

A systematic review of the interrelations of urban form and mode choice in African cities

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Abstract: Rapid urbanization and informal urban development sweeping across African cities underscore a complex yet inadequately explored link between urban form and mode choice. Extensively studied in Western urban settings, these dynamics when applied to African cities remain a relatively unexplored realm, necessitating an extensive empirical review. This paper explores how various aspects of urban form correlate with mode choices in African urban contexts. A systematic review approach was used to filter journal papers published between 2000 and 2023 in Africa. The application of the (filtering) methodology identified 22 studies from the African region as most suitable for review. The review reveals that high-density and mixed-use areas in African cities significantly promote non-motorized transport and public transit. Infrastructure development and improved connectivity further enhance these sustainable modes. Socio-economic factors, governance policies, and cultural norms also play pivotal roles in shaping mode choices and urban mobility patterns. However, high-density cities like Abuja and Nairobi face unique challenges such as overcrowding in public transport and walking facilities. Sprawling cities like Lagos and Johannesburg struggle with inadequate public transport infrastructure, leading to a heavy reliance on private cars. Connectivity is crucial for supporting non-motorized and public transport, particularly for lower-income groups who rely more on these modes and para-transit services than higher-income groups. The findings highlight the need for tailored urban planning strategies to address these challenges and harness existing opportunities, promoting more sustainable, inclusive, and efficient urban transportation systems in African cities. Moreover, this study discloses existing research gaps that warrant further exploration.

Keywords: Urban form, mode choice, public transport, mixed land use, urban sprawl, urbanization

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1 Introduction

The interaction between urban form and mode choice has captured the attention of academics and urban planners over a considerable period (Cervero, 2002; Consa, 2010;

Guerra & Li, 2021; Jasim et al., 2021; Nigro et al., 2019; Rodríguez & Joo, 2004; Schwanen & Mokhtarian, 2005). Understanding how the layout of urban areas influences transportation decisions is crucial for designing sustainable and effective cities (Conticelli et al., 2021; Martos et al., 2016; Zhang et al., 2015). In this context, urban form refers to a city or metropolitan area's physical characteristics and spatial organization, including factors such as density, land-use mix, street connectivity, and accessibility (Guerra & Li, 2021; Miotti et al., 2023). It encompasses the size, shape, scale, layout, and distribution of buildings, roads, walkways, and open spaces within an urban area (Blamah et al., 2023; Hermand & Quesada, 2019; Williams, 2014). Mode choice, on the other hand, describes an individual's selection of transportation mode (e.g., car, public transit, walking, cycling) for a given trip (Hermand & Quesada, 2019).

While mode choice is influenced by several factors such as cost, time, convenience, and individual preferences (Kim et al., 2021), research also indicates that urban form can influence it; for instance, higher densities are linked to increased public transport use and reduced reliance on private vehicles due to shorter travel distances and enhanced accessibility of vehicles (Cao et al., 2009; Guerra & Li, 2021; Miotti et al., 2023; Mokhtarian & Cao, 2008). Mixed land use, which integrates residential, commercial, and recreational areas, promotes walking, cycling, and public transport (Guerra & Li, 2021; Manaugh & Kreider, 2013; Zhuo et al., 2022). Furthermore, high street connectivity facilitates efficient movement and enhances access to public transport and non-motorized travel (Acheampong, 2020; Guerra & Li, 2021). Moreover, urban design, including sidewalks and greenery, creates appealing and safe public spaces, encouraging active transportation such as walking, cycling, and using non-motorized scooters (Guerra & Li, 2021; Manaugh & Kreider, 2013; Zhuo et al., 2022). While adequate transport infrastructure, comprising roads, transit systems, bicycle lanes, and pathways, is essential for supporting diverse mode choices and ensuring smooth urban transport operations (Guerra & Li, 2021; Zhuo et al., 2022)

1.1 Overview

The relationship between urban form and travel behavior has long been a central topic in urban studies. Early research laid the foundation by establishing how physical urban structures influence mode choices (Cervero & Seskin, 1995; Desbarats, 1983; Horton & Reynolds, 1971). Over time, more sophisticated methodologies and broader geographical scopes have contributed to a deeper understanding of this relationship, particularly regarding how density, land-use mix, street design, and transit access interact to shape travel patterns. Nevertheless, limitations persist, particularly in research concerning African cities, where urbanization occurs under socio-economic and governance conditions distinct from the more studied regions in the Global North.

One of the earliest pivotal studies in this area was Handy's (1996) investigation of urban form and pedestrian behavior in Austin neighborhoods. Handy's research was among the first to explore how urban form affects walking, distinguishing between trips made for leisure and those made to reach specific destinations. The study found that proximity to destinations, such as shops or services, was a significant driver of walking. This work highlighted how traditional, well-connected neighborhoods with higher street connectivity encouraged walking, in contrast to suburban, car-dependent areas. However, the study also recognized that urban form alone could not fully explain pedestrian behavior, as individual factors played a substantial role. Handy's research provided foundational insights into how neighborhood design affects travel behavior, particularly walking.

Around the same time, Giuliano and Narayan (2003) expanded the investigation to a comparative study between cities in the United States (US) and Great Britain, offering a broader geographic perspective on the influence of urban form. Their research demonstrated that urban density and metropolitan size are critical factors in reducing car dependency and promoting non-motorized travel. In the US, low-density suburban areas led to increased car usage and longer trips, whereas higher-density areas in both countries encouraged public transit use and shorter trips. Giuliano and Narayan's findings highlight the importance of density in shaping travel patterns, yet the study focused primarily on developed regions, leaving significant gaps in understanding how urban form affects travel behavior in less-developed contexts, such as African cities.

In the mid-2000s, Leck (2006) provided a comprehensive meta-analysis that consolidated findings from 17 studies, offering robust evidence that higher urban density and land-use mix were consistently linked to reduced vehicle miles travelled (VMT) and increased public transit, walking, and cycling. Leck's study reinforced the idea that mixed land use, where residential, commercial, and recreational spaces are integrated, helps minimize travel distances, thereby reducing the need for private vehicle trips. This study also highlighted the importance of employment density, showing that clustering jobs in dense urban areas increased the likelihood of public transit use. While this meta-analysis advanced the understanding of the impact of urban form on travel behavior, its focus on cities in developed regions left a gap in how these dynamics operate in rapidly urbanizing cities in the Global South.

Ewing and Cervero (2010) further refined the theoretical framework with their analysis of the "5 Ds" density, diversity, design, destination accessibility, and distance to transit. This study demonstrated that, while density remains a key determinant of travel behavior, destination accessibility and street design are equally important in influencing non-motorized travel. For example, intersection density is a measure of how connected streets are found to significantly affect walkability as it provides more direct and shorter routes for pedestrians. Ewing and Cervero's meta-analysis synthesized the findings from over 50 studies that link various aspects of the built environment to travel outcomes and highlight the need for a multidimensional approach to understanding how various elements of urban form interact to shape mode choices. This study further highlights the importance of compact, well-designed urban environments in reducing car dependency, providing valuable insights into how cities could be structured to promote sustainable travel.

Recent research has introduced advanced methodologies and expanded the analysis beyond traditional settings. Ton et al. (2019), for example, applied Mixed Multinomial Logit models to examine how urban form affects cycling and walking in the Netherlands cities. They found that high street connectivity and the presence of dedicated cycling infrastructure were critical factors in encouraging cycling over other modes of transport. The study's use of panel data allowed for a better understanding of how both the built environment and individual preferences shape travel behavior. While this study provides deep insights into cycling-friendly countries like the Netherlands, it highlights the need for similar research in developing countries, where infrastructure investment is limited and informal transit systems often play a dominant role.

Continuing with methodological innovation, Berrill et al. (2024) employed nonlinear models to capture the threshold effects of urban form on travel behavior. Their findings showed that beyond certain density thresholds, car ownership and mode share declined significantly, particularly in cities with strong public transit infrastructure. The study's use of gradient boosting decision trees allowed for a more detailed analysis of how various aspects of urban forms, such as density and proximity to transit, interact to reduce car dependency. However, as in many previous studies, the focus remained on European

cities, where public transit systems are well established. This raises questions about how these findings apply to cities in the Global South, particularly those with weaker governance and less-developed transit infrastructure.

The research by Guerra and Li (2021) marked a significant step toward addressing the gap in understanding urban form in developing contexts. Their comparative analysis of US and Mexican cities demonstrated that informal settlements in Mexico characterized by high densities and mixed land use fostered walking and public transit use despite limited infrastructure. This study highlighted how informality, often seen as a challenge to urban development, could support sustainable travel behaviors when density and land use are optimized. Guerra and Li's work begins to address the lack of focus on informal urbanization, a defining feature of many African cities. However, while this study provides valuable insights into Latin American cities, it still does not fully capture the specific dynamics of travel behavior in Africa, where informal transport systems play an even more dominant role.

Finally, Aston et al. (2021) updated meta-elasticities to further investigate the relationship between urban form and transit use. Their findings reaffirmed that land use mix and density were critical in promoting public transit ridership, particularly in cities with transit-oriented development (TOD) strategies. Aston et al. showed that areas with higher densities and better transit accessibility experienced significantly reduced car dependency. However, similar to earlier studies, the research primarily focused on cities with established transit systems, leaving a gap in understanding how these dynamics play out in regions with less formalized public transit, such as many cities in Africa.

This review paper makes a significant contribution to the study of urban form and mode choice in African cities by integrating the complex interaction of socioeconomic conditions, governance structures, and cultural dynamics. Unlike much of the existing literature, which tends to focus on the physical aspects of urban form (such as density, land-use mix, and street design), this review expands the scope by addressing how socioeconomic disparities, weak urban planning, and informal governance shape mobility in African contexts. African cities face unique challenges such as informal settlements and income inequality, which restrict access to basic infrastructure and limit formal transportation options. This unregulated expansion often leads to increased car dependency and a reliance on informal transport systems. By exploring these critical factors, the paper fills a notable gap in the literature and provides a more holistic understanding of how urban form interacts with social, economic, and policy dynamics in shaping mode choice, particularly within African urban environments.

The study also emphasizes the distinct socio-cultural factors influencing travel behavior in African cities, which sets them apart from cities in developed regions. African urban areas are characterized by significant socioeconomic diversity, with wide disparities in income levels, informal housing, and limited access to formal public transportation systems. As a result, low-income populations rely heavily on informal transport modes, such as paratransit and shared taxis, to meet their mobility needs. Systems like matatus in Nairobi and trotros in Accra are not just modes of transport but are embedded in cultural preferences and economic necessity, providing flexible, cost-effective alternatives to formal public transit (Saddier et al., 2017; Tembe et al., 2019, 2020). These informal systems, shaped by both economic realities and social norms, play a central role in mobility choices in African cities but are often overlooked in research focused on developed countries. By foregrounding these socio-cultural dynamics, the review contributes to a deeper understanding of how local factors in African cities influence mode choice. It calls for urban planning and transport policies that are context-sensitive, designed specifically to address the distinct needs and characteristics of these rapidly urbanizing regions.

1.2 Rationale for examining the influence of urban form on mode choice in African cities

The relationship between mode choice and urban form has been a topic of research in western cities for nearly six decades. However, studies on African cities are limited. Africa is experiencing rapid urbanization, with the urban population projected to reach 1.33 billion by 2050, representing 21% of the global urban population (World Population Review, n.d.). This urbanization differs from other regions because of the unplanned and unregulated development influenced by colonialism and ineffective urban planning institutions (Cobbinah et al., 2022; Güneralp et al., 2018a). The surge in urbanization presents challenges and opportunities for rethinking city development. Urban sprawl, exacerbated by the anticipated tripling of urban land area between 2000 and 2030 and the increase in motorization rates from 42 vehicles per 1,000 people in 2005 to 65 cars per 1,000 people in 2015 (Gambe et al., 2023), indicates a mode choice and urban form centered on the use of private cars, reflecting traditional transport planning processes that prioritize private cars.

Africa's unique urbanization, shaped by historical influences and unplanned growth, presents complex urban planning and transportation challenges. This development includes informalization, evident in the rise of informal settlements and businesses (Gambe et al., 2023; Güneralp et al., 2018; Yiran et al., 2020). These informal urban areas function independently of established formal planning structures, leading to transportation modes and routes that deviate from traditional frameworks within urban planning models and frameworks. Consequently, this complexity reshapes the traditional relationship between the urban form and mode choice, necessitating tailored urban planning and transportation. However, the distinct trajectory of Africa's unique urbanization and inadequate planning frameworks highlights the urgent need for focused research. The lack of systematic literature reviews or comprehensive studies centered on African cities creates a significant knowledge gap, hindering a thorough understanding of how urban form influences mode choice within the African urban landscape.

1.3 Study objectives

This paper examines the interrelations between urban form and mode choice in African cities undergoing rapid, informal urbanization and a declining share of public transport. This systematic review sought to answer the following questions:

- How do the various aspects of urban form correlate with the prevalence and selection of different transportation modes in African cities?

The remainder of this paper is organized into four sections. The following section highlights the methods adopted for systematic literature search and analysis. The second section presents the results, highlighting the complex interrelations between urban form and mode choice in African cities. The last section summarizes the acquired insights and suggests avenues for future research.

2 Methods

This paper adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach to gather, analyze, and synthesize relevant studies on urban form and mode choice in African cities. This systematic review approach ensures a comprehensive and unbiased analysis of existing literature (Page et al., 2021). The search was conducted across two academic databases, Scopus and Web of Science. As the literature on mode choice and urban form in Africa is limited, academic databases have yielded only a few search results. Thus, alternative online databases, Google Scholar and

Transport Research International Documentation (TRID), were utilized to circumvent these limitations and broaden the scope of the analysis. Keywords for the literature search included a combination of three categories: “Mode Choice” OR “Transport Mode” OR “Public Transport” OR “Travel Behavior” AND “Urban form” OR “ Built Environment” OR “Land Use” AND Africa.” This review primarily focused on peer-reviewed journal papers published in English between 2000 and 2023 with a specific emphasis on empirical studies, including both observational data and analytical results. Both qualitative and quantitative analyses were conducted to provide a balanced perspective on the research topic.

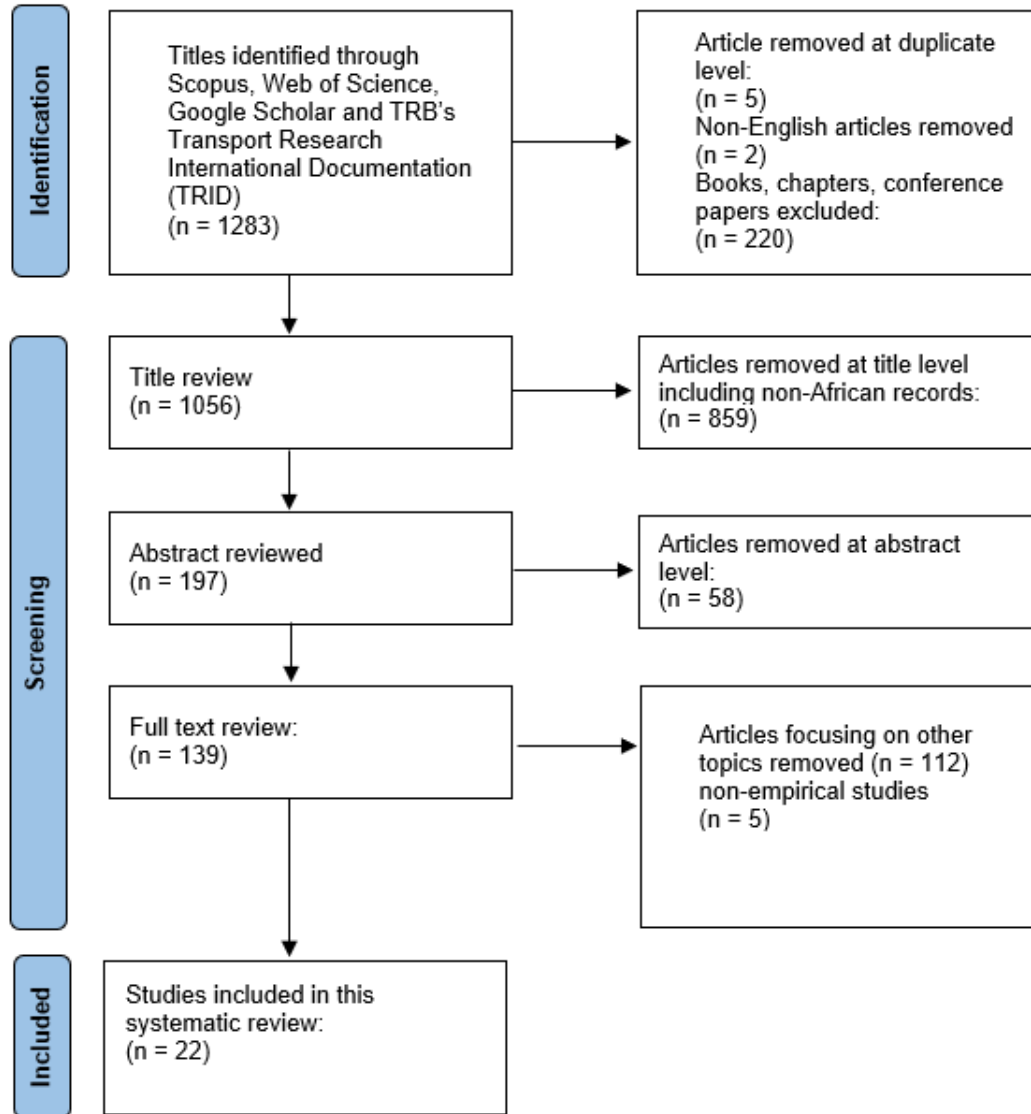


Figure 1. Article selection process based on PRISMA
Source: Author

Figure 1 illustrates the systematic search process and acquired findings. By 13 October 2023 Scopus produced 14 articles, Web of Science 308 articles, Google Scholar 481 articles, and TRB TRID 480 articles. After eliminating duplicates from the Web of

Science and TRID databases, the initial search results were screened based on titles and abstracts to identify 22 articles on African cities using the specified method (Figure 1).

The following section presents a comprehensive synthesis of the research findings aligned with the posed research questions. Figure 2 shows a visual representation of the empirical studies pertinent to this review, specifically focusing on the African region. The analysis drew upon a body of 22 peer-reviewed articles that were systematically reviewed using a coding scheme.

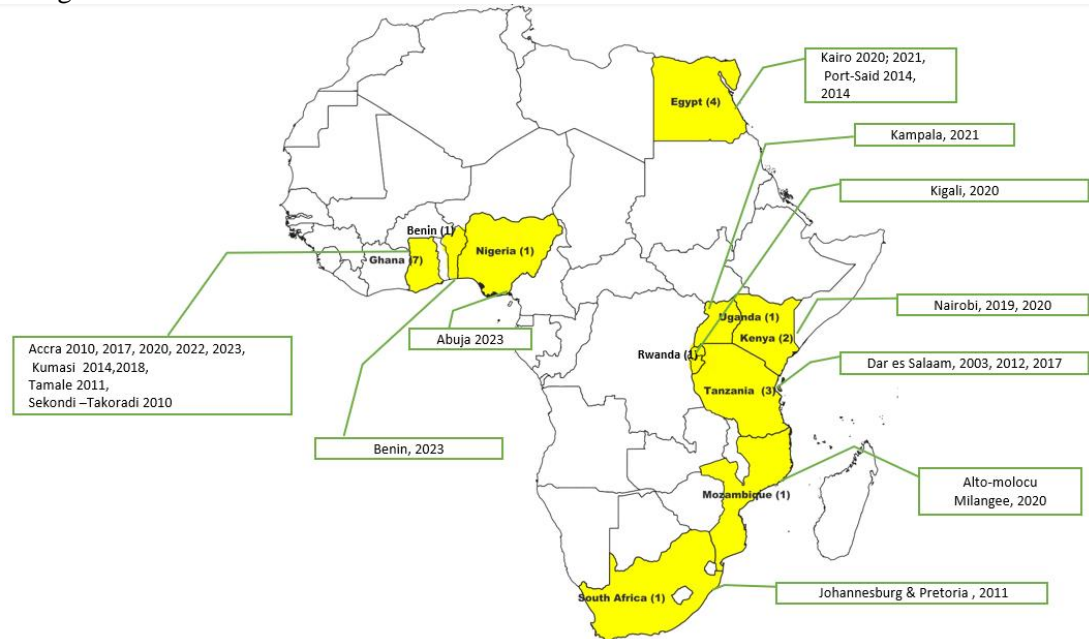


Figure 2. Overview of previously published studies on African cities
Source: Author

Subsequent to the PRISMA selection-based process, the 22 collected articles were imported into the ATLAS.ti software, Version 8. The methodology employed the reflexive thematic analysis (RTA) technique in ATLAS.ti, as shown in Figure 3. Reflexive thematic analysis is a method used to identify, analyze, and interpret patterns of meaning (themes) within qualitative data (Braun et al., 2018). It involves an iterative process in which the researcher engages reflexively with the data, continually questioning and re-evaluating themes as they emerge (Braun et al., 2018). Relevant text segments from these articles were coded according to the key aspects of the urban form and mode choice. The identified urban form aspects were categorized into six categories: density and land use, infrastructure and accessibility, connectivity, socioeconomic factors, policy and governance, and cultural and social norm factors. The mode choices identified were categorized into five broad categories: non-motorized transport (walking and cycling), public transport (formal bus service and trains), motorized transport (private cars and ride-sharing), and para-transit services (mini-bus taxis, motorcycle taxis, and tricycle taxis). Following the coding process, the data were analyzed to develop broader themes that capture the main patterns observed across the articles.

To quantify the strength of the relationships between urban form aspects and mode choices, the frequency and co-occurrence of codes were analyzed using ATLAS.ti's co-occurrence table. This tool visually represented how often specific aspects of urban form were linked to particular transportation modes. The relationships were quantified based on specific criteria: high frequency and strong co-occurrence were assigned values

between 50-60, moderate frequency and co-occurrence received values between 30-40, and low frequency and weak co-occurrence were assigned values between 10-20. For example, if “Density and Land Use” frequently co-occurred with “Non-Motorized Transport” in the reviewed articles, this relationship was assigned a high value of 60. Finally, the quantified relationships were visualized using a Sankey diagram, as shown in Figure 4, which provides a clear representation of the strength of each relationship. This methodology of assigning values is based on a systematic literature review, coding, and quantification using ATLAS.ti provides a framework for understanding the complex interrelations between urban form and mode choice.

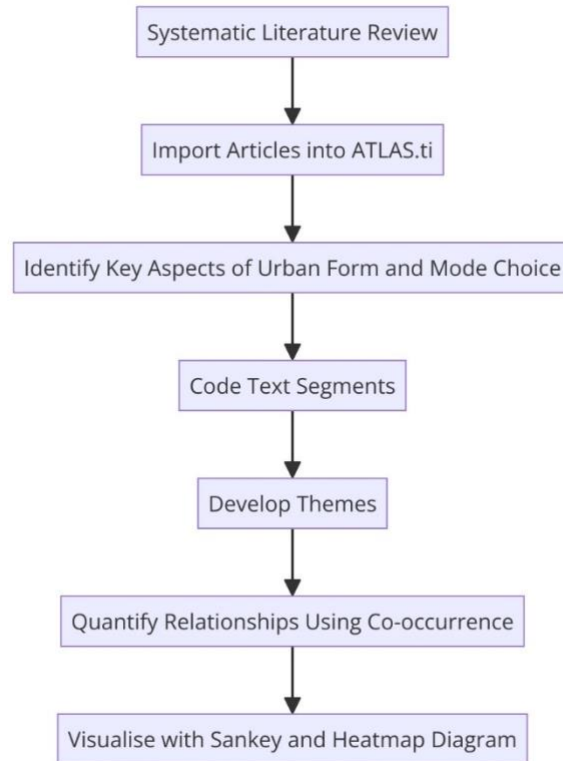


Figure 3. Atlas.ti methodological approach

Source: Author

The resulting Sankey diagram shown in Figure 4 effectively visualizes these relationships, making the data accessible and actionable for urban planners and policymakers. The Sankey diagram illustrates the flow and magnitude of the relationships between urban form aspects and transportation modes. By mapping these interrelations, the diagram uses the width of the lines to represent the strength of associations, clearly showing how each urban form aspect correlates with different transportation modes.

To further visualize these associations, a heatmap was generated using co-occurrence table data within Atlas.ti. The heatmap quantitatively represents the strength of the correlations between urban form aspects and mode choice. Each cell in the heatmap represents the degree of association between an aspect of the urban form and transportation mode, with darker colors indicating stronger associations.

The heatmap was then analyzed to identify patterns and trends in the data. The paper examined which aspects of urban form were most strongly associated with specific transportation modes by looking for consistent patterns across different articles. These

insights were synthesized to draw conclusions about how urban forms are associated with mode choice in African cities.

3 Results

3.1 Study characteristics

This section lists studies conducted in African cities that were examined in the review of the interrelations between urban form and mode choice in African cities.

Table 1. Summary of urban forms and mode choice study characteristics

Author, Year	Location	Study Design	Analysis Method	Data Collection Method	Sample Size	Mode Choice	Results: Urban form and mode choice	Results: Socio-cultural or non-physical factors and mode choice
Melbye et al., 2015	Dar Es Salaam, Tanzania	Cross-sectional design	Geospatial Analysis	Origin-Destination (OD) Cost Matrix analysis and Network analysis	Spatial data	Private car, formal public bus, mini-bus taxis, motorcycles, bike, walk	The physical infrastructure influences mode choice by providing options and facilitating different modes of transportation.	
Andreasen & Møller-Jensen, 2017	Dar Es Salaam, Tanzania	Cross-sectional design	Geospatial Analysis And Nvivo thematic Analysis	Survey, GIS-based modeling	174 Individuals and Spatial data	Private car, bus, motorcycles, bike, walk and scooters	The choice of transport mode is less influenced by the type of vehicle and more by the road and traffic conditions. The location of residential areas near central business districts or urban facilities significantly impacts daily travel mode choices.	
Olvera et al., 2003	Dar Es Salaam, Tanzania	Cross-sectional design	Regression analysis	Survey	1128 households	Private car, bus, motorcycles, bike, walk	Limited access to urban amenities, travel scheduling difficulties, rising travel expenses, and spatial disparities contribute to travel choices. Road congestion and limited road networks also affect mode choice.	
El-Bany et al., 2014	Port-Said, Egypt	Cross-sectional design	Multinomial Logit Model (MNL), Nested Logit Model	Survey	100 individuals	Private car, taxis, buses		Higher-income earners use private vehicles, and out-of-vehicle time impacts mode choice more.

Author, Year	Location	Study Design	Analysis Method	Data Collection Method	Sample Size	Mode Choice	Results: Urban form and mode choice	Results: Socio-cultural or non-physical factors and mode choice
			(NL), Mixed Logit Model (MXL) Analysis					
Mostofi, Masoumi & Diemel, 2020	Tehran and Cairo, Egypt	Cross-sectional design	Logistic regression	Interviews	4431 individuals	Walk, bike, Private car, ride-hailing		Regular ride-sourcing users are likelier to choose cycling for nearby destinations, and socio-cultural factors affect choices.
Eldeeb & Masoum, 2023	Cairo, Egypt	Cross-sectional design	Space syntax in-depth analysis	GPS data	Space syntax in-depth map within a 1.5 km catchment area from the main square or centre	Private car, Walk, bike	Compact urban designs offer better walkability compared to newer, less integrated areas.	
Blamah et al., 2023	Abuja, Nigeria	Cross-sectional design	Nvivo thematic Analysis	Survey	320 individuals	Private car, public bus, Mini-bus taxis, motorcycles, bike, walk	Unplanned urban sprawl leads to poor public transport access and infrastructure, increasing car dependence.	Socio-economic disparities affect mode choice: wealthier individuals prefer private cars, while lower-income groups rely on public or non-motorized transport.
El-Bany et al., 2014	Port-Said, Egypt	Cross-sectional design	Multinomial Logit Model (MNL), Nested Logit Model (NL), and	Survey	100 individuals	Private car, taxis, buses	Accessibility influenced by urban form significantly shapes mode choice in developing countries like Egypt by affecting travel time, cost, waiting time, walking time, and interchange.	

Author, Year	Location	Study Design	Analysis Method	Data Collection Method	Sample Size	Mode Choice	Results: Urban form and mode choice	Results: Socio-cultural or non-physical factors and mode choice
			Mixed Logit Model (MXL)					
Chakwizira et al., 2011	South Africa	Cross-sectional design	Creative analysis of secondary data	Survey and Interviews	300 individuals	Private car, public bus, Mini-bus taxis, train, bike, walk	The apartheid influenced city layout, affects mode choice due to the distant location of transport terminals from marginal communities. Residents often need to use multiple transport modes to access transit services.	Social exclusion and economic disparities significantly impact mode choice. Poorer communities face higher transport costs, limiting their options for efficient modes.
Ndibatya & Booyesen, 2021	Kampala, Uganda	Longitudinal design	Spatial Distance Analysis	GPS data	20 Mini-bus taxis	Private car, Mini-bus taxis, motorcycle, bike, tricycle taxis	Rapid population growth and scattered amenities create high dependence on flexible mini-bus taxis. Dispersed passenger demand and poor planning influence taxi routes. This adaptable, loosely regulated paratransit system is crucial in cities with weak transit-oriented policies.	
Campbell et al., 2019	Nairobi, Kenya	Cross-sectional design	Regression analysis	Survey	10,000 households	Private car, Mini-bus taxis, train, bike, walk	Place-based accessibility varies by transport mode and wealthier areas have lower access, and tenement areas have higher access.	
Tembe et al., 2020	Nairobi, Kenya	Cross-sectional design	Logistic regression analysis	Survey and Interviews	25,717 households	Private car, public bus, Mini-bus taxis, motorcycles, bike, walk	Limited road coverage reduces bus service areas, favouring paratransit. Urban infrastructure and layout constrain public transport effectiveness.	Vehicle ownership and employment status reduce bus usage likelihood, while income affects preference for paratransit over buses.

Author, Year	Location	Study Design	Analysis Method	Data Collection Method	Sample Size	Mode Choice	Results: Urban form and mode choice	Results: Socio-cultural or non-physical factors and mode choice
Agyemang, 2022	Accra, Ghana	Cross-sectional design	Descriptive Analysis	Survey	515 individuals	Private car, Ride-hailing services, public transport	Monocentric and sprawled urban form, long commutes, and the need for transit-oriented development (TOD).	
Oppong-Yeboah & Gim, 2020	Accra, Ghana	Cross-sectional design	Partial least square structural equation modeling	Survey	487 individuals	Private car, public bus, Mini-bus taxis, bike, walk	Urban form, including proximity to town centres and walkability, influences car use. Satisfying public transport reduces car usage, while easy access to bus stops, taxi ranks, and shops encourages public transport use and reduces reliance on cars.	
Abane, 2011	Accra, Kumasi, Tamale, and Sekondi-Takoradi Ghana	Cross-sectional design	Multinomial logit model Analysis	Observations, Survey and Interviews	1000 individuals	Private car and Mini-bus taxis	Factors such as the availability and accessibility of transportation infrastructure, including roads, sidewalks, and bike lanes, play a significant role in mode choice.	
Saddier et al., 2017	Accra, Ghana	Cross-sectional design	Regression analysis	Survey	1,200 trips	Private car and Mini-bus taxis	High urban population density increases demand for para-transit services due to inadequate road infrastructure and formal transit options.	Para-transit is cost-effective and favored by many, particularly in low-income areas lacking affordable or accessible transport alternatives.
Poku-Boansi & Adarkwa, 2014	Kumasi, Ghana	Cross-sectional design	Regression Analysis	Observations, Survey and Interviews	400 Individuals	Private car, public bus, bike, walk	Higher population density increases public transport use. Well-maintained roads encourage bus and taxi use, while poor conditions lead to walking or cycling.	Low and middle-income earners prefer public transport for its affordability over private vehicles.

Author, Year	Location	Study Design	Analysis Method	Data Collection Method	Sample Size	Mode Choice	Results: Urban form and mode choice	Results: Socio-cultural or non-physical factors and mode choice
Poku-Boansi & Cobbinah, 2018	Kumasi, Ghana	Cross-sectional design	Regression analysis	Survey and Interviews	400 individuals	Private car, public bus, Mini-bus taxis	Urban form affects mode choice. Well-maintained roads and efficient public transport systems encourage bus and tro-tro use, while high population density increases demand for public transport. Population,	
Acheampong, 2020	Kumasi, Ghana	Cross-sectional design		Survey and Interviews	1,158 individuals	Public bus, Trains Ride-hailing services, Private car	Polycentric urban configurations affect commuting distances, influencing travel behavior. Proximity to the CBD, sub-centres, and transport infrastructure impacts mode choice. Higher car ownership leads to increased car use for work, highlighting the urban form's influence on transport choices.	
Baffoe et al., 2020	Altolocu Milangee Mozambique	Cross-sectional design	Descriptive Analysis and GIS Spatial Analysis	Survey	130 individuals	Private car, public bus, Mini-bus taxis, motorcycles, bike, walk	Urban form factors such as activity location and household residence significantly influence walking, especially for formal and informal jobs.	
Bagenzi, et al., 2021	Kigali, Rwanda	Cross-sectional design	Regression analysis	Survey and Interviews	11 individuals for interviews and 116 individuals for survey	Private car, public bus, Mini-bus taxis, motorcycles, bike, walk	Land-use design, such as the mix of residential and commercial areas, significantly affects the mode choice, as it can reduce travel time and promote walking and cycling in neighborhoods	
Nkeki & Asikhia, 2023	Benin	Cross-sectional design	Nested logit choice model	Survey and Arc-GIS	1,735 individuals	Private cars, tricycles, taxis	Built environment factors like urban sprawl weakly influence travel mode choice.	socio-economic factors play a crucial role in travel decisions in African cities.

3.2 The correlations between various aspects of urban form and the prevalence and selection of different transportation modes in African cities

The Sankey diagram provides a visualization of the relationships between various aspects of urban form and mode choices in African cities. This analysis revealed the distribution and strength of these correlations, offering valuable insights into how urban planning influences mobility patterns.

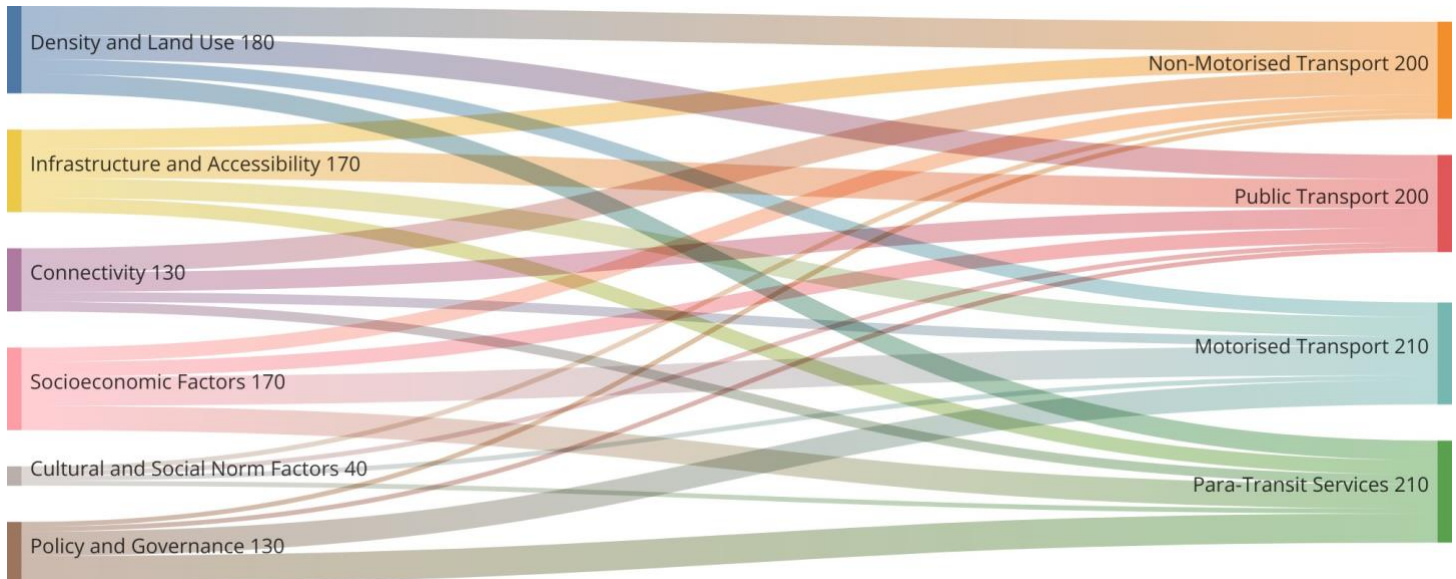


Figure 4. Correlations between urban form and mode choice in the African city Sankeymap
Source: Secondary data -ATLAS.ti

The largest flows from density and land use are directed towards non-motorized transport and public transport. This indicates that high-density areas and mixed land use significantly promote walking, cycling, and public transport. Cities such as Cairo, which are densely populated areas, show high public transport usage (Mostofi et al., 2020). Compact urban designs in regions like Old Cairo and parts of Tehran support walking and cycling by making destinations more accessible (Bagenzi et al., 2021; Eldeeb & Masoumi, 2023).

Significant flows from infrastructure and accessibility are towards non-motorized and public transport. This highlights the crucial role of a well-developed infrastructure in encouraging these modes of transport. For instance, Kigali's investment in pedestrian infrastructure has increased walking and cycling, whereas Johannesburg's Bus Rapid Transit (BRT) system exemplifies how reliable and extensive public transport infrastructure can drive public transport usage (Bagenzi et al., 2021; Chakwizira et al., 2011).

Connectivity makes substantial contributions to non-motorized and public transport. With well-integrated transport networks, high connectivity in cities such as Accra and Johannesburg supports walking and cycling for daily commutes (Chakwizira et al., 2020; Chakwizira et al., 2011). Conversely, poor connectivity in cities, such as Dar es Salaam, leads to increased reliance on para-transit services, underscoring the need for improved connectivity to reduce dependency on informal transport modes (Andreasen & Møller-Jensen, 2017).

The flows from socio-economic factors are notably directed towards non-motorized transport and public transport for lower-income groups and motorized transport for higher-income groups. This reflects how economic status dictates mode choices. In cities such as Benin and Abuja, lower-income populations predominantly walk because of affordability (Blamah et al., 2023; Nkeki & Asikhia, 2023), while wealthier individuals prefer private cars in Nairobi. Thus, socioeconomic status is a critical determinant of transportation preferences (Tembe et al., 2020).

Policy and governance influence all modes of transport, with noticeable flows towards motorized transport and para-transit services. Transit-oriented policies in Dar es Salaam enhance public transport usage by improving the infrastructure and service reliability (Melbye et al. 2015). Conversely, car-oriented policies in cities, such as Kampala, encourage private car use, demonstrating how governmental policies significantly shape urban transport dynamics (Ndibatya & Booysen, 2021).

Cultural and social norms affect all transportation modes. There is growing cultural acceptance of cycling in Kigali, driven by initiatives promoting cycling as a viable mode of transport (Bagenzi et al., 2021). However, cultural barriers persist in cities such as Cairo, limiting the adoption of cycling. This highlights the importance of addressing cultural attitudes and social norms to promote diverse and sustainable transportation options (Mostofi et al., 2020).

The Sankey diagram effectively visualizes the complex interactions between aspects of urban form and mode choices in African cities. This highlights the importance of high-density and mixed land use, well-developed infrastructure, and connectivity in promoting sustainable transport modes such as walking, cycling, and public transport. Socioeconomic factors and governance policies also play pivotal roles in determining mode preferences, whereas cultural and social norms can either facilitate or hinder the adoption of these modes. This analysis provides a framework for urban planners and policymakers to understand and enhance urban mobility, ultimately contributing to sustainable and efficient transportation systems in African cities.

Furthermore, the heatmap provides a detailed visualization of the correlations between urban form and transportation mode choices in African cities. Each cell in the heatmap represents the strength of the relationship between an urban form aspect and mode choice, with darker colors indicating stronger correlations.

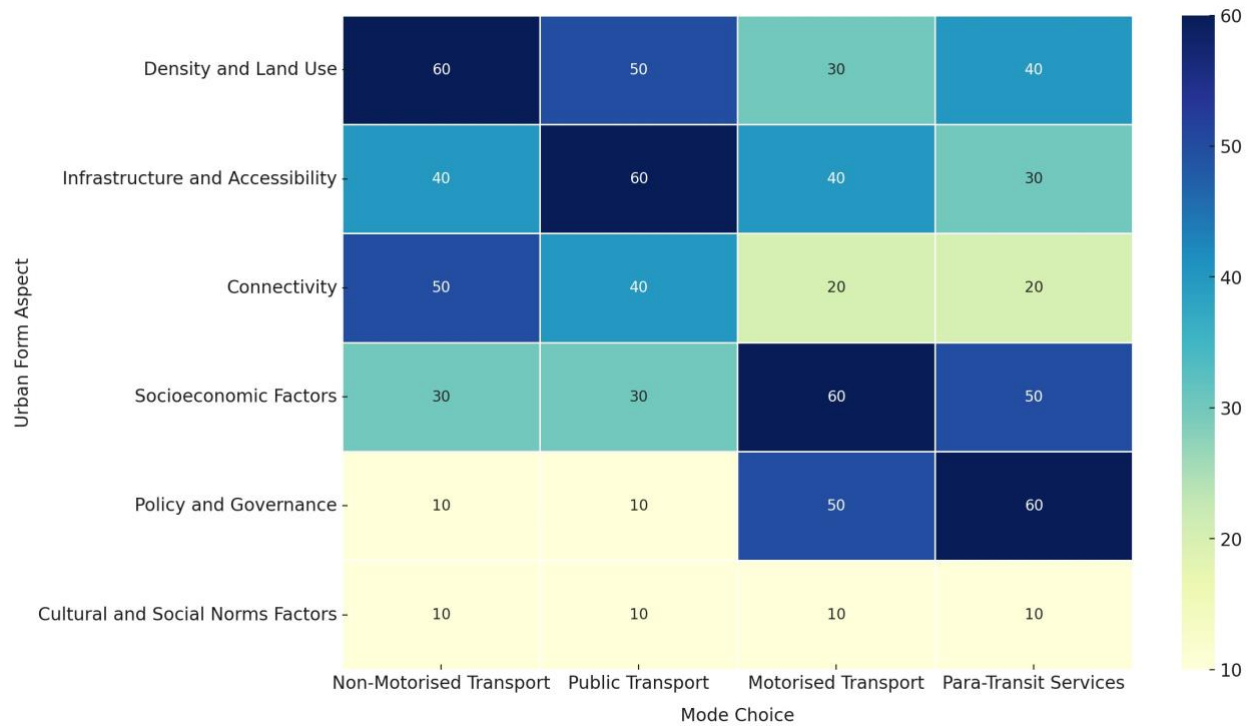


Figure 5. Correlations of urban form aspects and mode choice in the African cities heatmap
Sources: Secondary data -ATLAS.ti

The relationship between density, land use, and non-motorized transport was the strongest, with a value of 60. This indicates that high-density areas and mixed land use significantly promoted walking and cycling in African cities. High-density environments create shorter travel distances and more accessible destinations, which facilitate the use of non-motorized transport (Eldeeb & Masoumi, 2023; Oppong-Yeboah & Gim, 2020). Public transport also showed a strong correlation with density and land use, with values of 50. This reflects cities where high population densities create a substantial demand for public transport services, making it a viable and necessary mode of transport. The correlations with motorized transport and para-transit services are lower at 30 and 40, respectively, suggesting that while density and land use influence these modes, the impact is not as significant as it is on non-motorized and public transport.

Furthermore, infrastructure and accessibility are strongly correlated with public transport (60) and non-motorized transport (40). Well-developed infrastructure, including pedestrian pathways and reliable public transport networks, support the use of these modes. Cities such as Kigali and Johannesburg illustrate how investments in infrastructure can enhance walking, cycling, and public transport usage (Bagenzi et al., 2021; Chakwizira et al., 2011). Motorized transport and para-transit services also benefit from a good infrastructure, with values of 40 and 30, respectively. Efficient road networks and accessibility improvements facilitate these modes, although the impact is less pronounced compared with public and non-motorized transport.

Connectivity is correlated with non-motorized transport (50), indicating that well-connected urban environments encourage walking and cycling. High connectivity reduces travel distances and enhances accessibility, thereby increasing non-motorized transport (Abane, 2011). Public transport also benefitted from good connectivity, with a correlation

value of 40. Integrated transport networks that connect various parts of a city make public transport a convenient option for residents (Chakwizira et al., 2011). The impact on motorized transport and para-transit services was lower, with values of 20 each. This suggests that, while connectivity is important for all modes, its effect is most significant for non-motorized and public transport.

Socioeconomic factors strongly correlate with motorized transport (60), reflecting that higher-income groups tend to use private cars more frequently. Economic status is a critical determinant of mode choice in African cities, with wealthier individuals preferring the convenience and comfort of private vehicles (Nkeki & Asikhia, 2023). Non-motorized and public transport have a correlation value of 30, indicating that lower-income groups predominantly use these modes owing to affordability constraints. Socioeconomic status thus dictates mode choice, with more affordable options being preferred by those with lower incomes. The correlation with para-transit services was also significant at the 50. This finding suggests that lower-income groups rely on informal para-transit options in cities where formal public transport is lacking or insufficient.

In addition, policy and governance have a noticeable correlation with motorized transport (50) and para-transit services (60). Car-oriented policies and inadequate regulation of informal transport sectors have led to the increased usage of these modes in African cities (Ndibatya & Booysen, 2021). The influence on non-motorized transport and public transport was lower, with values of 10 each. However, as observed in Dar es Salaam, transit-oriented policies can significantly enhance public transport usage and promote more sustainable transport options (Krüger et al., 2021). Moreover, the cultural and social norm factors showed uniform values of 10 across all modes. This indicates that while cultural attitudes and social norms influence mode choice in African cities, their impact is relatively modest compared with other aspects of urban form.

The heatmap further visualizes the complex interrelations between aspects of urban form and mode choices in African cities. High-density areas and well-developed infrastructure promote sustainable transport modes such as walking, cycling, and public transport. While connectivity plays a crucial role in supporting non-motorized and public transport, socioeconomic factors dictate mode preferences based on affordability. Policy and governance significantly shape urban transport dynamics, and cultural and social norms have modest but notable impacts.

4 Discussion

This section discusses the systematic review findings in relation to the context of other evidence and answers the research question. The discussion of the results is followed by the contribution of this paper to the knowledge gap, highlighting the various working practices to study the relationship between mode choice and urban form in African cities.

The analysis revealed complex interrelations between urban form aspects and mode choices in African cities. High-density areas with mixed land use, such as those found in Cairo and Kigali, promote walking, cycling, and public transport by making destinations more accessible. This trend aligns with global examples, such as Copenhagen and Amsterdam, which prioritize non-motorized transport through compact urban designs (Pucher & Buehler, 2008). Similarly, Bogotá benefits from innovative public transport systems that reduce congestion and enhance quality of life (Guzman et al., 2018).

However, high-density cities in Africa such as Abuja and Nairobi face unique challenges. Overcrowding in public transport and walking facilities can undermine their efficiency and appeal, as highlighted by Blamah et al. (2022) and Blamah et al. (2023). Conversely, sprawling cities, such as Lagos and Johannesburg, deal with extensive

suburban development and inadequate public transport infrastructure. This results in a heavy reliance on private cars, leading to severe traffic congestion and environmental issues (Gambe et al., 2023; Salisu et al., 2023).

To enhance sustainable transport options, it is crucial to develop high-density mixed land use areas. However, these benefits can be undermined by issues, such as overcrowding. Therefore, effective urban planning must address specific challenges by improving both the density and transport infrastructure. Examples from Kigali's pedestrian infrastructure and Johannesburg's BRT system, along with global cases such as Seoul's well-funded subway system and Copenhagen's extensive cycling infrastructure, demonstrate the importance of robust infrastructure investment (Robinson et al., 2022).

Moreover, the findings reveal that connectivity plays a critical role in supporting non-motorized and public transport in African cities by reducing travel distances and enhancing accessibility. High connectivity in cities such as Accra and Johannesburg promotes sustainable transport modes, while poor connectivity in cities such as Dar es Salaam leads to reliance on informal transport services. This mirrors the trends in cities such as Amsterdam, where integrated networks improve public transport convenience (Calisto Friant et al., 2023). Improving connectivity should be a strategic priority for urban planners in African cities to reduce their dependency on less sustainable modes and enhance overall urban mobility.

Socioeconomic factors also influence mode choices in African cities. Lower-income groups often rely on non-motorized and para-transit services owing to affordability, while higher-income groups prefer motorized transport. Studies in cities such as Benin, Abuja, and Nairobi support this finding, showing the impact of income, education, and age on mode choice (El-Bany et al., 2014; Nkeki & Asikhia, 2023). Globally, similar trends have been observed in New York, where income disparities affect transportation preferences (Bueno et al. 2017). Inclusive transport policies are required to ensure equitable access and promote sustainable choices across economic segments.

Moreover, policies and governance significantly shape the mobility patterns. Transit-oriented policies in Dar es Salaam enhance public transport usage (Melbye et al., 2015), whereas car-oriented policies in Kampala encourage private car use. This aligns with global trends, where supportive policies in cities, such as Bogotá, improve public transport systems (Boisjoly et al., 2020). Aligning policies with sustainable transport goals is essential to positively influence mode choice and promote sustainable urban mobility patterns in African cities.

Cultural attitudes and social norms were also correlated with transportation choices. Initiatives promoting cycling in Kigali show how cultural acceptance can drive sustainable transport adoption (Bagenzi et al., 2021), while cultural barriers in Cairo limit it (Mostofi et al., 2020). Globally, cities such as Copenhagen have successfully integrated cycling into their culture, enhancing social equity (Calisto Friant et al., 2023). Addressing cultural and social norms through targeted campaigns is crucial for promoting diverse and sustainable transport options.

This review highlights the importance of considering regional backgrounds to fully understand transportation dynamics in African cities. North African cities, such as Cairo, benefit from high-density and mixed land use, which promotes non-motorized and public transport by making destinations more accessible. East African cities such as Nairobi face challenges related to socio-economic disparities, heavily influencing mode choices, and making lower-income groups reliant on affordable non-motorized and public transport. In West Africa, cities such as Accra have high connectivity within their transport networks, facilitating efficient public and non-motorized transport by reducing travel distances and enhancing accessibility. Southern African cities, such as Johannesburg and Cape Town, exhibit unique urban forms and socioeconomic contexts. These cities often struggle with

sprawling layouts and heavy reliance on motorized transport, highlighting the need for improved public transport infrastructure and better connectivity.

Despite these differences, commonalities across regions include the need to promote sustainable transport modes through high-density mixed land use, robust infrastructure, and high connectivity. However, region-specific policies are necessary to consider local socioeconomic and cultural contexts, ensuring that urban planning strategies are both effective and equitable.

While this paper provides valuable insights, it is crucial to recognize its limitations. It focuses on a review of prior research conducted on four platforms: Scopus, Web of Science, Google Scholar, and TRB's TRID. Although it is possible that some studies were inadvertently excluded, it is unlikely that their exclusion would have had a significant impact on the analysis of how aspects of urban form correlate with mode choice in African cities. This review sheds light on the scarcity of empirical literature on the interrelations between urban form and mode choice in Southern African cities. Despite the substantial body of literature from North, East, and West African regions, the representation of Southern African regions in this paper is limited.

Current research on African cities has identified notable gaps, particularly in the realms of comprehensive planning for bikeability, walkability, and public transport infrastructure within specific urban forms, as well as in understanding the socioeconomic factors that influence mode choices and the role of government policies in promoting sustainable modes of transport. Further investigation is needed to address these research gaps and explore the impact of government interventions on achieving integrated urban mobility and land use planning objectives.

Furthermore, current research methodologies have notable limitations. There was a lack of longitudinal design methods in the reviewed studies, which are crucial for capturing temporal changes and establishing causality. The absence of robust causal inference techniques in many studies limits the ability to ascertain the direct impact of the urban form on mode choice. Future research endeavors should prioritize longitudinal studies and employ advanced causal inference methodologies to deepen the understanding of these aspects. Such approaches would enable more analysis of how changes in urban form over time influence transportation behaviors and outcomes.

5 Conclusion

This paper explored the complex landscape of urban form and mode choice in African cities, revealing that High-density, mixed land use areas, such as those in Cairo and Kigali, facilitate walking, cycling, and public transport, aligning with global trends observed in cities such as Copenhagen and Amsterdam. However, high-density cities such as Abuja and Nairobi face challenges such as overcrowding, whereas sprawling cities such as Lagos and Johannesburg suffer from inadequate public transport infrastructure, leading to heavy reliance on private cars. Connectivity and socioeconomic factors also play critical roles, with lower-income groups relying more on non-motorized and para-transit services, necessitating inclusive transport policies to ensure equitable access and sustainable choices.

Despite valuable insights, this review highlights significant gaps in the existing literature, particularly concerning comprehensive planning for bikeability, walkability, and public transport infrastructure, as well as the socioeconomic factors influencing mode choice and the impact of government policies. The scarcity of empirical studies, especially in Southern African cities, highlights the need for further research using longitudinal designs and robust causal inference methodologies. Future studies should focus on addressing these gaps to develop effective urban planning strategies that

promote sustainable transport, considering local socioeconomic and cultural contexts to ensure both effectiveness and equity.

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Author contribution

Hilma Nuuyandja contributed to conceptualization, draft preparation, methodology, analysis and visualization. Noleen Pisa, Houshmand Masoumi, and Chengete Chakamera were responsible for conceptualization, supervision, review, and editing. All authors have read and agreed to the published version of the manuscript.

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