to have the highest median daily sound levels (69

dBA and 72 dBA) and the lowest percentage of intermittent sound in Accra (Clark et al., 2021). Also, road-transport sounds dominated the overall sound environment while mixtures of other sound sources, including animals, human speech, and outdoor music, dominated in various locations and at different times in Accra (Clark et al., 2021). As an equity concern, the poorest areas were found to have the highest noise levels on average, and higher by 5 dBA when compared to wealthier areas in Accra (Clark et al., 2022, 2021).

Relatedly, vehicular emission levels have been widely reported to be above WHO and national limits in SSA cities (Ajayi et al., 2024a, 2023a; Jones et al., 2016; Nyarku et al., 2019; Obanya et al., 2018). A study in Lagos, Nigeria, found that the concentration of vehicular air pollutants is highest between 8 and 9 am morning peak and 4–7 pm evening peak periods, but lowest between 12–1 pm afternoon off-peak (Ajayi et al., 2024b). In addition, 74% of residents along the studied road corridors reported symptoms, chest pain, frequent coughing, runny nose, sneezing, eye irritation, sore throat, difficulty breathing, weakness, fatigue, loss of appetite, headache, and rapid breathing. Women (54%) and children (6%) were identified as the most vulnerable groups. Similar findings that highlight the disproportionate burden of vehicular emissions on vulnerable populations in SSA cities have been reported (see Adepoju et al., 2018; Ajayi et al., 2023b; Dushie et al., 2017; Nyarku et al., 2019; Obanya et al., 2018).

Moreover, transport-related crimes are a significant concern in many African cities. These crimes can take various forms, including pickpocketing, bag snatching and jewelry theft, harassment, kidnapping, murder, robbery, assaults, injuries, loss of life and property, and verbal abuse from drivers (Olaniyan et al., 2023; Smith and Clarke, 2000). An emerging crime is 'one-chance' criminality, which has become a rampant threat to public transport in Nigeria, where passengers are trapped through deceit, robbed, and victimized by individuals or groups pretending to offer public transport services (Olaniyan et al., 2023; Tade and Faisol Olaitan, 2024). Longer commuting distance/time to opportunity destinations often exposes passengers to being victimized on buses, trains or minibus taxis, while changing from one mode of transport to another at stations, or when walking from drop-off points to their places of work or their homes (Kruger and Landman, 2007; Olaniyan et al., 2023). Some protective strategies or countermeasures adopted by passengers include changing the timing of travel, vigilance before boarding, hailing a private taxi, disguise/deception, taking unusual routes, tampering with the vehicle's central lock, reworking the seatbelt, and winding up glasses (Olaniyan et al., 2023; Tade and Faisol Olaitan, 2024).

Methodologically, a significant majority of these studies are quantitative in approach, with limited studies employing a qualitative or mixed methods approach, thus lacking a holistic approach to understanding the underlying motivations, considerations and perspectives to the topics studied (Goetz et al., 2009). This trend confirms the perception that transport research in SSA is largely quantitative, aligning with the historical and epistemological foundations of the field.

5.5.   Research gaps in transport-related health and safety in SSA cities

While quantitative approaches are valuable for generalizing findings to broader contexts, they often lack the depth needed to fully explain observed phenomena, as they may overlook variables that provide deeper insights into relationships or trends in the data. A mixed-methods approach, incorporating qualitative research, would enhance our understanding of transport-related health and safety in SSA cities by providing a more comprehensive analysis of the underlying factors and experiences.

Also, the other aspects of transport-related equity (i.e. access and efficiency) have received extensive attention across SSA countries, while the depth of research on transport-related health and safety in SSA appears comparatively limited. The closest examples concerning traffic safety relate to crash/accident casualty (Damsere-Derry et al., 2017; Sam et al., 2018; Tamakloe et al., 2021), injury patterns (Ackaah and Adonteng, 2011; Chokotho et al., 2013; Damsere-Derry et al., 2010; Sam et al., 2019; Solagberu et al., 2015) and other allied issues such as traffic enforcement and policing (Jones et al., 2016; Sam, 2022). A closer look reveals that these studies largely originate from South Africa, Nigeria, Ghana, and thus may not be content-valid for other SSA countries due to the varying driving contexts and social and cultural settings, which are predictors of traffic safety. There is thus an urgent need for studies exploring diverse contexts and settings.

Health and safety remain crucial issues in access and mobility, yet Africa, with fewer vehicles and roads, experiences more vehicle and passenger crashes than other continents. Research efforts in health and safety have not been evenly spread across SSA, as a few countries appear to dominate the road safety research space. The lack of a unified continental framework for road safety, ranging from data collection, policies and regulations, hinders any meaningful assessment of road safety Africa-wide. For this reason, researchers in individual countries strive to conduct isolated country-specific studies, with findings and lessons often limited to their local settings. Again, funding limitations constrain academics and researchers in the depth and relevance of their studies.

Consequently, literature on traffic safety has predominantly focused on crash statistics and general causes of traffic-related crashes (Glèlè-Ahanhanzo et al., 2021; Onywera and Blanchard, 2013; Verster and Fourie, 2018; von Beesten and Bresges, 2022; Zegeer and Bushell, 2012), as well as the influence of driver behavior (Akaateba et al., 2015; du Plessis et al., 2016; Maldonado et al., 2002) and seat belt usage (Ojo, 2018) on traffic crash outcomes. While these studies provide a comprehensive assessment of traffic safety in specific African countries/cities, they fail to address the extent to which transport-related safety, including road and personal safety, disproportionately affects socially, economically, and environmentally disadvantaged populations.

Critical research on traffic noise and emissions and transport-related crimes is limited in the literature. Considering the high spatial and social inequities in SSA cities, vulnerable populations are more likely to be pedestrians, cyclists, and two- and three-wheeler users. These users suffer the most from the harmful effects of vehicular noise and emissions such as particulate

matter (PM), carbon monoxide (CO) and nitrogen oxides (NOx). However, it is not well known how vulnerable populations in SSA perceive and adapt to these hazards, or the extent of the health burden and related socioeconomic costs of disproportionate exposure to vehicular noise and emissions. Relatedly, incidents such as assault, robbery, sexual harassment, and vandalism in PT and NMT systems can lead to serious injuries, trauma, and loss of property for victims. It is widely recognized that exposure to transport-related crimes is higher for vulnerable populations such as women, children, the elderly, and immigrants/refugees, where perceptions and experiences of safety can discourage them from using PT and NMT services.

6. Conclusion

The key priorities for impactful research towards enhancing transport-related equity in African cities are summarized under three sub-themes: universal access, efficiency, and health and safety. These three themes have been tested with stakeholders in the three study cities and based on findings summarized in our stakeholder workshops. In the context of universal access, critical research is needed to: (a) evaluate the disparities of access to basic opportunities for vulnerable populations, (b) assess mobility-based morphology and its implications on equitable access, and (c) investigate approaches to enhance the inclusivity of PT and NMT services in SSA. For transport-related efficiency, targeted studies are needed to: (a) examine space-time allocation of PT and NMT towards enhancing accessibility for vulnerable populations, (b) assess the affordability of PT modes for vulnerable populations, and (c) investigate the combined allocation and production performance of PT and NMT in SSA cities. Relating to transport-related health and safety, unique research contributions are needed to: (a) investigate the disproportionate burden of traffic crashes faced by vulnerable populations and approaches to mitigating them, (b) assess the health and socioeconomic burden of vehicular noise and emissions on vulnerable populations, and (c) evaluate the personal safety and transport-related crimes on vulnerable populations when accessing opportunities in SSA cities.

Relatedly, there are cross-cutting themes that can underpin impactful research on transport-related equity in SSA cities. Methodologically, there are measurement limitations, where much of the existing research relies heavily on quantitative measurements such as accessibility metrics and cost-benefit analyses. However, there is a lack of comprehensive qualitative research that captures the lived experiences of individuals affected by transport policies. This includes understanding the nuances of how different demographic groups perceive and navigate the transport system and services. One example is understanding different aspects of equity that can be measured to evaluate the quality of the transport service provided from a social perspective (Boisjoly and El-Geneidy, 2021; Pereira et al., 2017).

There are also issues of inadequate quality and availability of equity-related data in SSA cities. Most transport and local agencies rarely collect or analyze data that adequately reflects the needs of low-income and vulnerable populations. This lack of quality data impedes the ability to make informed decisions towards enhancing the equity of transport services in SSA cities. Systemically, there are institutional barriers and a lack of financial and political support which undermine equity-enhancing provisions and strategies.

In summary, addressing these research gaps is crucial for enhancing transport-related equity for all persons, especially vulnerable populations in SSA cities. Future studies should focus on improving access, efficiency, and health and safety for all persons, understanding the needs of vulnerable populations, localizing research efforts, and employing diverse methodological approaches to capture the full spectrum of transport-related equity challenges in SSA cities.

APPENDIX A – LITERATURE SURVEY ON TRANSPORT-RELATED ACCESS IN SSA

Appendix A. List of transport-related accessibility literature on SSA.

Paper	Study Focus & Method	Key Findings
Ashiagbor et al.(2020)	Use of quantitative data to investigate geographic accessibility to health services in Ashanti region of Ghana. Method: Dasymetric mapping technique and GIS	About 81% of the population had access to primary healthcare in the Ashanti region of Ghana, while about 61% have access to secondary-level, and 14% to tertiary care. Notwithstanding the relatively high rates of accessibility, about 30% of the population has to travel far to access primary care.
Agbenyo et al. (2017)	Examined accessibility to basic health services in rural communities in Wa West district of Ghana. Method: Mixed methods combining semi-structured interviews with GIS	Assessment of spatial access to three levels of health services in the Wa West District of Ghana showed that about 50% of communities have high accessibility to Community-Based Health Planning and Services (CHPS) compounds and health centers, whereas only 4% have high physical access to district hospitals.
Dumedah et al. (2021)	Characterized accessibility to healthcare by accounting for population demand, capacity of health facilities, and distance in the Greater Kumasi of Ghana. Method: Gravity-based approach in GIS using the Three-Step Floating Catchment Area (3SFCA), and Rational Agent Access Model (RAAM).	Low spatial access of about 2.34 physicians per 10,000 persons has been found in the Greater Kumasi of Ghana, where the health facilities were associated with detailed geographic coverage, low numbers of physicians, and high population demand
Dumedah et al. (2023c)	Examined the disparities in potential spatial access to health services for four selected cities in Ghana. Method: Gravity-based approach in GIS using the Three-Step Floating Catchment Area (3SFCA), Rational Agent Access Model (RAAM), and statistical regression.	Found that low spatial access is not equitable across and within the selected study cities, where the economically disadvantaged populations were found to endure longer travel distances to access health services. Inequities were found to be embedded within the selected cities where economically poor populations are also disadvantaged in their physical access to healthcare.

Paper	Study Focus & Method	Key Findings
Asare-Akuffo et al.(2020)	Examined the potential spatial access to health services in Kumasi, Ghana. Method: Gravity-based approach in GIS using the Two-Step Floating Catchment Area Method (2SFCA).	Applied the 2SFCA approach to investigate the spatial accessibility to hospital facilities only in Kumasi, Ghana, using travel time. Most people in the study area could reach a hospital within 20 minutes, but those in peri-urban areas have very limited spatial access to health facilities.
Lawal and Anyiam (2019)	Examined geographic access to Primary Health Care Facilities in Akwa Ibom State in the Niger Delta region of Nigeria. Method: Combination of open data and GIS techniques.	Identified underserved areas for primary healthcare facilities in Nigeria and estimated the potential spatial accessibility for travel times based on topography and road network. About 98.3% settlements have good access (<30 min), 1.5% are located in the poor access class (31–60 min), while 0.1% are within the very poor access class (>60 min).
Lawal and Anyiam (2019)	Examined geographic access to Primary Health Care Facilities in Akwa Ibom State in the Niger Delta region of Nigeria. Method: Combination of open data and GIS techniques.	Identified underserved areas for primary healthcare facilities in Nigeria and estimated the potential spatial accessibility for travel times based on topography and road network. About 98.3% settlements have good access (<30 min), 1.5% are located in the poor access class (31–60 min), while 0.1% are within the very poor access class (>60 min).
Ouko et al. (2019)	Evaluate geographic access to health facilities offering delivery services in Siaya County of Kenya. Method: Mixed-methods approach incorporating GIS (AccessMod5 and ArcGIS) and semi-structured interviews to derive travel time to facilities using different travel scenarios.	Identified underserved areas specifically for maternal health facilities where they evaluate the potential spatial accessibility of travel times by walking, motorcycle, and car. Land cover types were used to constrain the estimated travel times for walking, motorcycle, and car. About 26% and 67% of the pregnant women could reach any facility within one and two hours respectively. By walking, 7% and 20% can reach any facility within one and two hours respectively. The predicted probability of a pregnant woman delivering in a health facility ranged between 0.14 and 0.86.

Paper	Study Focus & Method	Key Findings
Stewart et al. (2020)	Identified and evaluate spatial barriers to cervical cancer prevention services in Ondo State, Nigeria. Method: Gravity-based approach in GIS using the Multi-Mode Enhanced Two-Step Floating Catchment Area model	About 73.5% of clients of the hospital in Ondo City resided in the two highest access zones, 21.5% of clients were from locations estimated to be in the lowest access catchment, and a further 2.25% resided outside these limits. Some areas that were relatively close to cervical cancer screening centers had lower access values due to poor road network coverage and fewer options for public transportation. Variations in spatial access were revealed based on client residential patterns, travel time differences, distance decay assumptions, and travel mode choices.
Huerta Munoz and Källestål (2012)	Estimate the potential spatial accessibility for walking, cycling, and public transportation in Western Province of Rwanda. Method: Used GIS to generate travel time to primary health facilities by accounting for coverage capacity, population, topography, and travel modes.	Used GIS through a least-cost algorithm to identify the catchment area for health facilities for walking, cycling, and public transportation. Walking and cycling has the highest degree of geographical accessibility followed by walking and public transportation. The lowest level of accessibility is walking. The population covered differs depending on the type of travel scenario. Walking and cycling covers 26.6% of the population; walking and public transport has 58%; and walking covers 34.3%.
Dumedah et al. (2023a)	Evaluates the allocation of paratransit terminals and routes, their access to populations, and overall coverage in the Oforikrom Municipality of Ghana. Method: Used General Transit Feed Specification (GTFS)-like data, a nearest neighbor analysis, and a service area estimation in GIS.	Paratransit allocation is highly inefficient being associated with fragmented routes and poor connectivity, where the travel distance to paratransit service ranges from 1 to 2800 m, and existing routes can be reduced considerably by 53%. A close matching with an R-square of 0.977 was found between the proportion of the population served by paratransit and the coverage of the land area where they live. Economic status based on the relative wealth index was found to be moderately related to the travel distance to paratransit services, the population served, and the land area covered.

Paper	Study Focus & Method	Key Findings
Andreasen and Møller-Jensen (2017)	Examined access to the city for residents living in the periphery of Dar es Salaam, Tanzania. Analyzed mobility practices of residents and mobility constraints of the urban transport system. Method: Used qualitative interviews, travel speed data and GIS-based modelling of overall accessibility.	Examined access to the city of Dar es Salaam from its outskirts where they found that travel times are less influenced by mode of transport and more by road traffic conditions and the urban morphology of the city. Found widespread dependence on motorized transportation, with the vast majority depending on public transport. Private cars appear marginally faster, but differences in travel times are very limited.
Falchetta et al. (2021)	Examined accessibility to public transport, its network coverage and frequency in 7 SSA cities: Abidjan, Accra, Addis Ababa, Freetown, Harare, Kampala, and Nairobi. Method: Quantitative analysis of paratransit services. Used General Transit Feed Specification (GTFS) in GIS to estimate travel time to public transport.	Estimated the accessibility to paratransit services in SSA cities using the General Transit Feed Specification (GTFS) data while highlighting transport inequality and urban segregation.
Acheampong and Asabere (2022b)	Analyzed place-based accessibility in the Greater Kumasi city-region of Ghana. Method: Used GIS approach to integrate Landsat satellite images, travel time data from Google Maps API and Openrouteservice, and relevant transport infrastructure data.	Evaluated differential accessibility by car and public transport in the context of urban expansion showing that overall accessibility is poor regardless of mode choice due to congestion. The CBD is within 15 min and nearly 30 min reach by car and public transport respectively, for only 1% of the city-region's built-up area. Overall accessibility is poor regardless of mode choice, due to congestion. The findings underscore the need for integrative urban development and accessibility planning in the city-region for equitable transport and mobility outcomes.
Nakamura and Avner (2021)	Examined spatial distributions of job accessibility, housing rents, and poverty in Nairobi, Kenya. Method: Used empirical analysis in GIS to estimate travel time to jobs.	Accessibility to jobs has been linked to transport networks, showing that residents, particularly those from informal settlements face a job accessibility challenge in Nairobi, Kenya. On average, residents can access fewer than 10 percent of existing jobs by foot within an hour. Even using a minibus, they can reach only about a quarter of jobs. Poorer residents living in informal settlements are even more limited. Living closer to job opportunities is costly in Nairobi.

Paper	Study Focus & Method	Key Findings
Campbell et al., (2019)	Conducted a place-based accessibility across neighborhoods, and transport modes, with explicit linkages made between residential developments and physical access to health facilities in Nairobi, Kenya. Method: Gravity-based approach in GIS using the service area estimation to estimate number of health facilities that can be reached in 60 min, and a gravity measure quantifying the number of health facilities weighted by a time-decay function.	The wealthiest areas have very low levels of place-based accessibility for all modes, while poor areas have comparatively better walking access to health facilities. The medium-low residential level, characterized in part by tenement apartment buildings, has significantly higher accessibility than other residential types. One way to reduce inequality in access across income groups is to increase spatial accessibility for the modes used by low- and middle-income households, for example, with policies that prioritize public transport and non-motorized travel, integrate paratransit with land use development, and provide safe, efficient, and affordable options.
Timpabi et al. (2024)	Examined walking and cycling to school in two cities, Ayawaso East Municipal and Tamale Metropolis of Ghana. Method: Gravity-based approach in GIS using the Three-Step Floating Catchment Area (3SFCA).	Found a poorly connected dendritic road network system in study communities and shortcomings in school and street network planning that have left some communities vulnerable to low education opportunities. Without policy and planning interventions to address school siting and improve street connectivity, walking and cycling will not only be hindered, but education for some communities may be compromised.
Dumedah et al. (2024)	Examines potential and perceived access to six socioeconomic activity types in Kumasi-Ghana, and Dar es Salaam-Tanzania. Method: Quantitative study using questionnaire, GIS analysis, and multinomial logistic regression to examine potential and perceived access.	The study identified factors relating to age, education, income, travel time, road condition, access to major roads, travel modes, community location, inclusivity, safety, and affordability as strong indicators to enhance travel experiences. Across all activity types, the potential travel time underestimates the perceived travel time by 133% in Kumasi-Ghana, and 50% in Dar es Salaam-Tanzania. The overall access to socioeconomic activities based on travel distance and times was found to be relatively more favorable in Kumasi-Ghana than those in Dar es Salaam-Tanzania.

Paper	Study Focus & Method	Key Findings
Venter (2016)	Used access envelopes metric to examine the potential impacts of various restructuring options on passengers' wage-earning potential at job opportunities across space in Johannesburg, South Africa. Method: GIS approach to estimate access envelopes metric.	Examined the implication of formalizing paratransit and restructuring of public transport networks on passenger access and social inclusion in Johannesburg showing that the only way to improve access and affordability is a full integration of trunk with feeder services. For feeder services supplied via a hybrid formal-informal approach, an integrated and progressive fare policy is critical to maintaining affordable access for poor passengers.
Ndibatya and Booysen (2021)	Used floating car data to analyze and describe the movement characteristics of nine minibus taxis in Kampala, Uganda. Method: Quantitative analysis through analysis of floating car data.	Characterized the movement pattern of paratransit vehicles in Kampala, Uganda. In searching for, picking up and transporting passengers, minibus taxi trajectories followed a heavy-tailed power-law distribution where their routes' topology and shape gradually changed. The extraordinary winding of the paths suggested the determination of the drivers' search for passengers.
Ndibatya and Booysen (2020)	Analyzed the operations and efficiency of paratransit using 'floating car data' in Kampala, Uganda. Method: Quantitative analysis of economic metrics (minibus taxi fares, taxi occupancy and drivers' profitability index (PI)) and efficiency metrics (passenger waiting time, taxi hold-back time, operating speed and commercial speed).	Evaluated the efficiency of paratransit from passengers' and drivers' perspectives in Kampala, Uganda. Driver profitability index is low – ranging between 0.76 and 1.12 – and the waiting and hold-back times are high – ranging between 22 and 59 min and 35 to 110 min respectively. Finding indicates an overall minibus taxi system inefficiency.
Tekest et al.(2022)	Examined paratransit inefficiencies and loss of revenue by paratransit operators in the Arada sub-city of Addis Ababa, Ethiopia. Method: Questionnaires, interviews, as well as observation. Convenience sampling method.	Study revealed that the presence of complex owner-driver relations, customary operational practices, and poor institutional organization of owners' associations, as well as inefficient regulation, creates unpleasant work situations and hence profoundly affected service delivery. In addition, the study found that all these situations are threatening the sustainability of the sector as most vehicle owners have less interest in staying in the business.

Paper	Study Focus & Method	Key Findings
Dumedah et al. (2022a)	Examined the capacity of bus terminals, population demand, travel distance, and pedestrian response to congestion in Kumasi, Ghana. Method: Gravity-based approach in GIS using the Three-Step Floating Catchment Area (3SFCA), and Rational Agent Access Model (RAAM).	Found that access to bus terminals is low, averaging 0.5 bus terminals per 10,000 people, underpinned by random distribution, low capacity, and high demand. Incorporation of urban morphology showed that high-dense settlements have better accessibility, while moderate-dense and low-dense settlements have comparable accessibility.
Dumedah et al.(2022b)	Investigated the suitability of, and the use of electoral polling stations to build a reference database for geocoding towards enhancing access to socioeconomic opportunities. Method: Geocoding, service area estimation, and regression analysis using GIS.	Found high proximity with a nearest neighbour distance of 663 m, a reasonable service area of 4300 m, and a median distance of 3700 m from a community location to electoral polling stations. The widespread availability, large geographic spread and moderate detail make polling stations a credible data source for geocoding towards enhancing access to socioeconomic opportunities.
Dumedah et al. (2023b)	Investigated the disparities of access to electoral polling stations in four selected regions in Ghana. Method: Geocoding, service area estimation, and regression analysis using GIS.	Economic status and access to Electoral Polling Stations (EPS) are inversely related, indicating that access to EPS is not equitable within and between regions. The poor access for economically disadvantaged populations is indicative of unequal access to basic socioeconomic opportunities.
Ukam et al.(2023)	Quantified the components of paratransit travel time on a selected route in Kumasi, Ghana. Method: Space-time analysis of travel times within the day and from day to day using mobile phone app data and GPS data.	About 16% of travel time was spent dwelling (boarding and alighting). The variation in travel times across the day was comparatively higher than that of formal bus services and fluctuated across the day with no distinct pattern within any given time period. Both early and late trips contributed to this variation across the day. Fridays had significantly different variability from other weekdays.

Paper	Study Focus & Method	Key Findings
Chakwizira et al. (2018)	Used 1550 randomized household sample conducted in Gauteng, South Africa, to examine different access strokes and constraints. Method: Secondary data analysis using summary statistics.	Highlighted differentiated access and transport constraints for public transport commuters in Gauteng province. The driving group has to deal with problems of traffic congestion, road rage, travelling time and travel delay among other issues. The public transport group in addition to long commuting distances, travelling times has to deal with low service levels, off-peak infrequent to non-existing service, crime as well as challenges associated with non-scheduled transport systems. There is, therefore, differentiated access and transport problems for public transport users who make use of the three main modes, namely train, bus and minibus taxis.
Diaz Olvera et al. (2013)	Examined access to the city as revealed by the daily travel behaviour of urban dwellers based on secondary analyses of six household travel surveys carried out in West and Central African cities between 1992 and 2003. Method: Secondary data analysis using summary statistics.	Examined access to the city as revealed by the daily travel behaviour of urban dwellers based on secondary analyses of six household travel surveys carried out in West and Central African cities between 1992 and 2003. Method: Secondary data analysis using summary statistics.
Seedhouse et al. (2016)	Explored how the use of transport for business activities, transport barriers that they are subject to and ways in which these barriers are being surmounted. Method: Telephone surveys, supported by in-depth interviews to generate data about their business and transport behaviours.	Many of the women feel that the current transport situation is having a negative impact on the success of their businesses, and has affected their ability to recruit employees, service customers, and deliver goods. Whilst the women had a very poor understanding of transport policy, many of them felt that the main issue was the poor quality of the roads.

Paper	Study Focus & Method	Key Findings
Randall et al.(2023)	Reviewed the literature on active travel and paratransit in African cities, published from January 2008 to January 2019. We included 19 quantitative, 14 mixed-method and 8 qualitative studies (n = 41), narratively synthesizing the quantitative data and meta-ethnographically analysing the qualitative data. Method: Mixed-method systematic review and meta-ethnography.	Noncommunicable diseases are rising in Africa as populations urbanise and motorise. To offset this, active travel (walking, cycling, public transport) is desirable. Paratransit (informal public transport) is a key mode for urban African residents. Despite limited formal public transport many city authorities are anti-paratransit. Further paratransit research can foster more effective integrated mobility systems. Walking was high, cycling was low, and paratransit was a critical option for poor peripheral residents facing long livelihood-generation journeys. The studies varied in quality and showed uneven geographic representation, with data from Central and Northern Africa especially sparse; notably, there was a high prevalence of non-local authors and out-of-country funding.
Acheampong et al.(2022)	Analyzed public transport access in the Accra city-region, a contiguous conurbation comprising Accra, Ghana's capital city and the surrounding peri-urban settlements. Method: GIS analysis focused on the relationship between built-up land as of 2021 and the existing primary road infrastructure.	A huge accessibility deficit with respect to the public transport system is revealed. The chapter highlights the need for an integrated, accessibility-oriented paradigm to land use and transport planning that prioritizes urban growth management as well as public transport and non-motorized transport infrastructure development. This is vital in creating healthy, inclusive and environmentally sustainable urban futures.
Heinrichs et al. (2017)	Examined how informal transport service providers organize their activities, negotiate for gaining access rights, and their demand regarding urban space in Bogotá, Colombia and N'Djamena, Chad. Method: Used a case study approach.	Access to public space in Bogotá is the result of negotiation and 'co-regulation' by the associations of operators and government organizations, accompanied by a process of professionalization of informal operators. This is not the case in N'Djamena, where the use of public space is largely the result of self-regulation by the federations of motortaxi drivers.
Uzondu and Etika (2022)	Draws a future narrative for Non-motorised transport (NMT) by examining the current challenges faced by NMT users in Sub-Saharan Africa and provide insightful policy ideas and infrastructure development strategies. Method: Consultations with relevant stakeholders and experts.	Suggested pathways for the integration of NMT to urban mobility plans in African cities and towns.

Paper	Study Focus & Method	Key Findings
Bashingi et al.(2020)	Assessed congestion in Gaborone, Botswana, as experienced and perceived by regular travellers, using public and private transport. Method: Used regression models to evaluate individuals' travel times, predicting total trip duration and travellers' experiences with the public transport system.	Congestion levels have increased in Gaborone due to population growth and increasing rates of vehicle ownership. Even though people travel at different times, there is a similar pattern in their perceptions about the congestions for all travelling times. Most road users experience unpleasant levels of traffic.
Munuhwa et al. (2020)	Analyze urban transportation congestion, identify causes and proffer solutions through engaging road user perceptions, transport planning authorities and transport policy makers in Gaborone, Botswana. Method: Used an exploratory design to sample 208 respondents through the administration of questionnaires. Quantitative data were used and analyzed using SPSS.	Found a massive influx of motor vehicles in the city, inadequate urban infrastructure, poor infrastructural planning, poor or no urban transport policy framework, and Road Traffic Incidents were the main causes of traffic congestion. The effects of traffic congestion are higher transport costs, massive delays, pollution, decreased productivity and stress to motorists as a result of longer travelling time.

APPENDIX B – LITERATURE SURVEY ON TRANSPORT-RELATED EFFICIENCY IN SSA

Appendix B. List of transport-related efficiency literature on SSA.

Paper	Study Focus & Method	Key Findings
Ndibatya and Booysen (2021)	Used floating car data to analyze and describe the movement characteristics of nine minibus taxis in Kampala, Uganda. Method: Quantitative analysis through analysis of floating car data.	Characterized the movement pattern of paratransit vehicles in Kampala, Uganda. In searching for, picking up and transporting passengers, minibus taxi trajectories followed a heavy-tailed power-law distribution where their routes' topology and shape gradually changed. The extraordinary winding of the paths suggested the determination of the drivers' search for passengers.
Ndibatya and Booysen (2020)	Analyzed the operations and efficiency of paratransit using 'floating car data' in Kampala, Uganda. Method: Quantitative analysis of economic metrics (minibus taxi fares, taxi occupancy and drivers' profitability index (PI)) and efficiency metrics (passenger waiting time, taxi hold-back time, operating speed and commercial speed).	Evaluated the efficiency of paratransit from passengers' and drivers' perspectives in Kampala, Uganda. Driver profitability index is low – ranging between 0.76 and 1.12 – and the waiting and hold-back times are high – ranging between 22 and 59 min and 35 to 110 min respectively. Finding indicates an overall minibus taxi system inefficiency.
Bwire and Zengo (2020)	Examined excess commuting and compared its parameters between public and private transport modes in Dar es Salaam, Tanzania. It evaluates the effects of land use patterns using 2007 as the baseline and 2030 as the projected year. Method: used Household Interview Travel Survey data to carry out traffic analysis zones using System for Traffic Demand Analysis (STRADA).	The study findings show that public transport in Dar es Salaam is very good in terms of providing excellent options to get everywhere in the city as it connects homes and jobs. It found that the land use scenario in 2030 encourages a travel pattern that increases the actual average travel distance. The study recommended an analysis of the average travel distance by quantifying the excess travel in terms of energy consumption for motorized public and private transport users.
Venter et al. (2021)	The study investigated the mobility issues of the urban periphery in the context of increasing travel distances and transport efficiency for the metropolis of Tshwane-Johannesburg-Ekurhuleni, the largest urban area in South Africa. Method: used survey data and carried out accessibility mapping to examine migration, marginalization, travel burdens, and car use by residents in urban periphery in contrast to those in other parts of the city.	The study found that urban expansion is putting increasing pressure on cities to manage social, environmental, and infrastructure challenges as they grow. New analysis shows that urban expansion manifests very differently in terms of outward and upward growth across different regions of the world, driven by a variety of demographic, land market, and institutional factors. Outward growth leads to low-density sprawl that exacerbates transport challenges in terms of increasing travel distances and reducing transport efficiencies, which in turn has been linked to peripheral growth with higher levels of social exclusion and spatial inequality.

Paper	Study Focus & Method	Key Findings
Venter (2016)	Used access envelopes metric to examine the potential impacts of various restructuring options on passengers' wage-earning potential at job opportunities across space in Johannesburg, South Africa. Method: GIS approach to estimate the access envelopes metric.	Examined the implications of formalizing paratransit and restructuring of public transport networks on passenger access and social inclusion in Johannesburg, showing that the only way to improve access and affordability is a full integration of trunk with feeder services. For feeder services supplied via a hybrid formal-informal approach, an integrated and progressive fare policy is critical to maintaining affordable access for poor passengers.
Tekest et al.(2022)	Examined paratransit inefficiencies and loss of revenue by paratransit operators in Arada sub-city of Addis Ababa, Ethiopia. Method: Questionnaires, interviews, as well as observation. Convenience sampling method.	Study revealed that the presence of complex owner-driver relations, customary operational practices, and poor institutional organization of owners' associations as well as inefficient regulation, creates unpleasant work situations and hence profoundly affected service delivery. In addition, the study found that all these situations are threatening the sustainability of the sector, as most vehicle owners have less interest in staying in the business.
Dumedah et al. (2023a)	The study evaluates the allocation of paratransit terminals and routes, their access to populations, and overall coverage in the Oforikrom Municipality of Ghana. Method: compiled General Transit Feed Specification (GTFS)-like data, applied a nearest neighbour analysis, and a service area estimation to evaluate the allocation of paratransit service routes.	The study found that paratransit allocation is highly inefficient, being associated with fragmented routes and poor connectivity, where the travel distance to paratransit service ranges from 1 to 2800 m, and existing routes can be reduced considerably by 53%. Strong correlation was found between the proportion of the population served by paratransit and the coverage of the land area where they live. The study suggested that enhanced paratransit allocation be co-formulated, co-developed, and co-enforced by all stakeholders, especially local governments, driver unions, paratransit operators, passengers, and pedestrians.
(Okafor et al., 2014)	This study measured the energy efficiency of powered petrol and diesel vehicles commonly used for public passenger transport operating in Onitsha, Anambra State, Nigeria. Method: applied statistical regression to model the energy efficiency of the public transport vehicles.	Found the average energy efficiency of petrol-powered vehicles to be 0.474 MJ/seat-km, whereas diesel-powered ones were 0.269 MJ/seat-km. Provided a simplified fuel consumption model where the model goodness of fit is 88.6% and 83.6% for petrol-powered and diesel-powered vehicles, respectively.

Paper	Study Focus & Method	Key Findings
Ukam et al.(2023)	Quantified the components of paratransit travel time on a selected route in Kumasi, Ghana. Method: Space-time analysis of travel times within the day and from day to day using mobile phone app data and GPS data.	About 16% of travel time was spent dwelling (boarding and alighting). The variation in travel times across the day was comparatively higher than that of formal bus services and fluctuated across the day with no distinct pattern within any given time period. Both early and late trips contributed to this variation across the day. Fridays had significantly different variability from other weekdays.
Ajayi et al. (2024a)	Examined vehicle engine characteristics and their impact on the release of air pollutants from various vehicle fleets including motorcycles, tricycles, private cars, minibuses, large buses, and trucks in Lagos, Nigeria. It directly measured emissions from the exhaust pipes of 88 vehicles using gas analyzers. Method: applied statistical analysis using carbon monoxide (CO) and nitrogen oxide (NOx) emissions to develop a model equation based on vehicle type, engine type, vehicle age, and purchase status.	Found that personal cars and minibuses predominantly emit CO from gasoline engines, whereas large buses and trucks significantly contribute to NOx emissions from diesel engines. About 66% of the vehicles were over 10 years old, resulting in a 65% increase in emission levels. About 60% of gasoline and 75% of diesel vehicles exceeded the permissible emission limits, leading to air quality deterioration and heightened health risks. Study underscored the risks associated with ageing vehicles and different engine types, emphasizing the need for transition to low-carbon or electric vehicles to combat air pollution and mitigate health hazards.
Ajayi et al. (2023a)	Evaluated how traffic characteristics such as flow, speed, and vehicle composition affect emissions in a heterogeneous traffic situation in Lagos, Nigeria. Method: on-site traffic flow and vehicle mix data collection along selected arterial and two-lane collector roadways. Applied statistical regression to model the impact of traffic flow parameters on vehicular emissions.	Found that there is an exponential association between pollution concentration and traffic mobility parameters. Showed that pollutant emissions increase rapidly during peak traffic conditions in heterogeneous traffic on different classes of roads and recommended policies for managing vehicle fleets and traffic congestion with the aim of reducing the impact on the ambient air quality and health of the public on heavily trafficked roadways in Nigeria.
Ayetor et al. (2021)	Examined the state and adequacy of fuel and vehicle standards in Rwanda and Ghana. Method: employed experimental emissions tests on 200 vehicles each in Rwanda and Ghana to ascertain compliance with local and international standards.	Found that some new vehicles failed the emission tests, while almost all the diesel cars tested in both countries failed the international standard. Seven countries are responsible for 70% of greenhouse gas (GHG) emissions in Africa. GHG emissions from transport in Africa are growing at a rate of 7% annually. Poor fuel quality, aging vehicle fleet, and lack of mandatory roadworthy emission tests are the key drivers.

Paper	Study Focus & Method	Key Findings
Falchetta et al. (2021)	Compared paratransit in seven major African cities based on accessibility and network, and service quality. Method: Used (GTFS) data from DigitalTransport4Africa to produce comparative metrics of accessibility, network efficiency, and service quality of paratransit in seven major cities in sub-Saharan Africa (Abidjan, Accra, Addis Ababa, Freetown, Harare, Kampala, Nairobi).	Provided insight on typical operational characteristics in various cities (like number of routes, route lengths, speeds). Large variations are observed across cities, as well as common patterns. In most cities, paratransit provides very good coverage of the territory, although some groups remain excluded. Low levels of efficiency are observed in all cities, largely as a result of suboptimal route selection and overtrading of routes (i.e. too many vehicles, leading to low utilization and long waiting times.)
du Preez et al. (2019)	Explored the spread of paratransit services provided, and how they are arranged into a service network. Examined GPS tracking data from 490 routes in metropolitan Cape Town. Objective was to analyse operational metrics like route lengths, speeds, stops, and passenger numbers, to see if route typology can be developed through a statistical clustering approach.	Identified three clusters of types of routes, with very different operational characteristics. They are trunk (line-haul, longer distance, lower stop density), feeder/distribution (shorter distance, higher stop density), and intermediate (mix of the other two, serving intermediate OD pairs). Three route types are similar in terms of passenger turnover per stop, suggesting a clear route hierarchy but with complementarity where all three support each other, with some overlap in service areas and roles.
De Beer and Venter (2021)	Developed theoretical model to investigate interventions that would provide formal priority to paratransit vehicles at selected intersections during peak hours. Three options studies include a single lane pre-signal strategy, queue-jumping lane, and dedicated public transport lane. The objective of the paper is to quantify the potential economic impacts of such treatments on minibus-taxi operators, passengers and other road users.	The findings show that substantial savings could be realised in terms of travel time, user cost, and operating cost to taxi passengers and drivers without additional costs being incurred by other road users. The three types of priority lanes could decrease total hourly cost of operations of between 12% and 30%, including construction cost, user cost, and agency cost, indicating a net social benefit.
Nyaki et al. (2020)	Analyzed travel time reliability under heterogeneous traffic conditions. It focused on passenger waiting time at bus stops, in-vehicle travel time, and delay time at intersections. Method: Used data obtained from five main bus routes in Dar es Salaam to analyze buffer time, standard deviation, coefficient of variation, and planning time.	The results indicate low service reliability in the outbound directions compared to the inbound directions. Additionally, the study revealed that higher travel time variations were experienced during off-peak hour than the peak hours.

APPENDIX C – LITERATURE SURVEY ON TRANSPORT-RELATED HEALTH AND SAFETY IN SSA

Appendix C. List of transport-related health and safety literature on SSA.

Paper	Study Focus & Method	Key Findings
Ackaah and Adonteng (2011)	The study examined risk factors associated with fatal road traffic crashes and remedial measures to address them in Ghana for the 2005-2007 period. Method: Quantitative by using Micro-computer Accident Analysis Package (MAAP) to analyze road traffic crash data.	Study found that pedestrians account for 42% of all road traffic fatalities and nearly one-third (33%) of these crashes occurred during the early night-time hours. Children form about one-third of all pedestrian fatalities. The occupants of goods vehicles accounted for 12% of all road traffic fatalities, although goods vehicles constitute just about 9% of the total motor vehicle population in Ghana. Risk factors were identified to include excessive vehicular speeds, inappropriate use of goods vehicles for passenger transport, excessive loading and inadequate trauma care. These risk factors are highest during nighttime.
Akaateba et al. (2015)	Examined the influence of driver educational attainment, driving experience, and form of driver training on drivers' self-reported attitudes towards the frequency of commission of traffic safety violations in Kumasi, Ghana. Method: Mixed method using Questionnaire and Interviews for 285 participants.	Found that driver education, training and experience are related to the frequency of traffic safety violations. Increased education was associated with reduced violations on speeding and overtaking. More experience and formal training increased frequency of commission of violations. Drivers trained from driving schools reported an overall higher mean frequency of commission of traffic violations compared to other drivers interviewed.
Damsere-Derry et al.(2021)	Examined injury severity of inter-city bus transport in Ghana using the random parameters multinomial logit with heterogeneity in means and variances modelling technique. Method: Quantitative using traffic crash data on the 575km Accra-Kumasi-Sunyani-Gonokrom highway in Ghana.	Found that crashes involving pedestrians, unlicensed drivers, and drivers and passengers aged more than 60 years have a higher probability of sustaining fatal injuries. Probability of hospitalized injury increased for crashes that occurred in a village setting. There were 1364 public transport-related crashes on the selected route from 2013 to 2017. Female drivers who died in public transport-related crashes on the route were driving private cars.

Paper	Study Focus & Method	Key Findings
Damsere-Derry et al.(2010)	Investigated associations between pedestrian injury and explanatory variables such as vehicular characteristics, temporal trends, and road environment in Ghana. Method: Quantitative method using a retrospective analysis based on a multinomial logistic regression of de-identified pedestrian crash data between 2002 and 2006.	Found that pedestrian casualties comprised 33% fatal, 45% serious injuries, and 22% slightly injured. Crossing the roadway accounted for over 70% of all pedestrian deaths. Crash fatality due to excessive speeding is about 65% probability. Compared with buses, pedestrians were less likely to die when struck by private cars (52%), pickup trucks (57%), and motorcycles (86%).
Damsere-Derry et al. (2017)	Evaluated the relative risk of death among road users in northern Ghana. Method: Quantitative approach using road traffic crash data from 2007-2011 based on multivariable logistic regression.	Found that 35% of all injury-related collisions were fatal. Fatal casualties ranged between 21% for sideswipe collisions and 41% for rear-end collisions. Male fatalities are 6 times higher than females; 90% of all female fatalities occur as pedestrian; 78% of male deaths occur as drivers or riders. Pedestrians were 3 times likely to die compared with drivers/riders. For every driver fatality, there are 4 cyclists' deaths and 2 motorcyclists' deaths. Crash fatalities of children below 10 years and elderly above 60 years are double compared to those of age 30-59 years.
Wambui (2023)	Report on Kenya's National Transport and Safety Authority test on theory written and applied theory for public transport (matatu) drivers along Likoni Road in Nairobi, Kenya.	The report showed that 18% of matatu drivers passed the driver licence renewal test; where from 302 drivers tested only 54 passed. Most drivers were unable to identify road signs (i.e. UN traffic signs), and not able to follow the rules of a model town board.
Odame (2017)	Examined road transport infrastructure and mobility needs of students with physical disability in University of Cape Coast, Ghana. It assessed the extent of physical barriers that impede the movement of students with physical disability, determine the extent of usage of university shuttles by these students and examine the stakeholder roles in providing accessible facilities. Method: Qualitative approach using 28 visually impaired, 1 wheelchair user and 3 key stakeholders.	Found that the dominant passenger facility on was sidewalk but these sidewalks were saddled with obstructing objects such as potholes and electric poles. None of the traffic lights was augmented with audible transmitters to aid the visually impaired. The absence of a documented policy to offer free ridership to student with physical disability provided the platform for drivers of privately owned shuttles to deny these students from enjoying free shuttles services.

Paper	Study Focus & Method	Key Findings
Sam (2022)	Investigated the perceived effectiveness of police road presence as a road safety strategy in the Ghanaian context. Method: Qualitative using interviews of a convenience sample of 42 persons comprising 25 commercial drivers, 12 private drivers, and 5 traffic police officers.	Found that drivers practice widespread road tactics to outwit the traffic police officers, police extortion and driver bribery (road traffic corruption), and punishment avoidance. These behaviours undermine deterrence and negate the seriousness and expected general deterrent effect of the police road presence and enforcement.
Sam et al. (2020)	Examined the predictive validity of the public bus passenger safety attitude scale, a measure of personal safety attitude, to predict future intention to use public bus/minibus for long-distance trips in Ghana. Method: Quantitative for a sample size of 510 using descriptive analysis and structural equation modelling.	Found that personal safety attitude has a positive significant effect on both a direct measure for attitude towards personal safety on public bus/minibus, and future intention to use public bus/minibus for long-distance trips. That is, a belief-based measure for personal safety attitude has convergent validity. Also, personal safety attitude significantly predicts attitude towards personal safety. Personal safety attitude significantly predicts future intention to use PT.
Sam et al. (2018)	Examined factors that influence bus/minibus traffic crash severity in Ghana. Method: Quantitative, using bus/minibus traffic crash data from 2011–2015.	Found that traffic crash factors are related to the driver, road and weather conditions, vehicle, time of the traffic crash and the collision type. Weekends, the absence of road median, night-time conditions, bad road terrain (curved, wet and rough roads), hit-pedestrian collisions, and drunk driving are associated with more severe bus/minibus crash outcomes.
Sam et al. (2019)	The study examined street hawkers' lived experiences and risks in traffic in Ghana. Method: Qualitative, using the phenomenological case study design. Data are based on 24 hawkers and field observation.	Found that participants' traffic incidents were mainly self-induced, attributable to their negligence on the road, indiscriminate road crossing and car-following behaviour. There is a perceived relationship between socio-demographic characteristics and personal traffic accident encounters. Also, traffic management measures seem to influence hawkers' traffic risk perceptions, with gender and age as possible mediators.
Tamakloe et al. (2021)	Examined the effect of contributing factors on the severity of bus/minibus traffic crashes in Ghana by accounting for pavement and light conditions. Method: Quantitative using traffic crash data.	Found that crash-risk factors were temporally unstable, warranting the division of the data into weekend and weekday time-periods. Factors such as sideswipes, median presence, merging, and overtaking have varying effects on bus/minibus crash severity under different pavement and light conditions for weekdays and weekends.

Paper	Study Focus & Method	Key Findings
Tamakloe et al. (2022)	Examined hidden groups of crash-risk factors leading to each bus/minibus crash severity level on pothole-ridden/ poor roads categorized under different lighting conditions in Ghana. Method: Quantitative using data mining approach and 2,832 crash records from 2011 and 2015.	Found that fatal crashes, especially hit pedestrian were more frequent on straight/flat roads at night. Median presence is highly associated with severe bus/minibus crashes on dark-and-unlighted roads, whereas median absence is associated with severe crashes on dark-but-lighted roads. On-street parking was identified as a leading contributor to property-damage-only crashes under daylight conditions.
Ackaah and Aidoo (2020)	Investigated the current rate of red light running and to determine the associated risk factors in the Kumasi, Ghana. Method: Quantitative, using an uninterrupted roadside observational survey at 10 signalized intersections using a pro-forma checklist. Data analysis was based on binary logit model.	Found that drivers run the red light in 35% of all the red phases studied. Red light running is influenced by the age and gender of the driver, presence of a passenger in the vehicle, vehicle type, junction type, cycle length of the signal and queue length.
Aidoo et al. (2021)	Investigated the risk factors associated with seatbelt use by vehicle occupants, and the relationship between driver and passenger seatbelt use in Ghana. Method: Quantitative using bivariate probit model on 5,433 vehicles observed.	Found that the prevalence rate of driver and front-right passengers' seatbelt use was 81% and 33%, respectively. Found a positive relationship between driver and passenger's seatbelt use with a correlation coefficient of 0.53. The unobserved factors that influence the probability of a driver's seatbelt use also influence their front-right passenger's seatbelt use propensity.
Salifu and Ackaah (2012)	Examine realistic estimates of the overall shortfall (under-reporting) in the official crash statistics in Ghana over an eight-year period from 1997–2004. Method: Quantitative using traffic crash data, and surveys on hospitals and drivers.	Found that non-reporting varied significantly with the severity of the crash, with 57% for property damage crashes, 8% for serious injury, and 0% for fatal crashes. Crashes involving cyclists and motorcyclists were substantially non-reported. Under-recording declined considerably by an average of 37% in 1997–1998 to 27% in 2003–2004.

Paper	Study Focus & Method	Key Findings
Damsere-Derry et al. (2017)	Examined the knowledge, attitudes, and practices toward drink driving or riding as a risk factor for road traffic crashes in 3 regional capitals in Ghana. Method: Quantitative using face-to-face approach to randomly sample motorists who were accessing various services at fuel stations, garages, and lorry terminals.	Found that the volumes of alcohol that motorists consume per drinking occasion were very high and their estimates of the number of drinks required to reach the legal BAC limit was also very high. About 24% of all motorists and 55% of motorists who were current alcohol users reported driving or riding a vehicle within an hour of alcohol intake. Motorists/riders who were current alcohol users consumed 4 standard drinks per drinking occasion. About 83% of motorists who currently use alcohol walked, rode, or drove home after consuming alcohol away from their homes. Motorists/riders who reported drink driving were 4 times more likely to have had previous traffic violation arrests compared to those who reported no drink driving/riding.
Teye-Kwadjo (2019)	Investigated the pathways through which traffic risk perception and traffic fatalism affect risky driving behaviour and effective road safety education and health promotion interventions among drivers in Ghana. Method: Quantitative using structural equation modelling on 519 licensed drivers.	Found that attitudes towards risky driving mediated the effects of fatalistic beliefs and risk perception on risky driving behaviour. Fatalistic beliefs were positively associated with attitudes towards risky driving. Risk perception was negatively associated with attitudes towards risky driving. Attitudes towards risky driving positively predicted risky driving behaviour. Risk perception and risk-taking differ among male and female drivers and among married and never-married drivers.
Jones et al. (2016)	Synthesized the professional opinion obtained from on health issues related to the provision of public transport in rural SSA, specifically Addis Ababa-Ethiopia, Accra-Ghana and Nairobi-Kenya. Method: Quantitative using in-person interviews and an internet survey.	Found that public transport vehicle condition and maintenance are major crash contributors. Increasing use of motorcycles for public transport is seen as a major safety concern. Rural transport passengers are considerably exposed to particulates through vehicle exhaust and road dust. Poor mechanical conditions of vehicles and risky driving behaviours are an important source of injury from rural road crashes. The factors contributing to unsafe rural public transport were attributable to economic barriers to proper operation. There is a lack of understanding of the health impacts of rural air pollution in relation to basic needs for the provision of safe mobility.

Paper	Study Focus & Method	Key Findings
Kouabenan (1998)	Examined the relationship between fatalistic beliefs, risk perception and traffic safety-related behaviors in Cameroon. Method: Quantitative using a sample of 525 road users with a questionnaire measuring fatalistic beliefs, perceived risk for dangerous traffic events, and reported safe behaviors.	Found that participants with higher levels of fatalistic beliefs perceived dangerous traffic situations as less risky and reported less safe behaviors. Perceived risk partially mediated the association between fatalistic beliefs and reported safe behaviors. Perceiving dangerous traffic situations as risky can mitigate the magnitude of one's fatalistic beliefs on the engagement in protective behaviors.
du Plessis et al. (2016)	Examined blood alcohol concentrations in different road-users based on epidemiological variables in Ga-Rankuwa, South Africa. Method: Quantitative descriptive study involving 672 road-users over 5 years.	Found that about half of the fatalities involved have positive blood alcohol concentrations (BAC). BAC was high with the majority above 0.05 g/100 ml, which is the current BAC law in South Africa. Female fatalities under the influence of ethanol demonstrated a high mean BAC. The majority of fatalities occurred at night, during weekends, and in the spring, with August being the month with the most fatalities. The most common injuries were external injuries and injuries to the head and chest. Cause of death, irrespective of blood alcohol concentrations, was multiple injuries.
Maldonado et al. (2002)	Investigated sleep, work schedules and crash risk factors for long-haul truck drivers in South Africa. Method: Quantitative using 102 male truck drivers aged 43±8 years (mean ± s.d.) with 16±8 years of professional driving experience.	Found that 24% of heavy-vehicle road crashes in South Africa are due to falling asleep at the wheel. Three-quarters of the drivers reported being tired at work because of working long hours (93 ± 30 hours/week), and half reported insufficient sleep (5.4 ± 2.3 hours/day) as a reason for their tiredness. About 80% of drivers reported interrupted sleep due to noise, while 62% of truck drivers admitted to nodding off at the wheel. Drivers with sleep-disordered breathing or other sleep complaints are more likely to have a sleep-related crash. Also, they are more likely to have a body mass index greater than 25 kg/m2, and a collar size larger than 40 cm.
Nordfjærn et al. (2014)	Examined country cluster differences, based on the Culture's Consequences framework, in road traffic risk perception, attitudes towards traffic safety and driver behaviour in Norway, Russia, India, Ghana, Tanzania, Uganda, Turkey and Iran. Method: Quantitative using 2418 individuals and cluster analysis.	Found that Norwegians reported safer attitudes and driver behaviour than the other clusters. Social cognition predicted driver behaviour in Norway and the Russia/India clusters. Road traffic culture was a direct predictor of driver behaviour. Individuals in Africa reported the highest risk perception. Cultural factors were stronger predictors of driver behaviour than of risk perception. Campaigns need to increase their cultural sensitivity in order to be efficient.

Paper	Study Focus & Method	Key Findings
Nordfjærn et al. (2011)	Investigated cross-cultural differences in road traffic risk perception, risk sensitivity, risk willingness, driver attitudes and driver behaviour in Norway, Russia, India, Ghana, Tanzania and Uganda. Method: Quantitative using questionnaire survey with random sample in Norway (n=247) and stratified samples in Russia (n=245), India (n=196), Ghana (n=299), Tanzania (n=559) and Uganda (n=415).	Found that Norwegians reported safer attitudes regarding drinking and driving and speeding in road traffic. Respondents in Africa reported higher road traffic risk perceptions and risk sensitivity than those from Norway, Russia and India. Respondents from Tanzania reported the highest willingness to take risks both in traffic and in general. Participants from Africa and India reported safer attitudes in regard to speaking out to an unsafe driver, rule violations and sanctions, attitudes towards pedestrians, and traffic rules and knowledge. Respondents from Africa reported more cautious behaviour and less speeding.
Matheka et al. (2015)	This study explored the characteristics of 2- and 3-wheeler-related road traffic injuries (RTIs) in Kenya. Method: Quantitative using cross-sectional survey of motorcycle drivers involved in a RTI in the preceding 3 months in 11 urban and rural sites in Kenya's Thika town through face-to-face structured interviews.	Found that for 200 drivers injured, 98% were male, with an average age of 28.4 years (SD±6.6). For these drivers, 33% were not wearing any protective equipment. Negligence was the most reported cause of the crash (33%), followed by slippery roads (21.0%) and speeding (17.5%). The risk of sustaining a bodily injury was 1.3 times higher in drivers who had not received prevention education compared to those who had received such education. People injured at night were 5 times more likely to sustain a bodily injury compared to those injured during the day. Only 8.5% of the drivers reported the injury incident to the police.
Verster and Fourie (2018)	Assessed the good, the bad and the ugly of the fatal crashes in South Africa. The cost of human lives indisputably equates to 'the ugly' and the economic cost of accidents associates with 'the bad'. 'The good' relates to the reduction of both these costs. Method: Quantitative using crash data for 2015	Found that fatal traffic crashes are driven by factors: human factors, road and environmental factors and the vehicles involved in the incident. Human factors contributed to about 80% of the fatal crashes, of which 52.5% of these incidents related to jaywalking and 11.6% to speeding. Road and environmental conditions contributed to 12.7% of the accidents, with sharp bends (22.0%) and poor visibility (16.5%) the main causes. The remaining 7.8% of the fatal crashes were caused by vehicle factors, with tyres bursting prior to the crashes in 71.7% of the cases.

Paper	Study Focus & Method	Key Findings
Chokotho et al. (2013)	Assessed whether the quality of the available road traffic injury (RTI) data was sufficient for determining the burden of RTIs and for implementing and monitoring road safety interventions in the Western Cape Province, South Africa. Method: Quantitative by comparing data reported by the South African Police Services (SAPS) in 2008 with data from 18 provincial mortuaries. Completeness of the driver death subset of all RTIs was assessed using the capture-recapture method.	Found extensive data quality problems, including missing data, duplication, and significant under-reporting of traffic injury deaths in the police data. The mortuary and police data sets comprised 1696 and 860 fatalities, respectively for 2008. The corresponding traffic mortality rates were as follows: 32.2 deaths/100,000 population per year and 16.3 deaths/100,000 population per year. The police data set contained 820,960 crashes, involving 196,889 persons, indicating duplication of crash events. The estimated total number of driver deaths/year was 588.6, yielding estimated completeness of the mortuary and police data sets of 57.6 and 46.4 percent separately and 77.3 percent combined.
Glèlè-Ahan-hanzo et al. (2021)	Analysed the environmental and road factors associated with the pedestrians involved in traffic crashes in Benin. Method: Quantitative using multiple logistic regression analysis of national road crash statistics for the period 2008 to 2015.	Found that there were 3760 crashes involving at least one pedestrian. The death rate among these pedestrians was 27.74%. The mortality predictors are the area in which the crash occurred, the day of the crash, light levels, road classification, the condition of the road surface and the position of the pedestrian during the crash.
Solagberu et al. (2015)	Investigated injury control and reduced morbidity and mortality in Lagos, Nigeria. Method: Quantitative using a one-year prospective study on pedestrians attending the surgical emergency room in one hospital.	Found that 702 pedestrians with 70% males. Common injuries sustained were to the head (40%), lower limbs (35%), upper limbs (9%), multiple regions (6%), pelvis (3%), and others (7%). By gender, the main injury location in males was the head, followed by lower limbs; the opposite was true for females, though both regional injuries were fewer in females than in males. Students constituted 20% of victims, with about 50% injured by a motorcycle. The mechanism of injury included crossing a highway (63%), walking along the pavement (17%), standing by a bus stop (12%), at a shop/house (5%), and others (3%). However, 76% injuries occurred on highways, 22% on inner city roads, and 2% elsewhere. Vehicles included motorcycles (33%), cars (27%), buses (22%), trucks (6%), tricycles (2.4%), and other (9%). Overall fatality was 10% and about half were due to being knocked down by buses and cars.

Paper	Study Focus & Method	Key Findings
Puvanachandra et al. (2012)	Defined the health impact of RTIs in Egypt and identified the strengths and weaknesses of each data source for the purpose of improving the current RTI data systems. Method: literature review.	Found a total of 20 studies, of which 6 were multi-country and 5 were hospital-based studies. None examined risk factors such as speeding, alcohol, or seat belt use. Secondary data sources are national hospital-based injury surveillance, a community-based health survey, pre-hospital injury surveillance; the Ministry of Transport, the General Authority for Roads, Bridges and Land Transport; death certificates, and the central agency for public motorization and statistics. Risk factor data are limited from these sources.
Clark et al. (2022)	Measured, modelled and predicted environmental noise across the Greater Accra Metropolitan Area (GAMA) in Ghana, and evaluated inequalities in exposures by socioeconomic factors. Method: Quantitative by measuring environmental noise at 146 locations with weekly (n = 136 locations) and year-long monitoring (n = 10 locations). Modelling was based on land use regression.	Found that the majority of the population exposed to noise levels above WHO guidelines. Poorest areas had the highest predicted noise levels on average, and higher by 5 dBA when compared to wealthier areas. Predicted day-evening-night noise levels were highest in the city-center (median: 64.0 dBA) and near major roads (median: 68.5 dBA). Models can support local environmental health assessments and policy making.
Clark et al. (2021)	Leveraged a large-scale measurement campaign to characterize the spatial and temporal patterns of measured sound levels and sound sources in Accra, Ghana. Method: Quantitative by measuring environmental noise at 146 locations with weekly (n = 136 locations) between 2019 and 2020.	Found that environmental noise levels exceeded both international and national health-based guidelines. Commercial, business, and industrial areas and areas near major roads had the highest median daily sound levels 69 dBA and 72 dBA and the lowest percentage of intermittent sound; the opposite was found in peri urban areas. Road-transport sounds dominated the overall sound environment but mixtures of other sound sources, including animals, human speech, and outdoor music, dominated in various locations and at different times.
(Ibili et al., 2023)	Investigated current practices of traffic noise regulations and policy, and agencies responsible for the control of noise pollution in Ghana. Method: Quantitative using interviews of stakeholders and a survey of 30 participants.	Found that the current policy does not include transport noise regulation. About 87% of the survey participants experience traffic noise pollution, while 76.7% reported various health effects due to exposure to traffic noise. Observed noise levels exceeded the dissatisfaction score of 5 (89 dB(A)), and Leq value (109.1 dB(A)) was greater than the environmental permissible limit of the EPA standard of 70 dB(A).

Paper	Study Focus & Method	Key Findings
Ajayi et al. (2023b)	Assessed the perception of the public about vehicle traffic emissions and the health hazard associated with them in Lagos, Nigeria. Method: Quantitative using structured questionnaires and analyzed using multivariate statistical analysis and structural equation modelling.	Found that the majority (78.9%) were aware of the haze air pollution from vehicles and its adverse effects on health. Found a significant relationship between age, education status, employment status, road proximity, vehicle ownership and air pollution awareness. Also, age, gender, marital status, education, employment status, and road proximity exhibit statistical significance and indicate a linear relationship to perception of vehicular emissions.
Ajayi et al. (2024b)	Assessed the impacts of vehicle emissions exposure on the risk of health burden for residents near major urban intersections in Lagos, Nigeria. Method: Quantitative using portable gas detectors, air pollutants emitted from vehicles, traffic flow, vehicle fleet composition and speeds along with 400 structured questionnaires.	Found that concentration of air pollutants is highest between 8 and 9am morning peak periods and 4–7 pm evening peak but lowest between 12–1 pm afternoon off-peak. About 74% of respondents around the road corridor suffered from chest pain, frequent cough, nose running, sneezing, eye irritation, sore throat, difficulty breathing, body weakness, fatigue, eye irritation, loss of appetite, headache, and fast breathing, of which 6% of children and 54% of women were the most susceptible. Key predictors are proximity to the road corridor, years spent at the corridor, daily work duration, perceived health symptoms and risk of health burden disease.
Obanya et al. (2018)	Investigated the levels of air pollutants around residential areas and transport sector locations (TSLs) in Lagos, Nigeria. Method: Quantitative using in situ data and calibrated hand-held devices at selected residential and TSLs.	Found that air quality parameters were considerably higher around bus stops, except for CO and humidity. PM10 and PM2.5 were much higher than the World Health Organization (WHO) guidelines. For air pollutants in residential areas: carbon monoxide (CO), particulate matter (PM10 and PM2.5), sulphur dioxide (SO_2), noise, temperature and humidity were within the ranges of 1.00 – 6.0 5.97 ppm, 43.345.2 – 127.2159.7 µg/m3, 20.3 23.25 – 69.058.16 µg/m3, 0.0 0 – 0.20.17 ppm, 47.7 50 - 65 70.1 dB, 26.2227.2 – 35.536.7°C and 57.0157.6 – 91.8492.3%, respectively. Values of the measured air pollutants at the TSLs are: 2.011.0 – 5.397.7 ppm, 103.3360.7 – 179.77404.0 µg/m3, 50.2832.3 – 91.01184.0 µg/m3, 0.00 – 0.40 ppm, 64.2153.1 – 71.1376.3 dB, 27.1826.2 –27.9332.6°C and 60.3660.0 – 75.0178.0%, respectively. Hydrogen sulphide (H_2S), ammonia (NH_3), nitrogen oxide (NO_2) were below detection limits in both sampling locations while volatile organic carbons (VOCs) ranged from 0.00 – 0.10 ppm in the TSLs.

Paper	Study Focus & Method	Key Findings
Dushie et al. (2017)	Assessed the implications of vehicle emissions on the health of traders in Madina, Ghana where road traffic is very congested, and traders are directly exposed to vehicle emissions. Method: Quantitative using 300 traders, made up of 150 traders within a distance of 50 meters and 150 traders within a distance beyond 50 meters of the main road, were purposively selected. The data obtained was analyzed using descriptive and inferential statistics.	Found that a large proportion of the respondents had good knowledge about the health consequences of their exposure to emissions, yet they were reluctant to relocate due to their inability to afford a different location and scarcity of urban space. Frequent coughing, nausea, poor visibility and difficulty in breathing were among the major self-reported health outcomes. Key predictors of respiratory diseases among respondents are distance to the source of vehicle emission, years spent in the occupation and average daily work hours per week.
Adepoju et al. (2018)	Estimated the emissions of gaseous criteria air pollutants (CAPs) from the road transport system, and their ground-level concentrations from 2004 to 2007 in Lagos, Nigeria. Method: Quantitative where vehicle emission rates is performed using emission factor approach, while ground-level concentrations of the CAPs were determined using the Industrial Source Complex Short Term 3 view model.	Found that the maximum ground-level concentrations were highest along the roadside, and the average CAPs concentrations and cumulative exposure concentrations that were estimated throughout the study period are a major health concern, as these concentrations are several times higher than international limits. The mean concentrations of carbon monoxide in the ambient air were 26,741.12, 31,675.95, 54,515.48, and 72,388.09 micrograms per cubic meter (μg/m3) for years 2004, 2005, 2006, and 2007, respectively, while the estimated concentrations for oxides of nitrogen were 1,377.91 μg/m3 for 2004, and 1,620.76, 2,897.33, and 3,839.68 μg/m3, respectively, for 2005, 2006, and 2007. The estimated concentrations of sulfur dioxide during the study period were 51,354.16, 57,244.76, 113,083.26, and 136,332.01 μg/m3 for 2004, 2005, 2006, and 2007, respectively. For volatile organic compounds, the estimated concentrations were 3,839.68, 6,839.65, 7,067.62, and 8,431.35 μg/m3 for years 2004, 2005, 2006, and 2007, respectively.

Paper	Study Focus & Method	Key Findings
Nyarku et al. (2019)	Assessed schoolchildren's exposure to Ultrafine particles (UFPs) and apportioned their daily exposure to seven different microenvironments that they inhabited on a typical school day in Accra, Ghana. Method: Quantitative using measuring UFPs exposure of 61 pupils attending three junior high schools using wearable monitors over a period of 10 weeks. Two of the schools were located in suburbs of Accra and the third in Berekuso, a nearby rural community.	Found that information on personal UFP exposure in Ghana is lacking. Exposure to UFPs in Accra was among the highest in the world. Emissions from cooking, combustion of biomass and trash, and vehicular traffic were the main sources of UFPs. Pupils attending the schools in urban Accra received higher exposure than those attending the school in the rural environment of Berekuso.
Agarana et al. (2017)	Examined ways to minimizing the carbon emissions (carbon dioxide emission) from transportation which is a channel of greenhouse pollution in Lagos, Nigeria. Method: Quantitative using linear programming model	Found that to minimize vehicular carbon emission, there is the need for high-quality fuel, good roads, multimodal transport, and adequate investment.
(Olaniyan et al., 2023)	Investigated the crime and the victimization experiences of commuters in Ibadan city, Nigeria. Method: Qualitative using routine activity theory using data from victims of the crime, police personnel and motor-park officials through in-depth interviews and focus group discussion methods.	Found that one-chance transit crime is commonly perpetrated by criminals making use of taxis for commercial transport. Money and mobile phones of commuters were the major targets of this category of criminals. One-chance transit criminals lure their victims through different strategies.
(Tade and Faisol Olaitan, 2024)	Examined "one-chance" strategies and the victimization experiences of passengers in public transport corridors in Lagos, Nigeria. Method: Method: Qualitative using routine activity theory and an exploratory research design based on interviews for participants selected by snowball sampling.	Found that timing, disguise/deception, taking unusual routes, tampering with the vehicle central lock, reworking the seatbelt, and winding up glasses are methods adopted by the one-chance robbery perpetrators to victimize. Physical assaults such as sexual assaults, forced dislodgement from vehicle, and loss of valuables. Participants increased vigilance before boarding, hailing a private taxi and instrumentalised religion for protection as coping strategies. The study lead to the mapping of "one-chance" hot-spots by law enforcement authorities and routine adjustment for commuters.

Paper	Study Focus & Method	Key Findings
(Kruger and Landman, 2007)	Examined issues related to transport and security with a focus on the physical environment for increasing or reducing prospects for crime. It focuses on crimes on public transport and the use of planning and design interventions to reduce crime in South Africa. Method: Quantitative using engineering and planning designs.	Found that majority of poorer people stay relatively far away from their places of employment requires a considerable amount of time travelling. Commuters are very vulnerable to crime during these journeys. They are exposed to being victimised on busses, trains or minibus taxis, while changing from one mode of transport to another at stations, or when walking from drop-off points to their places of work or to their homes.

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