

When Rainfall Dictates the Ride: Exploring the Impact of Rainfall on Mobility in Accra

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Abstract

The rapid urbanisation in Sub-Saharan Africa poses significant challenges to peri-urban transport systems, especially amidst escalating climatic events. This study examines the impact of recurrent heavy rainfall events and associated flooding on transport infrastructure and commuters' choice of transportation modes in peri-urban areas of Accra, Ghana. Using data from a comprehensive mobility survey and qualitative interviews, the study examines the state of road infrastructure and its effects on daily mobility. The findings reveal that poor road conditions, exacerbated by heavy rainfall, limit the availability and reliability of transport options, compelling residents to rely on motorcycles and other less conventional modes for part of the entire trip. This paper highlights the interaction between inadequate transport infrastructure and rainfall-induced disruptions, demonstrating how these factors collectively shape transportation choices in peri-urban areas. Our findings underscore the urgent need for sustainable urban planning and flood-resilient transport systems to improve mobility and environmental resilience in rapidly urbanising regions. The study contributes to existing research by providing empirical evidence on the mobility challenges faced by commuters in flood-prone regions of Sub-Saharan Africa.

Keywords: urbanisation, transport modes, flood-vulnerable transport systems, mobility challenges

Introduction

Urbanisation is the continuous growth in the number of people residing in urban centres or cities (Bodo, 2019). Population growth in the Global South, especially in Africa, has been described as explosive, increasing from 177 million in 1950 to about 1.41 billion in 2022, representing an increase of nearly 8 times the 1950 population (Population of Africa, 2022). Consequently, Africa currently accounts for approximately 17 percent of the global population (Population of Africa, 2022). The population of Africa, especially sub-Saharan Africa (SSA), is expected to increase rapidly. With an average annual growth rate of about 2.6 per cent, SSA's population is projected to reach 2.1 billion in 2050 and 3.44 billion by 2100 (UN DESA, 2022).

The rapid urban expansion in SSA is

characterised by unplanned and unregulated growth, which is worsened by weak urban planning institutions resulting from structural adjustment, neoliberalism, and colonialism (Fuseini et al., 2017; Güneralp et al., 2017). The growth of cities has led to the emergence of slums in some areas (Takyi et al., 2021) and, at the same time, an uncontrolled physical expansion into the peripheries of cities (Cobbinah and Aboagye, 2017; Yiran et al., 2020). This pattern of development presents significant infrastructural and planning challenges.

One of the challenges that city managers face is the demand for urban infrastructure. In the broader context of recent financial trends, urban infrastructure is moving from being seen as a public and shared resource to becoming an alternative investment category in the global financial market (Inderst, 2010, cited

in O'Brien et al., 2019). Urban infrastructure is increasingly viewed as an investment asset, offering diversified returns and varying risk profiles compared to conventional investment options (O'Neill, 2019). As a result, demand for infrastructure has increased significantly, resulting in substantial deficits across multiple sectors in many SSA cities (Edobor Arimoro, 2022). To bridge the infrastructure gap, governments in many African countries liberalised infrastructure provision and allowed the private sector, including individuals, to undertake development, especially in the housing sector (Fuseini et al., 2017).

The involvement of private entities and individuals in the housing sector has contributed significantly to the growth of many African cities. However, many of these cities lack proper land use plans, resulting in what is commonly referred to as leapfrog development or urban sprawl (Owusu, 2013; Viana et al., 2019). Housing development in these peri-urban areas occurs incrementally, predominantly by middle- to high-income households, and is largely contingent on the availability of disposable income (Andreasen et al., 2022). This mode of development generates additional demands for infrastructure provision to ensure that such areas can function effectively as an integral part of the city.

Although many important infrastructures support the livelihoods of people in urban and peri-urban areas, this study will specifically focus on transport infrastructure. This is because transportation infrastructure plays a crucial role in peri-urban areas by aiding mobility and making it easier for people to access job opportunities, as well as social amenities like hospitals and schools, and markets for goods and services (Khanani et al., 2021). Furthermore, the ability to commute efficiently to work is associated with improved job satisfaction (De Vos, 2024). Transport services in many African cities, including Accra, Ghana, depend on road infrastructure and the level of demand. In peri-urban areas, where roads are often poorly constructed, it

can be difficult to travel on foot, by bicycle, motorbike, car, paratransit, taxi, or by bus. This limited access to transport means that people in these areas may have to combine different modes of transportation to complete their daily activities.

However, much transport infrastructure, particularly road networks, is susceptible to climatic hazards, as frequent and intense rainfall events often surpass drainage capacities and trigger flooding (Mitoulis et al., 2023; Gupta and Dixit, 2024). Heavy rainfall is common in many cities (Ansah et al., 2020; Owusu and Obour, 2020), leading to an increase in runoff and subsequent erosion and flooding. As rainfall frequency and intensity continue to increase due to climate change (Maity and Maity, 2022), the mobility challenges faced by residents of peri-urban areas and informal settlements are likely to persist or intensify (Finn and Cobbinah, 2023). These challenges affect the mode of transport residents use to travel to and from their daily activities.

In the Global South, much of the research focus has been on transport systems and networks, safety, as well as the impacts of climate change on these structures (Jack et al., 2021; Møller-Jensen et al., 2022). Other studies have also examined the impacts of peri-urban transport on climate, especially its contribution to greenhouse gas emissions (Sporkmann et al., 2023; Huang et al., 2024). However, there remains a gap in understanding how intense and recurrent rainfall events interact with structurally inadequate transport infrastructure to shape commuters' choices of transportation. This paper advances existing scholarship by providing empirical insight into the role of heavy rainfall events, particularly through their intersection with deficient transport infrastructure in shaping transportation choices in peri-urban areas. Using Peri-urban Accra as a case study, this research fills a gap in understanding the connection between transport infrastructure and the transport modes used by commuters in their daily activities, particularly in the context of frequent and intense rainfall resulting in

flooding. This study addresses three main questions: (i) what the nature of the road infrastructure within the study communities is; (ii) how rainfall events affect road conditions; and (iii) how the combined effects of road conditions and rainfall influence residents' choice of transport modes.

Answering the above questions is particularly critical as transportation is one of the key factors influencing the sustainable development of cities (Du *et al.*, 2024). The Sustainable Development Goal 11, which focuses on making cities and human settlements inclusive, safe, resilient, and sustainable, has many targets that focus on transport and disasters. In particular, Target 2 (affordable and sustainable transport systems) and Target 5 (reduce the adverse effects of natural disasters) are of interest to this paper as climate-related events have the potential of derailing the achievements of these targets (Nyirenda, 2023). Ensuring progress towards achieving these calls for building climate-resilient transport infrastructure.

Materials and methods

Description of the study areas

This study is part of different modes titled 'Climate Change Resilience in Urban Mobility (CLIMACCESS)', conducted in the Greater

Accra Metropolitan Area (GAMA). Ten (10) neighbourhoods located in different parts of GAMA were selected (Figure 1). These neighbourhoods were identified to be among flood hotspots within GAMA (Balstrom, 2020).

The characteristics that were used as a basis for the selection of the neighbourhoods have been described fully by Moller-Jensen *et al.* (2020); notable among them is the kind of urbanisation GAMA is experiencing. As shown in Figure 1, the neighbourhoods exhibit different levels of urbanisation (consolidation). The degree of consolidation is critical, mainly regarding road infrastructure, as more urbanised areas in Ghana tend to have improved road infrastructure. In the peripheral neighbourhoods within GAMA, residential developments occur in areas with very poor road infrastructure and limited connectivity (Møller-Jensen *et al.*, 2012).

Methodology

The data used in this paper were derived from a comprehensive study on the resilience of urban transportation to climate change. The data were derived from 1053 survey respondents on mobility in the selected neighbourhoods from July to August 2021. In addition, qualitative interviews were conducted with local key

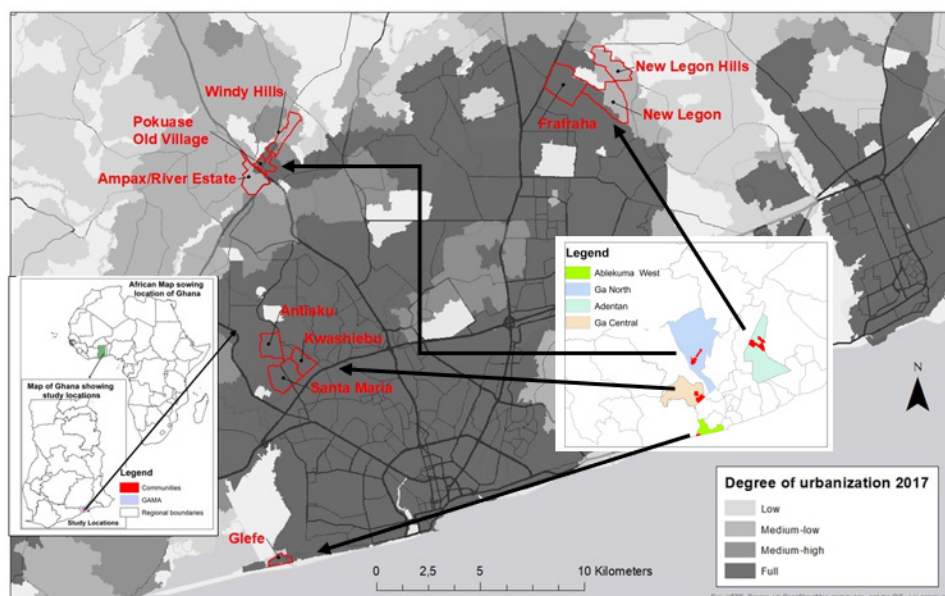


Figure 1 Map of the study neighbourhoods
Source: Modified from Yiran *et al.* (2024)

informants (n=75), such as representatives from the Metropolitan, Municipal, and District Assemblies (MMDAs), the National Disaster Management Organisation (NADMO), traditional authorities, and residents' associations. During the data collection process, both quantitative and qualitative data were collected, and extensive field observations were made, particularly on the condition of the roads, to assess the condition and characteristics of road infrastructure in the neighbourhoods.

Survey design

The survey involved 1053 economically active residents in 10 neighbourhoods in Accra's periphery. These 10 neighbourhoods were drawn from four MMDAs: Adentan, Ga North, Ga Central, and Ablekuma West Municipalities (Figure 1). The survey was administered through face-to-face interviews. Enumerators were trained on the questionnaire and the use of the SurveyExact online platform before commencing the data collection. The research team consisted of researchers from the University of Copenhagen, the University of Ghana, and the Council for Scientific and Industrial Research. The survey focused on adult household members over 18 who were economically active and engaged in regular travel (at least once a week) for income-generating activities. The survey questionnaire was deployed and managed on the SurveyExact online platform, with responses being directly recorded in the digital questionnaire on tablets. Additionally, the enumerators captured visual documentation to support and validate their observations during the interviews.

The selection and delineation of survey neighbourhoods were informed by the preliminary round of qualitative fieldwork in 2019, and the aim was to ensure maximum variation between neighbourhoods and a degree of homogeneity within neighbourhoods. The neighbourhoods selected for the study possess varying characteristics, such as different degrees of consolidation, levels of accessibility, and other geophysical and

socioeconomic characteristics of the resident populations. The distinction of neighbourhoods is based on administrative boundaries, i.e., the enumeration areas used by the Ghana Statistical Service (GSS) for censuses, which have subsequently been adjusted manually to accommodate natural and man-made barriers like rivers/streams and roads, and ensure homogeneity within areas based on the timing and characteristics of housing developments. Among other data collected through the questionnaire were data on daily mobility patterns concerning income-generating activities and other purposes, their assessments of local transport infrastructure and services in their neighbourhoods, and their self-reported experiences with different modes of transport. The survey also collected information on the time taken for respondents to walk from their homes to the nearest bus stops/stations. This paper also analysed part of the survey data containing the primary respondents' experiences with the modes of transport, especially during floods and heavy rainfall. It will also examine how the current transport infrastructure affects the transport mix available for daily movements.

Sampling procedure

Before the questionnaire data collection, in-depth interviews were conducted with over 50 participants across the 10 neighbourhoods. The respondents were drawn across the socioeconomic groups and officials of government institutions. A spatially informed simple random sampling approach was employed for the survey. In each neighbourhood, 300 GPS points were randomly generated and numbered in ArcGIS. These 300 points were divided into 3 sets of 100 points. The first set of 100 points was overlaid on Google maps with grids on tablets and used for the survey. Each enumerator was assigned to a grid and tasked to interview all points within the grid. Enumerators navigated to each GPS point using the tablet, selected the closest building to the point, and invited residents to participate in the survey. If multiple buildings

were equally close, one was randomly chosen. If a building housed multiple households, each was interviewed separately, which may have resulted in the overrepresentation of tenant households. However, they were informed not to interview more than two households in a house. If no occupants were found on the first visit, the enumerator revisited the building, and if no occupants were found again, the point was closed. After the first round of 100 GPS points, the required number of households was not achieved, so additional secondary points were overlaid. The process continued until at least 100 respondents were reached per neighbourhood. Data collection occurred on both weekdays and weekends to maximize the response rate. Only one person per household, chosen by the household members, participated.

Data analysis

The research team visited 1478 GPS points across different communities to gather responses. From these visits, they received 1053 valid responses, which accounted for approximately 71% of the GPS points. The data collected were processed using the Statistical Package for Social Sciences (SPSS), and all points without valid responses were omitted from the analysis. The data were further analysed using frequency distribution and cross-tabulations, which were then exported

into Excel for graphing and integration with the coordinates of the valid GPS points in ArcGIS. The qualitative data and photographs were analysed using vignettes to support the quantitative data.

Results and discussion

Roads infrastructure

Connectivity to road infrastructure is a critical determinant for how people can access various means of transportation. To unpack this, the research team identified the types of roads leading to the surveyed respondents' homes and classified them into large or small roads, or footpaths, and identified homes that do not have direct road access. As shown in Figure 2a, a large road typically accommodates at least a single carriageway, drainage system, and pedestrian walkways on both sides. On the other hand, small roads (Figure 2b) can only accommodate a single carriageway and gutters. The space provided for the road in Figure 2a is large enough to construct a dual carriageway and make provision for other road users.

On some of the large roads, pedestrians and motorcyclists are able to navigate them even if vehicles are not, because the inundation or erosion may not cover the entire width, and these are lighter modes of transport and may not



Figure 2 Size of roads in some parts of Adentan
Source: Authors

get stuck. However, the road shown in Figure 2b can only accommodate two vehicles (i.e., a single carriageway) after the construction of the drainage system (gutters), forcing all road users, including pedestrians, to use the same space. This situation affects walking and cycling on such roads, which lends credence to some studies that have reported an increase in health problems due to less physical human activities in peri-urban areas (Malik et al., 2019; Quan et al., 2022). Based on these classifications, the survey results indicate that small roads dominate the study communities, with 56 percent (589) of respondents' homes having small roads leading to them (Table 1). This is typical of unplanned settlements as landowners aim to maximise the number of plots while reducing the size of roads.

Additionally, individual developers, especially those who start developing first, locate their properties haphazardly or intentionally place fence walls on roadways, reducing the space available for road construction. This was confirmed by a respondent in an in-depth interview in Adentan who pointed to the road in Figure 2a and stated, *“This road you see here, part of it has been taken by the house, and it is left like that because the person is a ‘big man’”*. In peri-urban neighbourhoods in Accra, where planning schemes are almost absent, such developments are widespread, resulting in some roads being very narrow (see Figure 2b) or completely blocked in some

sections. From Table 1, only neighbourhoods in the Ga Central Municipality have many large roads. Between 39 and 43 (i.e., 36% to 43%) of respondents' homes in the neighbourhoods of the Ga Central municipality are by large roads, while the other municipalities have 30 residents or fewer (i.e., 18% to 30%). The neighbourhoods with the best connection were those in Ga Central. Our observations showed that, although the roads were largely narrow, their widths varied significantly across the neighbourhoods, with Glefe having more footpaths.

Glefe in the Ablekuma West Municipality has more than 77 percent (87) of respondents' homes with footpaths leading to them, while about 18 percent (20) of respondents (home locations) have dirt roads leading to them. Glefe is the least among the communities with poorer infrastructure, as it has only one tarred road and one dirt road. The Ga Central neighbourhoods have better or more potential road infrastructure than the others. The nature of road infrastructure, as presented here, points to the level of development in the neighbourhoods, with the Ga Central neighbourhoods being more developed and consolidated than the others. This observation reflects the findings in the community profiling report (Møller-Jensen et al., 2020), where Glefe is described as a low-income community and the rest as low to high-income communities. Besides the small

TABLE 1
Type of road leading to the house

Municipality	Neighbourhood/ Community	Large road (%)	Small road (%)	Footpath (%)	No direct access (%)	Total (%)
Ga Central	Santa Maria	3.9	6.1	0.4	0	10.4
	Kwashiebu	3.7	5.2	0.8	0	9.7
	Antiaku	4.1	4.7	0.6	0.1	9.5
Ablekuma West	Glefe	0.5	1.9	8.2	0	10.6
Adentan	Frafraha	2.0	7.5	0.7	0.2	10.4
	New Legon	2.8	6.3	0.3	0.2	9.6
	New Legon Hills	2.7	6.7	0.8	0	10.2
Ga North	Ampax/River Estate	2.2	6.3	0.8	0.3	9.6
	Pokuase Old Village	1.9	5.1	2.5	0.4	9.9
	Windy Hills	2.5	6.2	1.1	0.3	10.1
Total		26.3	56.0	16.2	1.5	100

roads, the surfaces of the roads are untarred (Table 2). This is typical of neighbourhoods within locations described as sprawled areas (Yiran, 2020), which are built up ahead of the provision of service infrastructure such as roads (Cobinnah *et al.*, 2018).

On average, about 93 percent of the homes in the area have dirt roads leading to them, which are not tarred (*i.e.*, unpaved) and are covered with gravel or laterite. Despite this, all neighbourhoods have at least one tarred road that passes through them, but the tarring in some cases does not cover the entire length. Using the length of the roads, we found that more than 99% of the roads in all the neighbourhoods are unpaved. The lack of paved roads poses a significant obstacle to movement, particularly during

periods of intense rainfall when erosion and the formation of potholes become prevalent. Additionally, the majority of the roads in the neighbourhoods lack drainage systems, causing rainwater to flow directly over the road surfaces, which results in erosion. This has left many roads in deteriorated condition, making them difficult to use. During rainfall, certain dirt roads become inundated with flowing water, which transports soil and forms deep ditches, rendering them untraversable (Figure 3b). Notably, the condition of the roads, being narrow, unpaved, and lacking proper drainage, reflects inadequate or absent urban planning in these neighbourhoods.

Stagnant water may also occupy some sections of the roads for days, making that portion impassable (Figure 3c). This makes it difficult

TABLE 2
Surface of roads leading to the house

Municipality	Neighbourhood/ Community	Tarred road	Dirt road	Used to be tarred, but the coverage of asphalt is no longer sufficient	Total (%)
Ga Central	Santa Maria	0.8	9.6	0	10.4
	Kwashiebu	0.8	8.8	0	9.6
	Antiaku	0.7	8.8	0	9.5
Ablekuma West	Glefe	1.1	9.1	0.4	10.6
Adentan	Frafraha	0	10.4	0	10.4
	New Legon	0.9	8.6	0	9.5
	New Legon Hills	0	10.1	0	10.1
Ga North	Ampax/River Estate	0.4	9.2	0	9.6
	Pokuase Old Village	1.7	8.4	0	10.1
	Windy Hills	0.1	10	0.1	10.2
Total		6.5	93	0.5	100



Figure 3 Nature of roads in Peri-urban Areas in New Legon Hills and Windy Hills
Credit: Prince Martin Gyekye and Stephen Yao Fiatornu, PhD students

for commercial vehicles like trotro (paratransit - Figure 3a), taxis, metered vehicles (Uber/Bolt), and motorbikes (okada) to use this road until the water evaporates or drains off. According to a Resident Association leader at New Legon Hills, *“the absence of gutters on the newly constructed roads causes water to run over and remain there for days whenever it rains”*. The statement highlights the effects of rainfall on transportation facilities in newly developed areas. Roads become muddy and impassable for vehicles, which forces commuters to take alternative, longer routes to reach their destinations. In some cases, the alternative route may involve more than one mode of transport and require walking at some point. When the alternative route is not feasible, commuters have to wade through the water. Additionally, some roads are completely cut off due to erosion, as depicted in Figure 4. Other studies have described similar findings regarding severe damage caused to road pavements by rain (Zumrawi, 2014; Ngezahayo et al., 2019). Critical to the low quality of roads is the acute lack of drainage, as illustrated in Figures 3 and 4. Gullies have been formed on some roads due to erosion, and residents have had to construct makeshift bridges (see Figure 4b) to enable them to cross. No vehicle, except bicycles and motorbikes, can use these bridges. This means that heavy rains and consequent flooding have severe

implications for the usability/motorability of a road. Depending on the frequency and intensity of rains, roads like those presented above, which are common in the study areas, will be ‘no-go’ areas for commercial vehicles and private cars. Residents who use these roads to and from their homes must look for alternative routes. Even though more than 75% of respondents in the survey agreed that there are alternative routes to and from their homes, some of those routes are similarly impassable when it rains.

It is important to note that not all roads used by commercial vehicles are the best routes available. The route choice for trotro drivers depends on the availability of passengers along the way. Figure 5 displays the most used routes in the neighbourhoods. Due to development patterns in peri-urban areas, roads passing through more populated areas receive more service from commercial vehicles. As a result, residential development along these popular routes is faster, causing trotro operators to provide services along those routes. These roads are frequently maintained by resurfacing with gravel, providing drains, and other upkeep activities because of increased activity. Except for Glefe, all neighbourhoods have reasonable provisions for residential roads.

Moreover, only 20 percent of respondents agreed that roads are adequately maintained. During the field survey, some routes were



Figure 4 Roads with makeshift bridges at New Legon and New Legon Hills

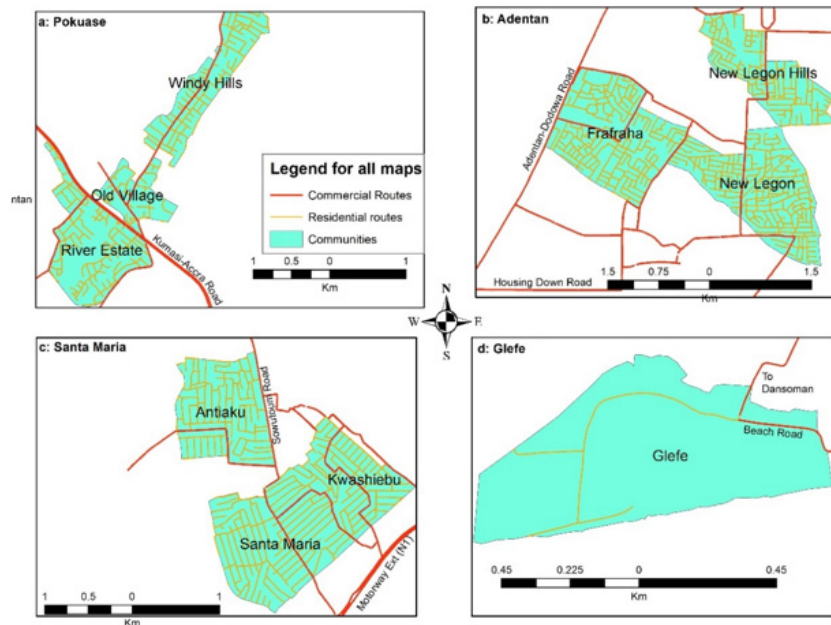


Figure 5 Road network in the study neighbourhoods
Source: Composed by Authors with Open Street Map data

observed being upgraded with re-gravelling and construction of gutters and bridges/culverts (e.g., Figure 3a). This rehabilitation was more visible in the Ga Central Neighbourhoods, followed by Adentan and then Ga North. However, the pace of rehabilitation is slow, causing most of them to revert to their former states after the rains. In the case of Glefe in the Ablekuma West, the whole neighbourhood is densely occupied by structures separated by very narrow footpaths, which permit passage by only pedestrians and, in some cases, motorbikes. Thus, evidence from our study suggests that road infrastructure in these neighbourhoods is presently distressed, with minor variations in intensity. Intense rainfall-induced flooding exacerbates erosion and water stagnation on poorly conditioned roads (see Figures 3 and 4), thereby strongly influencing transport mode choice. Based on the rising occurrence of these events linked to climate change, Finn and Cobbinah (2023) conclude that climate change exacerbates vulnerabilities in peri-urban neighbourhoods, thereby posing substantial risks to urban life.

Transport mode choice

The generally poor condition of road infrastructure has substantial consequences

for transport accessibility and modal choice, with pronounced effects on commercial transportation. Our findings indicate that many roads are not motorable for trotros and some private cars, especially in the rainy season. This has made the trotro drivers choose a few seemingly good roads to ply, as shown in Figure 5. From Figure 5, the Santa Maria neighbourhood has more routes used by commercial vehicles (trotro/taxis) than the others, with Glefe, as usual, having the least. The implication is that if trotro is the primary means of transport, residents must rely on alternative means to access transport services if they live far off the indicated routes.

From the perspective of drivers of commercial vehicles, the reasons why they do not use most of the roads revolve around the cost of car maintenance and the availability of passengers. In an interview with a commercial vehicle driver who operates from Madina to New Legon, he emphasised the high cost of operations, as they spend large amounts on buying spare parts and often agitate to increase fares to remain in business. During the conversation with this trotro driver, he stated that “*because some roads have a lot of potholes (some intense and large) in them, which makes us (trotro drivers) constantly*

¹Road quality included the surface (tarred, gravelled, laterite), presence of gutters, bridges, whether it is eroded, contained stagnant water and potholes.

²motorability is when a road is passable by motor vehicles, especially during rains.

change spare parts, and that increases our cost of operations. Even though sometimes the roads are re-gravelled, they quickly deteriorate as soon as it rains. So, when the rain comes, and the road becomes so bad, we stop using some roads because our vehicles can get damaged, and we might be unable to repair them as the spare parts are expensive”. Studies have found that the bad nature of roads results in a recurrent breakdown of vehicles, leading to increased maintenance costs (Naazie et al., 2018; Nwafor and Onya, 2019), confirming the sentiments expressed by this driver. Even though the driver’s statement focused on the cost of operations emanating from bad roads, it has excellent information on the impact of heavy rainfall, a climatic event, on the roads. According to this statement, the primary cause of deterioration of the roads is heavy rainfall and consequent flooding. Maintaining these roads is costly, with rain rapidly wearing them down and forcing frequent repairs. This is particularly problematic in Greater Accra, as the region experiences two rainy seasons each year. The perception of the motorability of a road, as found from the survey, however, depends on the type of vehicle. Car-owning residents use their access roads regardless of condition, turning to alternative routes only when they become completely impassable. For

these categories of road users, their comfort is paramount. However, even though the frequent breakdowns and changes of parts of the vehicles are critical, commercial vehicle operators still use some routes if passengers are available along them. The nature of the roads and the decision of commercial drivers as to which routes to use also shape the choice or availability of transport for the non-vehicle-owner residents, who constitute about 66 percent of the residents across the neighbourhoods. From the survey, the modes of transport that were available include bicycle, trotro, motorcycle (okada), shared taxi, dropping/pick up (i.e., taxi, Uber, Bolt, Yango), Metro mass transit (large buses), and others as presented in Table 3.

As can be seen from Table 3, more than 64 percent of respondents across all neighbourhoods use trotro services. A report from Columbia University states that 70 percent of Accra’s residents generally use trotro to commute to work or shopping (Okoye, 2020). This aligns with the claim that a significant percentage of respondents across all neighbourhoods use trotro services. Glefe and Santa Maria, which are dense settlements, have the highest percentage of respondents (i.e., 7.9 and 7.4, respectively) patronising trotro, while the lowest percentage of respondents, 5.4 and 5.6, were in New Legon

TABLE 3
Mode(s) of transportation used for primary livelihood activities

Neighbourhood	Mode (%)								
	Bicycle	Okada	Trotro	Shared taxi	Metro mass	Dropping	Private car	Other	Total
Santa Maria	0	0.4	7.4	0.6	0	1.2	1.3	0.2	11.1
Kwashiebu	0.1	0.2	5.6	0.9	0.1	0.8	1.6	0.3	9.6
Antiaku	0	0	6.3	0.6	0.1	1.6	1.3	0.3	10.2
Glefe	0	0.3	7.9	0.6	0.1	1.2	0.1	0.5	10.7
Frafraha	0.2	0.7	5.8	0.9	0	0.3	1.7	0.3	9.9
New Legon	0.2	0.5	5.4	0.4	0.1	1.5	1.5	0.2	9.8
New Legon Hills	0.2	0.8	6.6	0.6	0	0.4	1.4	0.2	10.2
Ampax/River Estate	0	0.2	6.3	0.5	0	1.1	0.5	0.4	9.0
Pokuase Old Village	0	0.4	6.7	0.6	0.1	0.7	0.4	0.4	9.3
Windy Hills	0	0.8	6.4	0.5	0.1	0.2	1.3	0.9	10.2
Total	0.7	4.3	64.4	6.2	0.6	9.0	11.1	3.7	100

³ This represent Taxis that are chartered or ride-hailing services

⁴ No qualitative or descriptive information was given but our observation indicated it is for those who walk the entire journey or take more than 2 modes

and Kwashiebu, respectively. The next most highly patronised means of transport were private cars and drop-off (ride-hailing services), with 11.1 percent and 9 percent, respectively. Even though these differences are small, they reinforce the arguments of geographic variations in transport choices (Elldér *et al.*, 2022). The percentages shown in Table 3 vary according to residents' socio-economic class, with neighbourhoods characterised by a higher proportion of middle-to high-income earners exhibiting greater vehicle ownership or a greater tendency to patronise 'dropping' services. A study by Esson *et al.* (2016) also links the choice of transport to the wealth of residents. This highlights the relationship between income levels and vehicle ownership. While the percentages may be small, the trend remains consistent across different income groups.

The survey also found that over 82 percent of respondents agreed that trotro services are available from 6 am to 8 pm, while a little over 86 percent agreed to their availability between 4 am and 6 am (Table 4). The reduction in agreement during the daytime (after 6 am) was attributed to traffic buildup, which reduces the frequency of trotro passing through the areas. This means one can easily find trotro services from 4 am to 6 pm, indicating that movement in and out of the neighbourhoods is good.

The highly populated neighbourhoods of Glefe,

Santa Maria, and Old Pokuase again recorded a higher number of respondents - 106, 97, and 100, respectively. These individuals concurred that locating a trotro during the early morning hours (4 am to 6 am) was straightforward. Even during the late hours of the day, these neighbourhoods continue to show the highest consensus. This underscores the relationship between the availability of trotro services and the presence of passengers commuting to and from these neighbourhoods. The study also found that many trotro services close around 8 pm and give way to taxis and other ride-hailing cars to operate. This agrees with Boateng and Adam's (undated) finding that trotros close around 9.30 pm. However, the high agreement to availability in the late hours (20 – 24) shows that the number of people closing beyond 6 pm is more than expected. This is particularly the case in Accra, where most of the people are informal workers (Yiran *et al.*, 2015) and only close when it is dark. This, therefore, puts pressure on the transport system. This situation becomes worse when there is a heavy downpour between 2 pm and 8 pm, as some roads are blocked due to flooding. Another implication of these trotros operating at night is that the passengers are concerned about their safety. According to respondents, recent reports in the media regarding kidnapping, ritual murder, and burglary linked to the use of taxis at night have heightened the security

TABLE 4
Availability of Trotro services during certain periods of the day

Time of day	04 -06			06 - 20			20 - 24		
	agree	neutral	disagree	agree	neutral	disagree	agree	neutral	disagree
Santa Maria	97	6	5	97	8	4	72	6	28
Kwashiebu	78	4	18	78	4	19	48	6	40
Antiaku	86	5	4	85	5	8	55	7	28
Glefe	106	2	4	105	2	5	79	5	25
Frafraha	78	2	27	78	3	28	39	16	52
New Legon	91	7	2	71	9	20	26	14	58
New Legon Hills	89	5	11	84	12	10	24	13	68
Ampax/River Estate	90	4	7	91	5	5	73	4	20
Pokuase Old Village	100	2	3	93	5	8	75	2	20
Windy Hills	89	4	14	79	8	19	54	6	46
Total	904	41	95	861	61	126	545	79	385

threats in using such vehicles at night.

Another observation from Table 3 is that middle- to high-income neighbourhoods generally have the highest percentages of residents who use private transport modes (private cars and dropping/pick up). A study conducted in the Philippines found that high-income neighbourhoods have higher levels of both capabilities (able to access) and functioning (actual travel), suggesting that income plays a significant role in shaping capabilities and functioning at an individual level (Hickman et al., 2017), which could explain the higher percentages of residents who use private transport modes in middle- to high-income neighbourhoods.

From Table 3, it can be seen that okada is becoming common in these peri-urban communities, as almost every community surveyed has people patronising their services. As can be seen from the table, more people in Frafraha, New Legon, New Legon Hills in Adentan, and Windy Hills in Pokuase patronise okada as compared to the other neighbourhoods. Our observation revealed that these neighbourhoods with higher percentages in Table 3 that use the okada services have more distant homes from the trotro stops. In many places in Ghana, trotros have set routes and usually stop at designated stops along the routes they ply (Dumedah and Eshun, 2020). So, people who live in places far from these stops use the okada to get to their homes. In an interview with an okada rider at the last stop in New Legon, he stated that “beyond this stop, the trotros do not go, so many of the passengers who do not carry large luggage hire us to take them to their houses since they cannot walk the distance with their loads. Our services are even more needed when it rains, as most of the people cannot wade through the water, and we have to take them to their homes”. From this statement, these findings suggest that okada is likely to remain an essential part of the transport systems in many peri-urban areas until a good road network is in place. Even though respondents wished they could use an okada due to its ability to manoeuvre

within their neighbourhoods, especially when their roads are inundated, and other vehicles cannot pass, the concerns about the high risk of accidents associated with its use were the primary deterrent factor. This fear is justified because the road infrastructure in Ghana, particularly in the peri-urban areas, makes no provision for other road users, such as Okada, bicycles, and pedestrians. Studies have shown that the dangerous manoeuvres of Okada riders between cars cause a lot of accidents, especially in densely populated areas (see Oteng-Ababio and Agyemang, 2012; Jack et al., 2021). According to Ghana's Road Safety Authority (NRSA), Okada alone accounted for 25 percent of the 1538 road fatalities recorded in the country in 2013 (Ghanaweb, 2013). Today, the chance of dying from an Okada crash in Ghana, according to the NRSA, stands at a troubling ten times higher than a car crash (Dapatem, 2020). Other studies have also reported safety concerns, such as road accidents due to precipitation (see Koetse and Rietveld, 2009).

The survey revealed that nearly all respondents, excluding private car owners and ride-hailing patrons (who make up only about 20 percent of the total sampled population), mentioned walking to a bus stop from their homes and back before using other modes of transportation. As shown in Figure 4, individuals living away from commercial routes have to walk to the nearest bus stop to catch a trotro or taxi to get to work. This suggests that a substantial proportion of residents rely on walking since commercial routes are limited in these neighbourhoods. According to the survey, 88 percent of respondents indicated walking between 2 and 30 minutes from their homes to the nearest bus stop/station (Table 5). Even though these estimates from respondents are subjective and dependent on the distance of one's residence to the bus stop and the walking rate of an individual, they indicate that people walk considerable distances before accessing transport. The walking time also depended on the usability of the road, as most of the roads were not tarred roads, which worsens when

TABLE 5
Time walked to the nearest bus stop/station

Neighbourhood	Time in minutes						Total
	0 - 1	2 - 10	11 - 20	21 - 30	30+	Can't tell	
Santa Maria	4	72	20	5	0	8	109
Kwashiebu	2	53	21	14	10	2	102
Antiaku	7	70	12	7	0	4	100
Glefe	4	76	24	5	0	3	112
Frafraha	7	48	31	5	9	9	109
New Legon	8	65	17	4	1	6	101
New Legon Hills	5	52	28	14	2	5	106
Ampax/River Estate	1	72	20	6	2	0	101
Pokuase Old Village	4	53	29	14	2	4	106
Windy Hills	10	74	7	8	1	7	107
Total	52	635	209	82	27	48	1053

it rains. The unpaved roads often get eroded, leaving them with deep ditches that increase the risk associated with walking, especially when the surface is covered by water. Nearly half of the respondents in Frafraha (54), Pokuase Old Village (49), New Legon Hill (49), and Kwashiebu (47) walk more than 10 minutes to the roadside to join public transport (trotro/taxi).

These neighbourhoods, except Kwashiebu, are in the peri-urban areas. A 37-year-old respondent in Kwashiebu, in a statement that supports some of the factors contributing to the variations in walking time, stated that *"the distance from my house to the bus stop through this road (pointing to a road) is about a 5-minute walk. However, during rainy days, the road becomes impassable due to the water level, which can reach waist height. In such cases, we have to take an alternative route that takes us nearly 20 minutes or more to reach the bus stop. This is because our lane is built as a block, and we have to walk all the way to the end of the block to turn."*

The findings suggest that prolonged walking times may be attributed to the use of lengthy and indirect alternative routes, as well as the considerable distance between some residents' locations and the available public transport routes. According to Table 4, the 52 people who walk one minute or less either own vehicles or live close to the roadside. Those who were unable to provide the time they walked were either vehicle owners or couldn't estimate the time it took to walk to the bus

stop or station. Clearly, the nature of the roads and weather conditions, such as rainfall and flooding, impact the choice of transport and the time it takes to access that transport. The impact of the nature of the roads and rainfall/flooding influence trip characteristics, such as long queues at bus stations, long waiting time at bus stops, wading through water, among others, has been shown to affect travel mood and subsequently job performance and life satisfaction (Khaleghi and Kato, 2023; De Vos, 2024).

It must, however, be noted that those who cannot walk this extended distance use taxis or okada from the bus stop/station to their homes or to the point where they can continue on foot. From all indications, respondents who rely on public transport typically use at least two modes before reaching their destination. Walking and okada services are open-air modes of transport; therefore, during heavy rainfall, commuters are often forced to seek temporary shelter until the rainfall eases and runoff velocities decline, disrupting travel. Andreasen *et al.* (2022) report many disruptions, including the postponement or cancellation of trips due to rainfall.

Conclusions

Research on transport in the Global South has largely focused on transport systems and networks, and the impacts of climate change on infrastructure, with limited knowledge of

how the interaction between poor transport infrastructure and frequent, intense rainfall influences commuters' transport mode choices. Addressing this gap, the study examined how frequent and intense rainfall events, subsequent flooding, and poor transport infrastructure affect daily transport mode choices in peri-urban Accra. The study draws on a mixed-methods approach, including a survey of mobility patterns conducted in 10 neighbourhoods in Accra, in-depth interviews, personal observations, and photographic evidence. The findings show that deficient road infrastructure, particularly untarred and poorly maintained roads, becomes significantly less motorable during heavy rainfall. These conditions constrain accessibility, increase walking times, disrupt travel, and strongly influence residents' reliance on specific transport modes such as walking, okada, and trotro while discouraging night-time taxi use because of safety concerns.

The study examined the close interconnections between transport infrastructure, mobility, and livelihoods in peri-urban settings, especially under intensifying extreme rainfall linked to climate change. It underscores the need for targeted investments in climate-resilient transport infrastructure that addresses drainage, road surfacing, and accessibility in peri-urban areas, in order to improve mobility, reduce vulnerability, and support sustainable livelihoods.

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