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Thesis title:

First Mile Last Mile (FMLM) Accessibility and its impacts on modal share and emerging motorization patterns. *Case of Ruiru Bypass Zone, NMR Kenya.*

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Summary

As cities grow, anarchic demand for mobility has been accompanied by highly diverse motorization patterns. In a bid to improve urban mobility, enhance connectivity, reduce greenhouse gas emissions and sustain the urban transport system, public transport mainline corridors have garnered significant attention with heavy capital investments being assigned to different forms of mass transit. Notwithstanding this; large-scale investments have failed to entice people to patronize public transportation due to the lack of seamless connectivity to the First Mile and Last Mile (FMLM) of commute trips. Access and egress from transit have continually been overlooked in transportation planning, and have thus become the weakest links in public transportation chains (Krygsman et al., 2004). Consequently, the prevalence of highly polluting low capacity automobiles, auto-dependency, meagre public transport ridership and sporadic intermediate public transportation has become increasingly burdensome for cities.

Against this backdrop, this study scrutinizes the accessibility of the first and last mile and evaluates how this affects a commuter's modal choice and the city's motorization patterns. To achieve this two-fold objective, a case study research strategy is adopted where Ruiru Bypass Zone, Kenya is selected for an in-depth analysis of the FMLM phenomena. This traffic analysis zone is conscientiously selected within the context of a developing country and a rapidly urbanizing city region. Premised on a profound review of literature, the study holds that a commuter is a rational utility-maximizing entity, who considers person-, place- and mode-based factors before selecting the preferred travel mode. Through a commuter survey, traffic counts, semi-structured interviews and content analysis, the study builds a comprehensive commuter inventory from which various forms of analyses are performed.

Descriptive analyses provide exhaustive summary statistics on physical environments (travel distance, infrastructure provision, and street attractiveness), social environments (gender, age, income, household size, and auto ownership) and modal environments (modal variability, travel time and travel costs). The study then applies multinomial logit modelling to predict motorization patterns as defined by modal share in the FMLM and line haul. Among the multi-fold factors assessed; infrastructure provision, modal variability, travel cost, auto ownership and income significantly predict motorization, with pronounced moderation by the commuter's age. The overarching discovery is that FMLM accessibility indeed affects motorization in the FMLM largely (58% explained variance) and moderately (43.1% variance) in the line haul. Notably, increased likelihood of choosing low capacity automobiles is attributed to increase in auto ownership, income and travel costs moderated by age. By contrast, the adoption of active mobility is attributed to lack of an automobile and infrastructure provision moderated by age. Likelihood of selecting public transport is attributed to increased modal variability and lack of auto-ownership. The study also unveils that the conventional 5-minute walk catchment area to access transit is an understatement of actual catchment areas in developing cities.

Lastly, the study provides possible courses of action that can be adopted to intercept auto dependency whilst increasing active transport patronage and public transport ridership. The study pioneers a systematic strategy for FMLM assessment in instigating holistic multimodal transportation and provides projections for further research to enrich this urban transportation theme. It is noted that as cities grow and become increasingly diverse, transportation services need to equally evolve to match up to society's differing needs.

Keywords

First mile Last mile (FMLM), active transport, paratransit, low capacity automobiles, modal share, motorization.

Acknowledgments

This study is inspired by current trajectories that characterize transportation as the fastest-growing contributor to climate change. This sector which plays a pivotal role in urban development faces numerous systematic challenges that have compromised efficient, equitable, reliable, healthy and environmentally-friendly mobility. The contemporary challenges call for agile action in instigating holistic strategies and policies for sustainable urban mobility. Through this thesis, I contribute to this global discussion and urban transportation planning practice by focusing on safe, resilient, sustainable, low carbon end-to-end connectivity for all urban residents.

The successful completion of this thesis is by virtue of instrumental, emotional, informational, appraisal, and spiritual support of many. My special gratitude to God, the Almighty, for the strength, perseverance, and motivation despite the prevailing tough times caused by the unprecedented COVID19 global pandemic. Profound gratitude to the OPEC Fund for International Development (OFID) for the benevolent scholarship opportunity that enabled the development my urban sustainability and climate change skills in an internationally recognized institution; Erasmus University Rotterdam.

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I dedicate this thesis to my parents; Peter and Susan Gitundu, and to my lovely siblings; Robert Maina and Gladys Kabura whose unconditional love, dedication, and unrelenting support have inspired me through the process.

Abbreviations

BRT	Bus Rapid Transit
CO_2	Carbon dioxide
EEA	European Environment Agency
EU	European Union
FMLM	First Mile Last Mile
GHG	Greenhouse Gas
GTFS	General Transit Feed Specification
IHS	Institute for Housing and Urban Development Studies
ITDP	Institute for Transportation and Development Policy
IPT	Intermediate Public Transport
JICA	Japan International Cooperation Agency
KeRRA	Kenya Rural Roads Authority
KURA	Kenya Urban Roads Authority
Ksh	Kenya Shillings
LRT	Light Rail Transit
MRT	Mass Rapid Transit
NMR	Nairobi Metropolitan Region
NMT	Non-motorized Transport
OSM	Open Street Map
PT	Public Transport
PTA	Public Transport Accessibility
SGR	Standard Gauge Railway
SOVs	Single Occupancy Vehicles
TAZ	Traffic Analysis Zone
WHO	World Health Organization

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Chapter 1: Introduction

1.1 Background information and problem statement

1.1.1 Introduction

The critical role of cities on the journey towards sustainable global development is becoming increasingly apparent. This is evidenced by the growing attention towards cities as underscored in the United Nation's SDG 11, which views cities as the engines of growth and leverage points to realizing more sustainable paths of development (United Nations, 2015). Despite their vital role, cities across the globe face manifold development challenges, mobility being part. Provision of efficient, accessible, all-inclusive and eco-friendly transportation systems has remained an intractable challenge for cities (Kanuri et al., 2019; Zuo et al., 2020). It is indisputable that the transportation sector holds a pivotal role in urban development, but its potential has been impeded by numerous mobility challenges resulting from the unavoidable nuisance of congestion, inefficient public transport modes, limited active mobility modes, deteriorated human and economic health, time pollution, inequitable mobility and increased greenhouse emissions, to mention but a few. Over the years, cities have further witnessed a rapid increase in automobile use which has had deleterious impacts on the environmental sustainability of the transportation system.

1.1.2 Background and problem statement

The international community has actively scaled up the discussion on the need for sustainable, safe, inclusive, efficient and resilient urban transportation which has provoked cities to address mobility challenges as a matter of urgency. In a bid to shift from the inefficient and highly polluting transportation modes, cities, especially in the European countries, have invested heavily in sustainable, low carbon modes with more than 87% of city dwellers having access to public transportation and active transport modes; walking and cycling (Poelman et al., 2020). In African cities, however, rapid urbanization has continued to pose critical questions for sustainable mobility. The transportation sector has been seen to contribute 26% of the continent's carbon (CO_2) emissions. This has been fuelled by the anarchic demand for mobility in the fast-growing cities which has been accompanied by a rapid increase in unregulated self-organizing paratransit industry, automobile ownership and highly polluting intermediate public transport (IPT) (Klopp et al., 2019; Ponodath et al., 2018; Sims et al., 2018).

In response to this, local and international capital investments have been directed to the transportation sector to stimulate public transport reforms in Africa. Initial investments prioritized highway construction; a supply-driven approach that subsequently gave precedence to the cars (International Road Transport Union, (IRU), 2016; Porter, 2007 cited in Klopp et al., 2019). Owing to the global pressure to sustain transportation systems, recent transport investments have been directed to the provision of mass transit evidenced by the increased Light Rail Transit (LRT) and Bus Rapid Transit (BRT) networks (Klopp et al., 2019; Liu et al., 2018). Kenya, East Africa has had a protracted public transport provision process but has not been completely left behind in these continental advancements. It recently commenced the operation of an intercity Standard Gauge Railway (SGR) commuter train and is in the process of implementing 5 proposed Bus Rapid Transit (BRT) lines in the Nairobi Metropolitan Region (NMR). Despite these efforts to improve mobility; road fatalities, private motorization, congestion, car dependency and highly polluting two/three-wheelers still dominate and have become burdensome for Nairobi and other cities in developing countries.

Heavy investments in mass transit have still not enticed people to patronize public transportation due to the failure to achieve seamless connectivity to the First Mile and Last Mile (FMLM) from transit (Liu et al., 2018; Scheltes and de-Almeida-Correia, 2017). People's movements in urban areas are not limited to happen between two mass transit stops, they exhibit scattered travel patterns. Livelihood opportunities and settlements tend to be located a distance from the transit hubs and thus commuters have to walk, cycle, drive or use alternative methods to move to, or from the transit hub. This makes the FMLM concept indispensable. Inaccessibility of the first and last mile weakens public transportation and impedes its ability to compete with the car (Krygsman et al., 2004; Wang and Odini, 2012 cited in Scheltes and de-Almeida-Correia, 2017).

Box 1: The Criticality of FMLM in Sustainable Urban Transport

Majority of the trips in cities are multimodal; use more than 1 travel mode. In the Nairobi Metropolitan Region, 63% of the trips are made using public and paratransit modes **but** passenger **cars are used to complete 54% of these trips**, while the rest of the trips are completed by the **emergent motorcycles (13%)** and a few by **foot (17%)** (JICA, 2013 cited in World Bank, 2016).

The transportation modes adopted for the **first and last stage of a passenger's trip are often unreliable**, costly and inflexible. This has been seen to cause high disutility of the public transportation modes (Krygsman et al., 2004; Scheltes and de-Almeida-Correia, 2017).

Although **public transport is core of most users' trips**, **it is unable to provide critical door-to-door travel needs to every corner of a city** (Fan et al., 2019; International Association of Public Transport, UITP, 2019).

For sustainable urban transport, mass transit is essential but a gap in the initial and final leg from transit still remains. **First and Last Mile options are thus required to create efficient accessibility of the distance before and after the core part of a trip** (European Environment Agency, 2020).

The value attached to the first and last leg, which is an integral part of transit in cities is highly polarized. In developed countries, multimodal transport is dominant which has triggered prioritization of non-motorized transport and other low polluting modes to complement mass transit. By contrast in developing countries, the first and last mile from public transit has continually been overlooked in transportation planning. It has been viewed to represent short distances and thus is treated as a minor stage in transportation, often left at the mercies of unregulated IPT[1] service providers. However, urban transportation is complex and requires a critical analysis of each component and its impact on the entire system. An exhaustive systems-thinking of the transportation system reveals that the effects of the initial and final leg (FMLM) are not only relevant for shorter distances but also significantly influence the modal choice for longer distances in cities (Fan et al., 2019; Liu et al., 2018).

Poor FMLM accessibility in the Nairobi, Kenya has made public transit unattractive, inaccessible and sub-optimized. As a result, urban communities have become more auto-oriented, opting for eco-unfriendly modes such as non-scheduled low-capacity vehicles, private cars, motorcycles and rickshaws to connect to origins and destinations. Although Nairobi City has the highest share (41%) of walking trips among African cities, high motorization trends are observed with 42% of trips being made using paratransit modes and 17% using private cars and motorcycles (JICA, 2013 cited in World Bank, 2016). The inaccessibility of the FMLM has forced people to use automobiles too much which in turn is "too much for the climate, people's pocketbooks, environment-congestion, people's time", as urbanist Peter Calthorpe puts it (Kunzig, 2019).

[1] IPT - Intermediate Public Transport

It is against this backdrop that this research seeks to assess the impact of FMLM accessibility on the share of automobile traffic and emerging motorization patterns in the Nairobi Metropolitan Region (NMR). The research draws focused attention to the Ruiru bypass zone; a mixed-use zone with a higher predominance of residential uses. The zone encompasses 3 neighbourhoods of distinct income and social character and is thus representative of the City region's demographics. The research reckons that mere provision of mass transit is not sufficing to sustain urban transportation and to deter commuters from using private cars and low-capacity IPT modes. The systematic challenges in urban transport require urban planners and policymakers to shift attention from highways and devote more time and resources on connecting people from the doorstep, which is where travel decisions are made. Identifying the FMLM gaps and bridging them can substantially boost the shift towards sustainable travel modes in cities and simultaneously yield economic, health, social, and environmental benefits (Kanuri et al., 2019).

1.2 Relevance of the research topic

Transportation in developing countries is slowly shifting towards mass transit. However, the transition is far from achieving sustainable mobility. Highly polluting motorcycles and rickshaws are still mushrooming, and overdependence on private motorization is still growing. It is increasingly pronounced that as cities grow, urban transportation will continue to become a serious, rapidly increasing threat to sustainability and there is need to draw deliberate focus to the leverage points that will trigger a systemic change in the urban transportation system (European Environment Agency, 2020; International Road Transport Union, (IRU), 2016). The focus of this research on first and last leg from transit will hereby contribute to an integral paradigm in sustainable urban mobility planning which will be particularly relevant for planning authorities, policy and decision-makers in cities to ensure mobility is more rational and coherent. Moreover, paying attention to FMLM in transportation planning will offer travel options and solutions for daily short-distance trips which are also of essence to urban residents.

Scrutinizing how people move about, their connectivity to the first and last mile and the consequent modal choices will enrich the transportation's body of knowledge by contributing great insights on drivers of increased private motorization, understanding travel patterns, impediments to the primacy of low carbon modes, transport multi-modality and improving mobility in cities (Liu et al., 2018).

1.3 Research Objectives

This research views FMLM as a neglected aspect whose impact on urban mobility is underestimated. The objective hereby is twofold;

i. To assess the accessibility of the first and last mile from transit in order to identify the logistic concerns of commuters in the initial and final stages of their trips.
ii. To evaluate the impacts of FMLM accessibility on modal share and motorization patterns in the TAZ and the Nairobi Metropolitan Region, Kenya.

1.4 Main, overarching research question

The **principal** research question for this study is: To what extent does accessibility to the first and last mile of a trip affect modal share and the motorization patterns in Ruiru Bypass zone, NMR Kenya?

1.4.1 Research sub-questions

- **a.** What share of the population can public transport services reach within a Mile (1.6Km) and 2 miles (3.2km) radius and what is the character of these households?
- **b.** What is the network character and traffic modal variability in the first and last miles in the selected Traffic Analysis Zone (TAZ)?
- **c.** What is the average time spent and the financial cost incurred in covering the FMLM and the line-haul?
- **d.** How does the FMLM gap affect the first-mile, line-haul, and last-mile travel mode adopted by commuters?
- **e.** What motorization patterns have FMLM choices induced in the City and how can they be controlled?

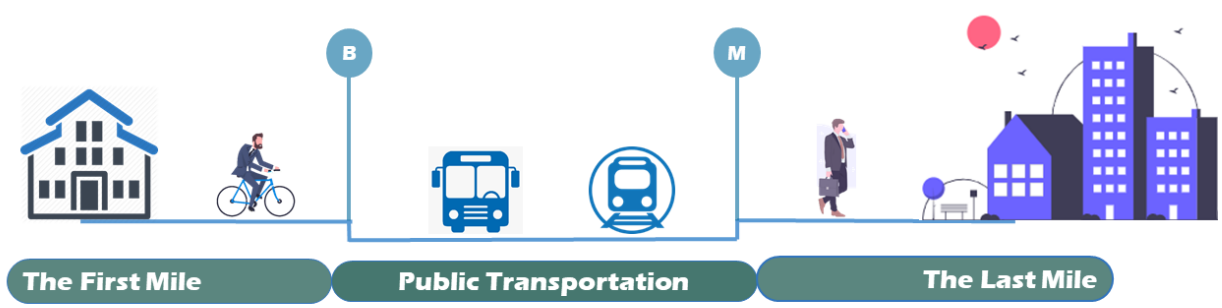
Chapter 2: Literature review

This chapter presents an exhaustive review of literature that provides indispensable insights on the state of knowledge, interpretation, and essential prognosis about the subject of study. The chapter kicks off by elucidating the main concepts related to the study (section 2.1). The independent variable, which is a fairly new concept in the passenger transport domain is then introduced with a reflection of how it has evolved (section 2.2). The micro- and macro-level dimensions applied in previous research to link the independent and dependent variables are then discussed in section 2.3-2.4. Significant theories (section 2.5) with particular pertinence to the variables rooted in the principal research question are also discussed. Based on these theories, section 2.6 highlights the indicators of FMLM accessibility and the sub-variables of urban motorization patterns. It is further acknowledged that there is a pre-eminent synergistic effect of FMLM and public transportation (section 2.7) which has motivated researchers to develop innovations (section 2.8) to leverage this synergy. The chapter concludes by providing a theoretical framework (section 2.9).

2.1 Operational terms

First Mile Last Mile (FMLM): In a layman's language, this is the First and Last leg from public transit. Technically it is the access and egress distance from public transport (Krygsman et al., 2004). The bottom line of FMLM is in reference to passenger travel in the context of getting to or from public transportation hubs. Comprehensively, FMLM can be defined as the first and last segment of a journey, denoted by the access distance; from trip origin to the public transit station, and the egress distance; from the transit station to the final destination (Fan et al., 2019; Kanuri et al., 2019; Krygsman et al., 2004; Li et al., 2019; Liu et al., 2018). "First mile" and "Last mile" may be used interchangeably depending on the direction of movement; departing origin and arrival at destination respectively. Although the concept embodies the "mile" element, the actual distance of the first and last leg can be more than a mile.

Figure 1: Illustration of the FMLM concept



Source: Author, 2020

Accessibility: Accessibility in the transportation domain refers to the presence and affordance of transport; in other words the physical and financial access to transportation. Assessing the accessibility potential in this study adopts the geographical dimension which refers to the relative ease of travel to a particular location and takes into account the physical ability to reach destinations (Litman, 2017).

Line-haul: The term as used in this study refers to the core segment of a commute trip (Tilahun et al., 2016). It is the section of the journey between two transit terminals.

Sustainable transportation: This is visionary transportation which; ensures safe and reliable accessibility, lowers financial and environmental costs to society, promotes equity, minimizes automobile dependency, offers multimodal transportation, minimizes resource consumption, and minimizes emissions (Center for Sustainable Transportation, 2005 cited in Hati, 2020).

Public transportation: This is simply defined as any mode of transport that is available to serve the travel needs of the members of the public, and is usually provided by scheduled bus, rail, metro/subway, and shuttle systems. The term is used interchangeably with "mass transit". (Klopp et al., 2019) argues that some public transport systems especially in developing countries could have flexible schedules and routes with less formalized operation structures, and are popularly known as paratransit systems. In this study, the term public transportation will represent these two dimensions. Public transportation services are often provided at a fee although some countries like Luxembourg are now providing free public transport.

Intermediate Public Transportation (IPT): This refers to a paratransit service comprised of ad hoc informal travel modes that offer connectivity of origins and final destinations from the public transport networks (Ponodath et al., 2018). They often emerge as commercial enterprises that aim at filling in mobility gaps of the public transportation systems.

Active transportation: These are modes of transport that rely on an individual's energy and power for movement and may include modes such as cycling and walking (Partnership for Active Transportation, 2014 cited in Liu et al., 2018).

Modal integration: This refers to the complementarity between transit and other modes of transport.

Motorization patterns: This is an area's transportation culture that reflects the main transport modes used in the area, with the typology being based on the modal share of 3 basic transportation modes; non-motorized (walking, cycling), cars and public transport (Ohta, 2017).

2.2 Evolution and state-of-the-art of FMLM

Conceptualization of the FMLM concept was originally inspired by the "Last Mile" concept which is primitively allied to logistics distribution and supply chains, denoting the last segments of a freight distribution trip (Boyer, 2009 cited in Liu et al., 2018). FMLM in the transportation domain gained immense popularity in the 2000s, under cognizance that commuters in cities incline towards public transport when its completeness in connecting origins to final destinations is assured (Bruntlett and Bruntlett, 2018). The FMLM ideology may be a fairly new parlance in sustainable urban transport planning, but the rationale behind it has been developed copiously by different transportation scholars (Cervero, 2001; Keijer and Rietveld, 2000; O'Sullivan and Morrall, 1996 cited in Krygsman et al., 2004).

The dire need to provide efficient, reliable, equitable, and environmentally-friendly transportation in cities has long since pushed attention towards public transportation as a substitute for highly polluting private transportation modes. The International Road Transport Union, (2016); Liu et al., (2018) and Klopp et al., (2019) observe that heavy investments have over time been dedicated to mass transit in developing and developed countries. Despite this heightened focus, public transportation remains weak due to the step-motherly treatment given to the accessibility of the first and last miles from transit (Krygsman et al., 2004; Liu et al., 2018; Ponodath et al., 2018). The missing link between transit hubs and other transport modes which offer door-to-door access dissuade commuters from utilizing public transport and instead encourages use of private vehicles and unprecedented high demand for IPT services provided by rickshaws, motorcycles, taxis, Single Occupancy Vehicles (SOVs), cycle rickshaws, scooters and minivans (Ponodath et al., 2018).

The FMLM significantly draws attention to the cost, connectivity, efficiency and logistic-challenges experienced by potential and actual users of public transit and paratransit in the first and last mile of their trip, which then affects their modal choice (Fan et al., 2019; Liu et al., 2018). It has been seen to hold great potential to induce higher public transport utility (Krygsman et al., 2004; Liu et al., 2018), shifts from private car use (Kanuri et al., 2019) and physical and environmental health (Liu et al., 2018). To cash in on this potential, cities are now implementing reactive measures to enhance first-mile last-mile accessibility. Fan et al., (2019) highlights that due to its vitality, this concept has secured ample attention in some developed countries which have put in place infrastructure and programs that support low carbon access to transit. These include the European "Bike-Train-Bike (BiTiBi)" model, Chinese "Bicycle Sharing System (BSS) program", Atlanta-Georgia's "Bike to Ride" program, and San Francisco-California's "Walk-and-Ride" et cetera (Bruntlett and Bruntlett, 2018; Cervero, 2001; Fan et al., 2019).

Scholars observe that these measures are still confined and have not populated all cities. Consequently, the FMLM problem still prevails, with these journey segments being typically characterized by long physical distances, limited road widths, dissuading streetscapes, poor modal integration, and lack of access to terminals (Fan et al., 2019; Tilahun et al., 2016). The general theoretical consensus, however, is that FMLM is a critical component in the urban transportation chain and can be leveraged to influence sustainable urban travel patterns. Prompted by this, scholars have explored mobility in the first and last miles at the micro- and macro-level to instigate modal shifts from high polluting low capacity modes and to increase the attractiveness of alternative sustainable modes of travel.

2.3 Micro-level scrutiny of FMLM

2.3.1 Modality assessment

The first and last mile is a segment in trip analysis that has stoke up interest among scholars, technicians and entrepreneurs. As Tilahun et al. (2016) observe, distances to and from transit stations are often undesirable for people to walk or cycle which ignites attractiveness for automobiles and alternative feeder services. This scenario has created a niche for micro-level assessments that have solely focused on the mobility options that arise in the FMLM. On this level of research, FMLM has been viewed and analysed with reference to modal choices available and their users, but in isolation from the overall transportation system in cities.

Structurally diverse modes of transport have been seen to mushroom owing to high mobility demand in the initial and final segments of trips (Ponodath et al., 2018). Scholars acknowledge the existence of both non-motorized modes such as walking and cycling and motorized modes such as small cars (taxis), auto-two/three-wheelers, minivans and other paratransit modes, each with its advantages and shortcomings (Fan et al., 2019; Kanuri et al., 2019; Li et al., 2019; Ponodath et al., 2018). Traditional logit models have been applied to identify single dominant variables that explain how commuters make modal choices. Palma et al., 2000 and Paulssen et al., 2014 (cited in Li et al., 2019) use logit models to analyse the impact of vehicle ownership and values/ethics respectively, on the travel-mode choices. These models simplify modality as a binary outcome, to wit; commuters will choose a certain mode of transport depending on whether they own a car or not (0/1). The complexity of modality is however later implied by multi-nominal logit models (MDL) containing multiple categories, for example; Ding et al., 2017 (cited in Li et al., 2019) evaluates how car ownership, travel distance, and the built environment affect modality in the first and last miles. With authors exploring and introducing new variables of FMLM modality as shown in table 1 below, the concept is deemed to become more complex;

Table 1: Additional variables of FMLM modality

Variable	Subjects	Source
▪ **Socio-economic characteristics**	Commuters	(Fan et al., 2019)
▪ **Economic cost of travel modes**	Commuters and service providers	(Li et al., 2019)
▪ **Travel demand**	Service providers	(Scheltes and de-Almeida-Correia, 2017)
▪ **Real-time information and travel time**	Commuters and service providers	(Kanuri et al., 2019)
▪ **Nature of streetscapes**	Commuters	(Tilahun et al., 2016)

The competitiveness among different modes is apparent but the link between this modality and travel behaviours in the entire urban transportation system remains vague at this micro-level of research. Further, the independent focus on the modality in this segment of a trip portrays FMLM as an end in itself, although practically FMLM is an element within a larger urban transportation system that operates interdependently with other transportation elements (Ponodath et al., 2018).

2.4 Macro-level scrutiny of FMLM

2.4.1 The FMLM problem for public transit

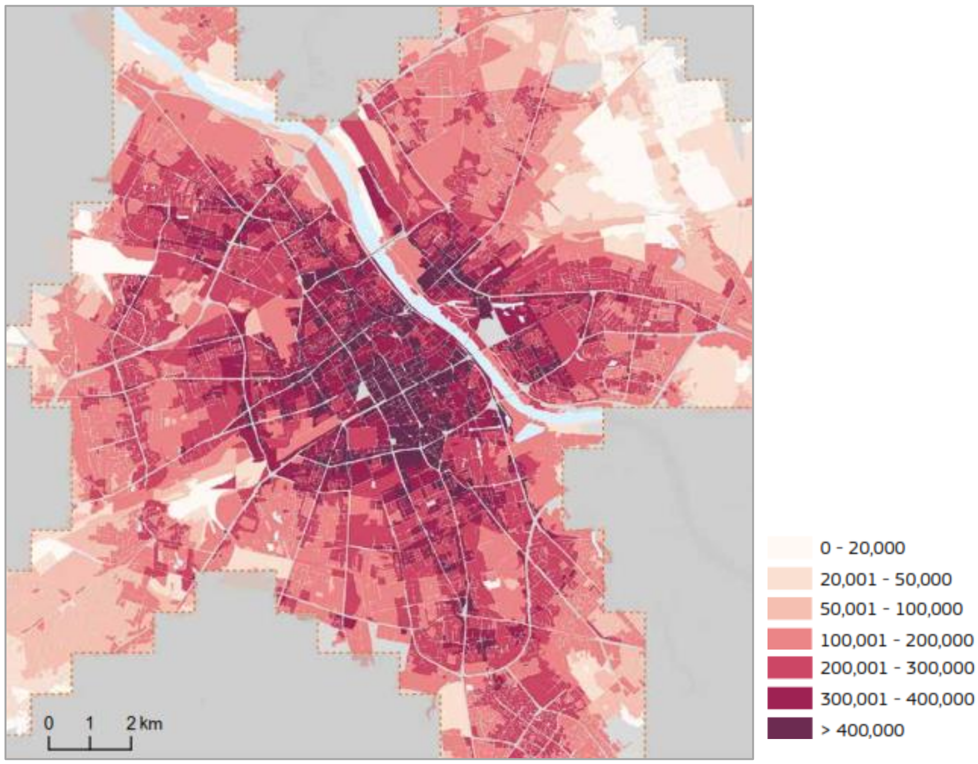
The macro-level of research attempts to diagnose the line-haul mobility challenges. At this level, public transportation garners special attention. It is univocal that public transport offers sustainable and environmentally sensitive mobility (Krygsman et al., 2004). However, public transport systems require heavy capital investments and only become worthwhile investments based on utilization. The recurring theme pertaining to this is how public transportation in itself can reach optimal utility. Consequently, a voluminous literature has been developed targeting different aspects of public transportation; (Liu et al., 2018; Poelman et al., 2020) assess public transport accessibility (PTA), public transport convenience - (Krygsman et al., 2004), public transport ridership - (Kanuri et al., 2019) inter alia. Although public transportation planning is rapidly picking up in developed and developing nations, scholars observe that it is often planned with the perspective of station-to-station instead of door to door, causing dilemmas at the transit stations for commuters (Bruntlett and Bruntlett, 2018).

Prevalent research has put emphasis on the transit mainline corridors and paid little or no attention to the catchment zones surrounding the transit stations, which have become the weakest part in the public transport chain contributing significantly to disutility (Krygsman et al., 2004). This orientation of research insinuates that urban trips originate and terminate along major public transport lines. However, empirically; the morphology of cities, rapid population increase, and the cost of land have substantially affected the settlement of urban communities towards or away from transit networks and stations. The distance of settlements from public transit hubs has been seen to increase as evidenced by 5 times increase in the Weighted Urban Proliferation (WUP[2]) from 1880-2015, and has further increased FMLM distances and consequently aggravated the

[2] WUP – Indicator for measuring urban sprawl

accessibility challenges in cities (European Environment Agency, 2020; Krygsman et al., 2004). Poelman et al., (2020) evaluate PTA in European cities and find out that public transportation reaches only 24% of the population within a 7.4km radius (30-minutes journey) and 54% within 11.25km (45-minutes journey). This is an indication of majority of human settlements being established away from transit hubs, which interestingly raises the question of how these residents reach transit stations.

Map 1: Public Transport Accessibility (PTA) within 30 minutes in European cities



Source: (Poelman et al., 2020)

Typically, public transport systems are designed for long-distance trips and usually involve large investments in construction, operation, and maintenance. Owing to these costs and its communal nature, it is unable to provide door-to-door services to all urban residents in all corners of a city (Fan et al., 2019). Consequently, the first and last mile becomes requisite as it provides a connection to/from public transport stations. The relationship between FMLM and public transport is reciprocal; failure of public transit to connect trip origins and culmination points yield FMLM inaccessibility, on the other hand, FMLM gaps continue to become a barrier to public transit ridership (Fan et al., 2019; Liu et al., 2018).

Planning for sustainable transportation needs not to treat FMLM as an afterthought, rather it should be integrated simultaneously with public transit to ensure well serviced end-to-end connectivity (Tilahun et al., 2016). Ponodath et al., (2018) analogize FMLM and public transport to the human anatomy with public transit as a skeleton, complemented by its veins and capillaries which in this scenario is the FMLM connectivity. An efficient urban transportation system ought to pay equal attention to FMLM as given to public transport. Also, notably, previous research has used FMLM accessibility as an indicator of public transport performance but the impact of this concept to other modes of transport and mobility patterns in cities has not been assessed explicitly.

2.4.2 FMLM - Motorization Affiliation

Macro-level research has also paid attention to rising motorization in cities. When the term motorization is floated, thoughts are immediately directed to private car use. However, patterns linked to motorization go above and beyond car ownership. Motorization patterns observed in cities reflect complex, evolutionary, repetitive modal decisions made by commuters (Li et al., 2019). Some commuters choose multimodal options that combine public transport and other modes, while others opt for unimodal alternatives which are dominated by private automobiles and involve less physical effort (Krygsman et al., 2004). In understanding the development of motorization, cities are seen to undergo 3 conventional stages;

Figure 2: Dominant stages of motorization

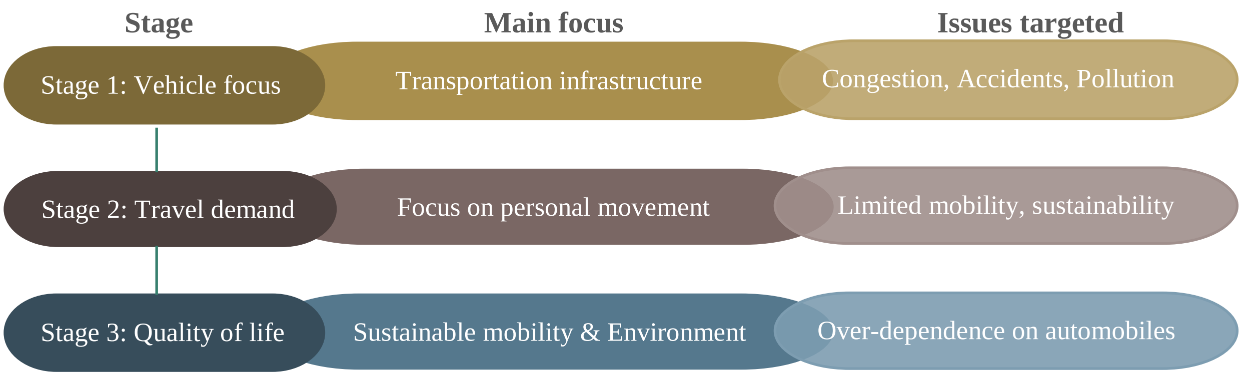
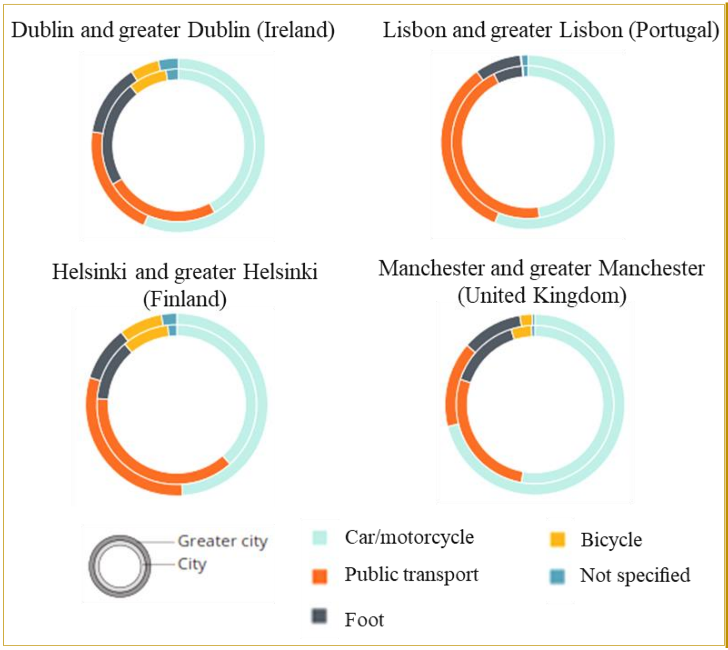


Figure by the author; data sourced from (Ohta, 2017)

At every stage, the modal choices of commuters have a direct impact on transit and automobile travel. Despite heavy investments in public transportation in cities, demand for alternative modes of transport to handle journey trips overlooked by transit is still on the rise (Ponodath et al., 2018). This has resulted in dynamic modal share in the first and last miles of urban trips and limited the ability of transit to compete with the car (Scheltes and de-Almeida-Correia, 2017). The FMLM challenges affect both the consumers (commuters) and suppliers (transit service operators), making motorization in cities more complex and diverse than never before. For commuters, poor accessibility to the first and last mile forces them to encounter multiple transfers, dig deeper into their pockets (financial), spend more travel time, and be reliant on automobiles. Transit operators on the other hand suffer a decrease in passenger flows, sporadic travel flows, and stiff competition from automobiles (Fan et al., 2019). Scholars observe that sustainable modal share in cities requires efficient public transportation services for the line-haul and reliable, environmentally-sensitive feeder services for the first and last miles. The failure of cities to achieve this has seen a rapid increase in two/three-wheelers and a surge in automobile modal share (Fan et al., 2019). Statistical evidence reveals such motorization trends in some European cities as shown in chart 1 below;

Chart 1: Modal split in selected European cities



In the 4 selected cities, the shift from private motorization to mass transit has not yet picked up as intended. A lagged response towards mass transit is apparent, with the car typically taking a larger share, but this significantly differs between the city core and the periphery.

In the core, the public service quality is perceived to be better and complemented by walking and cycling. Connectivity to public transport in the peripheries is however relatively low, explaining the low modal share of public transport and increased private cars and motorcycles (European Environment Agency, 2020).

Source: (European Environment Agency, 2020)

Admirable efforts by cities to bridge the FMLM gap through provision of sustainable, low carbon feeder modes such as cycling has resulted in an appreciable decline in the use of automobiles for short trips. Fan et al., (2019) observes that in Chinese cities, provision of bicycles as an active mode of transport to access and egress transit resulted in a 3.2% decline in automobile travel, considerable reduction in traffic congestion, and adoption of sustainable transportation modes for short-mile travels. Cities like Los Angeles by contrast have witnessed an increased use of automobiles in the FMLM, which is predicted to account for approximately 66% of GHG emissions (Hoehne and Chester, 2017). This is deleterious for the environmental and physical health of urban residents. Such motorization patterns may protract the city's efforts towards achieving sustainable transportation. A dearth of data and comprehensive studies that link FMLM to modality and motorization in the line-haul and short-mile travel simultaneously is however observed. This reflects the failure of scholars, practitioners and local governments to identify the lowest-hanging fruit in the quest to meet transport targets of the Sustainable Development Goals.

2.5 Theoretical underpinning of the FMLM problem

Understanding the complexity of the FMLM challenge in contemporary cities has driven authors to apply multifaceted models and theories to unravel this teething problem. The quest of most theorists has been understanding modality in the first and last miles and the impact of modal choices on the line-haul travel mode. Park (2008) in his "Critical Walking Zone" theory noted that physical components such as walking distance and path walkability considerably affect the use of active transportation to access and egress transit. The theory indicated high modal-choice-variance between distances of 0.5 and 1.5 miles from the transit station revealing that modality of the FMLM changes significantly with the distance from the station (Park, 2008). The latter is supported by the "Catchment Area Theory" which articulates the impacts of the built environment on FMLM accessibility. It holds that - due to small transit catchment in high-density neighbourhoods, commuters are more likely to walk to access transit but the large transit catchment in low-density suburbs prompts commuters to use private automobiles either to connect to transit or as the line-haul travel mode (Cervero et al. , 1995).

Conversely, Walton and Sunseri (2010) in their theory on walkability suggest that distance to transit stations, travel time, carriage of heavy luggage, and concerns of crime are of less importance in understanding why people use mechanized modes instead of walking short distances to the transit station. This theory is however contested by empirical evidence from theorists who underscore distance, time, type of transit mode available, the character of the road network, topographical characteristics, and availability of stops and stations as key factors affecting walk trips (Daniels and Mulley, 2013). These additional factors elucidate preference of walkability for FMLM connectivity but still leave some gaps in understanding general modal decisions in favour of NMT or motorized modes in the first and last miles.

Tilahun et al. (2016) later developed a discrete choice model, which combines different configurations to assess how the built and social environments affect the travel behaviours in the first and last miles. This multipronged theory integrates physical and social dimensions highlighted independently from the previous theorists. It views commuters as rational utility-maximizing individuals who make modal choice decisions based on various attributes of the first and last mile. By combining open source datasets; socio-demographic data, transit service data, traffic and parking data from OSM, GTFS and Census Bureaus, the author computes commuters' personal variables, travel time and out-of-pocket costs (expressed as a percentage of the income) which turn out to be important considerations for selection of travel modes. The personal variables include gender, age, household size and car ownership, while out-of-pocket costs include fare costs, vehicle operation cost and parking cost (Tilahun et al., 2016). A key social factor also introduced in this theory is safety. Tilahun et al. (2016) proves that crime prevalence along mobility routes deters the use of non-motorized alternatives which would expose commuters to street-level crime, and instead increases the attractiveness of private automobiles and ridesharing. The theorists substantiate that physical, social and mode-specific attributes influence the travel mode preferences, with a consequent effect on motorization patterns in cities.

2.6 Measuring FMLM accessibility in cities

Prior research and the extensive body of literature analysed identifies myriad parameters that can be used to assess the FMLM accessibility of commuter trips. The parameters can be categorized into 3 broad groups; physical environments, modal environments, and social environments.

2.6.1 Physical environment indicators

This category consists of the physical and built environment characteristics that are associated with the mobility routes used to access and egress transit. The proximity of origin and destination points to the transit stations is a key factor that determines the accessibility of the access and egress from the line-haul (Tilahun et al., 2016). In areas where public transportation is the line-haul travel mode, proximity is derived through a measurement of the **travel distance** in the catchment zones surrounding transit stops. It should be keenly noted that the catchment area is a function of modes of travel. Conventionally, the action area_radius for transit varies considerably across different modes of travel as summarized in table 2 below;

Table 2: Catchment area of different travel modes

Travel mode	Catchment Area	Source
∇ **Walking**	< 0.25 – 1 mile (< 0.4 – 1.6 Km)	(Daniels and Mulley, 2013; Zuo et al., 2020)
∇ **Cycling**	0.3 – 2 miles (0.5 – 3.2 Km)	(Fan et al., 2019; Zuo et al., 2020)
∇ **Paratransit feeder services**	1.24 -3.73 miles (2 – 6 Km)	(Smith, 2016)
∇ **Cars**	≥ 4.35 miles (≥ 7 Km)	(Smith, 2016)

The catchment area in mobility reflects the area within the vicinity of a public transport stop or station and is commonly determined by the passenger's willingness to walk (Andersen and Landex, 2008). An increase in the FMLM distance substantially reduces the attractiveness of public transport and instead paves way for the readily available low capacity intermediate public transport modes, private vehicles, and two/three-wheeler automobiles. It further dissuades commuters from using active transportation modes (Daniels and Mulley, 2013). Commuters tend to adopt active modes when the access distance is below 2 miles but opt for automobiles when the distance more than 2 miles up to a maximum of 3 miles (Zuo et al., 2020). In a city, therefore, the share of the population that is settled beyond this catchment area have less access to public transport and may be inclined to use automobiles for the FMLM or even for the entire trip.

Another traditionally popular measure in this category is the **mobility route profile.** Route profile incorporates material elements such as infrastructural attributes and soft elements such as safety and aesthetics, which considerably affect physical connectivity and the level of accessibility of the FMLM (Tilahun et al., 2016). These can be determined through the length and size of roads, quality of individual links, nature of streetscape, support infrastructure provided, traffic composition, safety (both from traffic and crime) (Li et al., 2019; Park, 2008). Daniels and Mulley (2013) observe that landscaping elements of a street have less influence on accessibility as compared to the other aforementioned factors. The availability of transportation infrastructure, however, is seen to be critical in determining intermodal connectivity and shaping commuters' rational modal choices (Zuo et al., 2020).

2.6.2 Modal environment indicators

These refer to characteristics associated with different modes of travel availed in the FMLM. A key measure here is **modal split**, a quantitative indicator representing the percentage share of each mode of transport within a selected geographic boundary. It reveals how many passengers use a particular mode of transport, making it requisite for travel demand modelling.

Variability of travel modes is also a key measure that refers to the availability of more than one mode of transport in a particular route. Travel modes available in the first and last miles are broadly categorized into contract carriages, personal modes, and informal public transport. The configuration of the 3 categories affects the level of accessibility of the initial and final leg from transit (Ponodath et al., 2018). Contract carriages are flexible and available on-demand but their travel prices are highly oscillating. Personal modes are also flexible but the individual, societal and environmental costs attached to the motorized modes are very high. Informal public transport on the other hand has tentatively fixed routes but is inconsistent, unruly, and fragmented.

Figure 3: Dominant FMLM travel modes

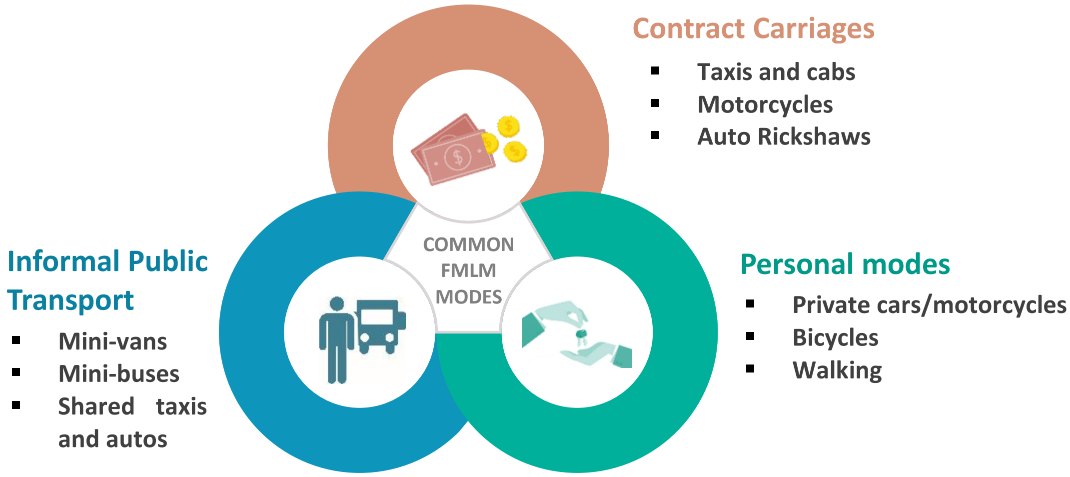


Figure by author; data sourced from (Ponodath et al., 2018)

Assessing accessibility in terms of modal integration is important to understand the options available for commuters and how they are connected to line-haul since modal decisions are made 'at source' with visible outcomes in the motorization patterns in cities.

Another conventionally applied modal indicator is **travel time.** The absolute time (expressed in minutes) required to cover the first and last miles varies significantly across non-motorized and motorized modes. Tilahun et al. (2016) notably identifies travel time as a usual determinant of modal choice. It is further highlighted that absolute accessibility can be defined as the population that can be reached within a fixed maximum time (Poelman et al., 2020). Commuters shun travel alternatives that have high travel time and patronize travel modes that save them time (Tilahun et al., 2016). It is worth noting that accessibility is not just a function of the absolute FMLM travel time but also of the relative share of the entire trip time. This is technically expressed as the ***interconnectivity ratio***, defined as the expression of the travel time spent on the first and last mile as a proportion of the entire trip time (Krygsman et al., 2004). The temporal impacts of the first and last mile of a trip can thus be comprehensively revealed by analysing the comparative relation between absolute travel time for the first or last mile and the total travel time for the whole trip.

The final modal indicator is **economic travel cost,** which typically characterizes the ease of travel by different modes, expressed by a cost function (Liu et al., 2018). The physical availability of different feeder services does not exclusively reveal accessibility to the first and last mile. The modes may be available but the relative financial costs attached to them limit their accessibility (Tilahun et al., 2016). Economic parameters hereby greatly influence the nature of connectivity between transit hubs and travel origins and destinations. The perceived travel costs are often dependent on the time spent in the travel mode used and the number of people that it can accommodate (Li et al., 2019).

Through the evolutionary game model of modal choice, theorists reveal a solid relationship between economic costs of travel and modality in the last mile by quantifying financial costs incurred by commuters who adopt different travel modes (Li et al., 2019). It is perceptible that the higher the perceived costs of a particular travel mode, the lower the modal share and vice versa. Supremely, the intensity of the cost parameter in the FMLM is felt when compared to the overall costs of the entire trip. This dimension is applied in a last-mile study in Delhi, where the FMLM constitutes only 18% of the total trip journey but disproportionately accounts for 48% of the travel costs incurred (Kanuri et al., 2019). Apart from the monetary costs, commuters may also incur other costs in terms of discomfort, time lost during transfers, delays, and waiting costs depending on the modes adopted (Keijer and Rietveld, 2000).

2.6.3 Social environments

Critical evaluation discerns that social-environment factors significantly affect the zero-order relationship between FMLM accessibility and modal share. Mobility patterns are often an expression of a complex decision-making process resulting from commuters' individual considerations. Fan et al, (2019) acknowledges the effect of age on the mode adopted by commuters with significant differences being observed in the mobility patterns of the young, middle-aged and aged/senior adults. Furthermore, male commuters are seen to prefer cycling more than their female counterparts (Tilahun et al., 2016).

Prior studies further reveal the significant role of household characteristics. In families where an automobile is available, the likelihood of non-motorized modes being used to access transit is substantially low while auto-use records the highest odds. Additionally, commuters from large families are more likely to choose shared rides over walking (Tilahun et al., 2016). Notably, the effect of income in the context of FMLM has not been considered to a great extent despite the cognizance that commuters with higher incomes have higher demands for transport services and that a commuter's primary travel-mode is a demonstration of their willingness to pay for transportation services (Daniels and Mulley, 2013; Fan et al., 2019).

The evaluation of commuter profiles hereby suggests that **age, gender, family size, automobile ownership, and income** habitually affect travel behaviours and modal share across active transportation modes, automobiles, and public transport. The correlation between the level of accessibility and motorization patterns is therefore not a direct link, it is moderated by these social environments which vary significantly in the catchment areas of public transport. Theorists argue that travel-mode choice is mainly a function of modal variables and less of socio-demographic variables. Their explanatory power is rather limited but their interaction-effect is pronounced (Krygsman et al., 2004).

2.7 Synergies from FMLM - Public transport integration

Pursuant to previous discussions, public transportation is not self-sufficient to offer door to door urban mobility. It is complemented by different FMLM modes to ensure that transit is accessible and is well connected to the user's final destination. With the integration of the two systems, urban transportation benefits from various synergistic effects as explained below:

- **Sustainable and resilient multi-modal networks**

The strength of a sustainable transportation chain is in its efficiency and its functionality in the context of multimodal networks, yet apparent weak links between access/egress and line-haul continue to enfeeble urban transportation in cities (Keijer and Rietveld, 2000; Krygsman et al., 2004). The sustainability and resilience of urban transportation is not how public transport and FMLM operate in isolation but how they superbly complement each other. Tilahun et al. (2016) notes that there is a high potential to achieve high returns from transit by enhancing convenient and safe access and egress from transit hubs.

FMLM facilitates the accessibility and utilization of public transportation. In countries like China, efforts to provide low carbon FMLM accessibility through cycling programs have been seen to increase public transport attractiveness, with 5.5% of automobile users shifting to public transportation (Fan et al., 2019). The scope of the FMLM benefits is twofold; at the city level and local neighbourhood level. Apart from improving public transport ridership in the city, the modes provided to bridge the first and last-mile gap serve as a convenient travel option for middle- and short-distance trips at the neighbourhood level, thus substituting the car (Fan et al., 2019).

Moreover, it is ordinary for public transportation to experience disruptions or hitches during operation. In such scenarios, FMLM travel modes can come in handy as alternative mobility options, thus increasing the resilience of the urban transportation system. This has been proven empirically in cities like London, where FMLM travel modes are used by commuters to connect to the intended destinations in the event of technical failure in public transit (Fan et al., 2019).

- **Breaks the vicious automobile-dependency cycle**

Reliable public transportation complemented by improved FMLM accessibility ensures end-to-end connectivity of trips which cuts off the need for private automobiles. A striking impact of enhancing FMLM accessibility in both developed and developing countries has been the modal shifts from the use of personal vehicles to active transport modes and public transportation. Fan et al. (2019) observed that introduction of cycling as a feeder service in the first and last mile of commuter trips in Montreal and Washington D.C, reduced automobile ownership by 3.6% and 2.1% respectively. A similar trend is observed in Bangalore, India where FMLM connectivity through new mobility enterprises induced a 43% modal shift from personal car use (Kanuri et al., 2019).

- **Reduced number of transfers**

FMLM accessibility allows commuters to travel seamlessly to/from transit stations. Integrated FMLM and public transportation thus eliminates sub-optimal efficiencies and minimizes stressful passenger transfers, which saves commuters time and money (Kanuri et al., 2019). Based on the notion that a majority of urban trips involve one or two transfers, it is recommended that 3 is the maximum number of transfers for an entire commuter trip (Liu et al., 2018). Transfers are a major motorization pattern that define the efficiency of multimodal transport.

- **Personal and Environmental health**

The heightened awareness for global health by WHO requires individuals to engage in 60-150 minutes of physical activity based on age (European Environment Agency, 2020). However, auto-dependence and minimal physical exercise leaves urban residents in a disastrous sitch of unhealthy lifestyles. In light of this, FMLM can be a remarkable source of health benefits for individuals when active transportation modes that involve physical exercise are used (Liu et al., 2018). Additionally, replacing FMLM auto trips with low or neutral carbon modes holds great potential to improve the air quality of urban environments through the reduction of tailpipe emissions and vehicle-kilometre-travelled (VKT). Liu et al., (2018) affirm that a 5% modal shift to cycling in short trips can reduce GHG emissions by 0.4%.

2.8 Towards end-to-end connectivity: Emerging innovations

In an effort to leverage these synergistic benefits, a considerable number of studies have been undertaken questing to solve the FMLM transit void left by public transport systems.

Subsequently, models and innovations to offer alternatives for first and last-mile connectivity have been developed and tested in different parts of the world. Tech-advancements, climate concerns, and new mobility models are changing the landscape of FMLM mobility (European Environment Agency, 2020). Each innovation pioneered has used one or more indicators of FMLM accessibility as a cornerstone for the provision of alternative feeder services to bridge the accessibility gap.

One of the most dominant approaches is the Mobility-as-a-Service (MaaS) Scheme. By bringing together transportation options from both private and public service providers in a one-stop-shop setting, the scheme allows commuters to shift away from individual mobility and personally owned travel modes to mobility options that are consumed as a service (International Road Transport Union, (IRU), 2016). In the e-marketplace, commuters have access to a variety of modal and tariff options which are integrated by an agent/aggregator.

On-demand mobility solutions are also rapidly picking pace in developing and developed countries owing to the contemporary global digital revolution. Scheltes and de-Almeida-Correia (2017) adopt an agent-based simulation model that introduces automated vehicles as an alternative for door-to-door accessibility in Delft, Netherlands. Other transportation specialists later introduce new mobility enterprises as a present-time convenient system for connectivity to the transit stations. These enterprises provide app-based mobility comprised of motorized two-wheelers, car-pooling services and a parking aggregator (Kanuri et al., 2019). It is envisioned that these services will continue to have a great stake in FMLM accessibility due to their convenience (European Environment Agency, 2020). A nerve-racking observation however is that these mobility options seem to popularize use of autos and park-and-ride systems which increases motorization in cities.

Sharing-Economy mobility models characterized by bike-sharing and car-sharing are also becoming popular as more sustainable modes which have induced an enthusiastic shift from one-passenger auto-mobility to shared mobility (Ponodath et al., 2018). In nations where the FMLM gap has been solved such as Europe and Japan, active transport modes (cycling and walking) have been proven the most effective strategies in providing carbon-neutral accessibility to the origins and destinations whilst reducing dependence on automobiles (Fan et al., 2019).

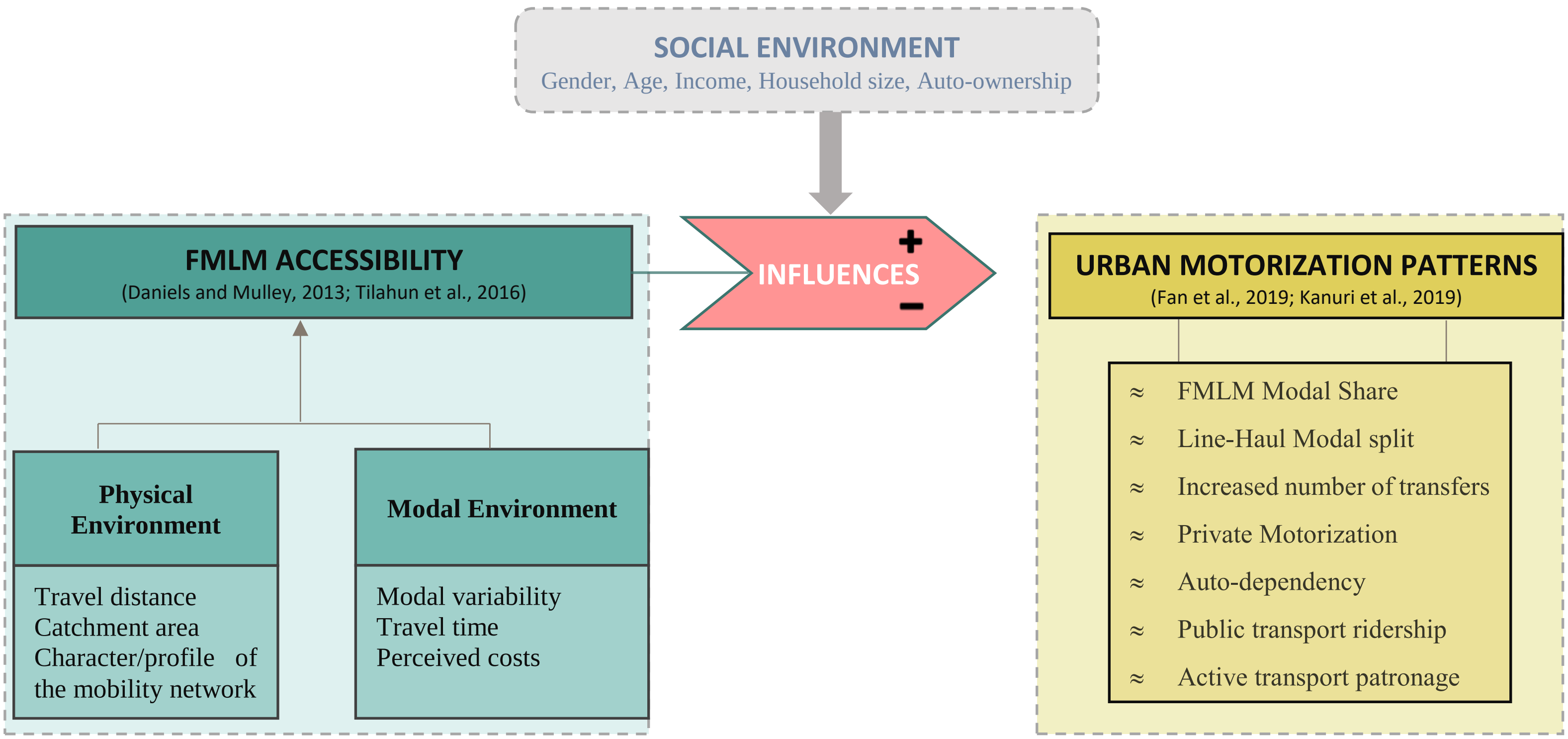
2.9 Theoretical framework

Analytical review of past research reveals that the FMLM problem not only affects public transport ridership but further shapes the travel behaviour of commuters which is explicitly visible from the motorization patterns in cities. In light of that, this section presents a distinct structural relationship between FMLM accessibility (independent variable), modal choices and the subsequent motorization patterns in cities (dependent variable). Consistent with theoretical underpinnings, the theoretical framework in Figure 4 below starts by outlining the **2 main parameters that determine FMLM accessibility;** Physical and modal environment indicators (boxes in shades of blue) (Tilahun et al., 2016). Under each parameter are **measurable indicators** (light blue boxes) which are mainly objective, which means that they relate to factual data as opposed to user perceptions. Some indicators, however, such as the character of the mobility route may include subjective information since users may have different perceptions about streets. A totality of these indicators will then determine if a particular link to the transit station is accessible or not.

The level of accessibility of catchment areas serves as a foundation for commuters to make travel decisions. It, therefore, **influences** travel mode choices and motorization patterns in the city (boxes in shades of yellow). Motorization patterns include modal shifts in the FMLM and line-haul, private motorization, public transport ridership, auto-dependency, and active transport patronage

(Li et al., 2019; Scheltes and de-Almeida-Correia, 2017). The influence of FMLM accessibility on these patterns can be positive or negative. The strength of this relationship is however **moderated by social environments;** which are individual and household variables of a commuter (in blue font). In prior studies, these social aspects have been treated as predictors and explanatory variables. However, after a critical review of literature in this study, it is noted that social elements do not really measure accessibility, rather, they influence the power or direction of the relationship between accessibility and its resultant outcomes. It is thus treated as a moderating variable which means that the impacts of FMLM accessibility on motorization patterns can be amplified or weakened based on the social environment characteristics of commuters. The significant social environment factors underscored here are gender, age, income, household size and automobile ownership derived from the discrete choice model and outcomes of other travel choice models as set out in section 2.6.3 (Daniels and Mulley, 2013; Fan et al., 2019; Tilahun et al., 2016).

Figure 4: Theoretical Framework



Source: Author, 2020

Chapter 3: Research design, methods and limitations

This chapter transitions this research from the conceptual research design into the technical design. It explains the strategy that was applied to respond to the research objective that underpins this study and describes the methodology used to undertake the study in consistency with the research questions.

3.1 Research questions

Main research question: To what extent does accessibility to the first and last mile of a trip affect modal share and the motorization patterns in Ruiru Bypass Zone, NMR Kenya?

Sub-questions*:*

- What share of population can public transport services reach within a Mile (1.6Km) and 2 miles (3.2km) radius and what is the character of these households?
- What is the network character and modal variability in the first and last miles in the selected Traffic Analysis Zone (TAZ)?
- What is the average time spent and financial cost incurred in covering the FMLM and the line-haul?
- How does the FMLM gap affect the first-mile, line-haul and last-mile travel mode adopted by commuters?
- What motorization patterns have FMLM choices induced in the City Region and how can they be controlled?

3.2 Conceptualisation

The latter section explicitly reveals this research as a causal study with distinguishable independent and dependent variables which are also the key concepts that took the central stage in this research:

Independent variable (X): This is the predictor variable which is usually presumed to be the cause of some effect in a causal relationship and remains unaffected by other predictors (Field, 2009). In this study, FMLM accessibility was the independent variable whose manifestation was assessed through a myriad of factors. The selection of factors studied here was based on the discrete choice model developed by (Tilahun et al., 2016) whose logic unpacks the FMLM problem through focused attention on physical and social environments. Additionally, modal environments which are briefly accentuated in this model but underscored in other models were considered to a great extent in this study (Liu et al., 2018; Tilahun et al., 2016).

Moderating variable (Z): By interpreting the theoretical underpinnings of this study, social environments were identified as moderating variables of the causal relationship. A moderator affects the magnitude of the relationship between the independent variable (X) and the dependent variable (Y). In this case, Z interacts with the effects of X on Y and consequently alters the strength and/or direction of the relationship based on particular circumstances and values of Z (Verschuren and Doorewaard, 2010).

Dependent variable (Y): This is the outcome variable that is expected to change as a function of changes in the independent variables. It represents the presumed effect, and whose strength is influenced by the moderating variable. Motorization patterns was the dependent variable in this study defined by statistical modal share.

3.3 Research type and strategy

To reiterate the study objective; this research aimed at unpacking accessibility in the first and last mile and elucidating how this affects the modal share and motorization patterns in a selected study area. This depicts that the aim was both exploratory and explanatory in nature. Being the first and last leg from transit, the FMLM is an unavoidable segment of a trip for all commuters which makes it a patent global phenomenon. In coherence with the principal research question, a holistic approach was needed to acquire a profound and full comprehension of how the phenomenon manifests itself and its consequent impacts within a specified location comprising of a relatively small number of units. The **case study design,** which is better adapted to explore, describe, and explain a contemporary phenomenon in its real-world setting therefore best suited this study (Yin, 2018). The strategy was aimed at examining the existing scenario of FMLM accessibility in the traffic analysis zone and drawing inferences on its relation to motorization patterns.

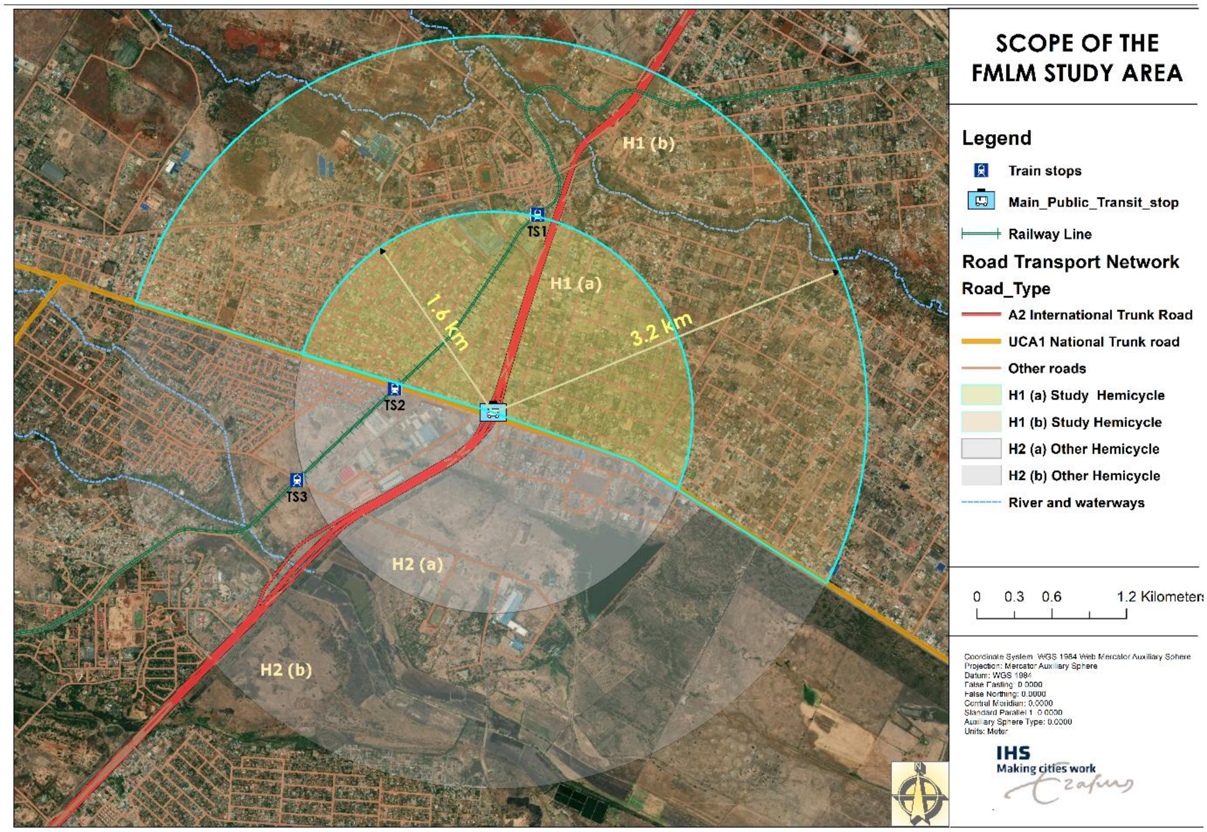
This strategy employed a single case approach which was examined once within a confined scope of time and geographical space. The research profited from a prior review of literature (chapter 2) which provided some theoretical propositions which refined the issues to be evaluated and guided the research design. Through a triangulation of methods and techniques, data that was requisite to respond to the main question was gathered, analysed, and interpreted. The approach developed an FMLM assessment model that can be used as the basis to undertake a large-scale survey of FMLM accessibility in the entire city.

3.4 Study scope, challenges and limitations

To explicitly understand and illustrate how the FMLM phenomena manifest in cities, a specific case was selected within the Nairobi Metropolitan Region (NMR) – Kenya. This is the most rapidly urbanizing region in the country with a 3.1% population growth rate per year which is relatively high compared to the national and global growth rates of 2.28% and 1.08% respectively (United Nations, 2019). The region hosts the capital city of Kenya, Nairobi and its surrounding counties of Kiambu, Murangá, Machakos, and Kajiado. The selected case was Ruiru Bypass Zone; a vibrant mixed-use area located within the jurisdiction of Ruiru and Juja sub-counties in Kiambu County. It lies within the jurisdiction of 3 ward administrative boundaries (Gitothua ward, Kiuu ward and Murera ward). The zone hosts low-, middle- and high-income residential neighbourhoods and is traversed by a classified international truck road (A2), and constitutes an explicit example of the FMLM phenomenon. The geographic proximity of the neighbourhoods to major transport infrastructural developments (Class A2 8-lane superhighway, commuter rail, and a proposed BRT network), major activity hubs (capital city, Nairobi - 23km and Ruiru town – 2km) further exemplified this zone for study. An additional criterion for the selection of this case study was its representativeness of the city in terms of location, socio-economic, and demographic factors.

The scope of the study was delineated through a spatial boundary created through a Mile (1.6km) and 2 Mile (3.2km) buffer from the major public transport stop serving the neighbourhood. The buffer zone was further split into 2 across its radius (geographically represented by the national trunk road UCA1-Nairobi = Eastern Bypass). The hemicycles populated with residential and commercial developments were selected as the research scope. This provided a maximum opportunity to gather adequate information to respond to the research objective. Map 2 below illustrates the extent of the study:

Map 2: Extent of the FMLM study area



Source: Author, 2020

Only elements indicated on the operationalization framework (next section) were covered within the study hemicycle. This research was however cognizant of some shortcomings which limited the study:

External validity: Being a case study, the research findings were case-specific and cannot be generalizable to all urban communities and populations across the globe. However, auspiciously the research results from the study can be generalizable to theoretical propositions (Yin, 2018).

Time and budgetary restrictions: Case studies are labour-intensive and time-consuming (Van Thiel, 2014). With 1 month for data collection and limited financial capacity, the researcher was forced to balance data requirements with financial and temporal restrictions. In this regard, the scope of the study was limited whilst ensuring that a valid research was conducted. Additionally, financial constraints could not accommodate a 2-day manual traffic survey (weekday and weekend) which would have been ideal.

Limitation of cases: The FMLM gap is an indisputable challenge in Kenyan Cities. Selecting multiple cases to compare with the results from Ruiru Bypass zone would have been desired to enrich the study outcomes. However, due to temporal and budgetary restrictions, it was only practical to do a single case study. The selected case however presented an interesting scenario as it encompasses 3 distinct neighbourhoods within which the FMLM concept was assessed.

COVID19 Outbreak: The pandemic resulted in movement and social interaction constraints which made it difficult to access respondents physically. However, to ensure the research was rolled out successfully, digital and physical questionnaires were deployed simultaneously until the sample target was reached. Additionally, the outbreak limited the ability to make accurate observations regarding traffic and mobility behaviours of commuters. The "stay-at-home" directives reduced traffic volumes and induced modal shifts. However, to counter the interference of traffic observations, manual traffic count data was triangulated with the modal data acquired from commuter questionnaires.

Logistic challenges: The rainy weather during data collection was burdensome, making the roads impassable and the commuters inaccessible. Also in an unfortunate event, one of the research assistants was mugged and his phone was stolen. Auspiciously through the help of the public, the muggers were apprehended.

3.5 Operationalization

This section systematically delineates the research by clarifying the empirical focus of the researcher. It highlights the variables that were included in the study as drawn from the principal research question. These variables take-on different measurable values which are expressed in the form of indicators (Van Thiel, 2014). In conformity with theoretical construct, research questions, and the conceptual framework, X, Z, and Y are operationalized as follows:

Table 3: Operationalization Matrix

Main variables (s)	Sub-variable (s)	Indicator (s)	Source (s) of data
FMLM ACCESSIBILITY **(Independent Variable, X)** This is the traveler's ease of travel between the nearest transit station and home, work, school, or other locality where travel originates and eventually culminates (Tilahun et al., 2016). The ease of travel is interpreted to be subject to the distance to the transfer location, type of travel mode used, travel time associated with the mode adopted, number of transfers, travel price, safety, the attractiveness of the mobility network (Krygsman et al., 2004; Tilahun et al., 2016).	**Physical environment variables**		
	✦ **Travel distance** Travel distance is the physical distance covered by a person to move from one point to another. In the context of FMLM, it refers to the proximity of trip origins and culmination points to the location of transit stations (Tilahun et al., 2016)	**FMLM planning regulations** – Maximum access and egress distances – Transit catchment areas for different modes – Institutional mandate over FMLM planning	Content Analysis Informant in-depth interviews: > Kiambu County department of transport >Nairobi Metropolitan Services (NMS) >Transportation planning expert
		First-mile distance (meters) – Distance in Km from Origin to the nearest public transport station	Commuter Questionnaire Spatial analysis (ArcGIS - Buffer zones around transit stations)
		Last-mile distance (meters) – Location of work/school-related destination – Distance in Km from the final transit station to Destination	
		Geographical catchment area – Share of population (%) accessed by transit within 1.6km and 3.2km	
	✦ **Character of the mobility network (network evaluation)** This refers to characteristics that define a particular travel route and can be described through the length and size of roads, quality of individual links,	**Infrastructure provision** – Presence of sidewalks, cycle tracks, street lighting, bus stops, landscaping	Non-participant Observation Commuter Questionnaire
		Attractiveness of the streetscape: – Vitality : Intensity of activities – Sanitation (Drainage & Solid waste) – Type and condition of road surface – Frequency of maintenance	Non-participant Observation Commuter Questionnaire Informant in-depth interviews: > Kiambu County department of transport

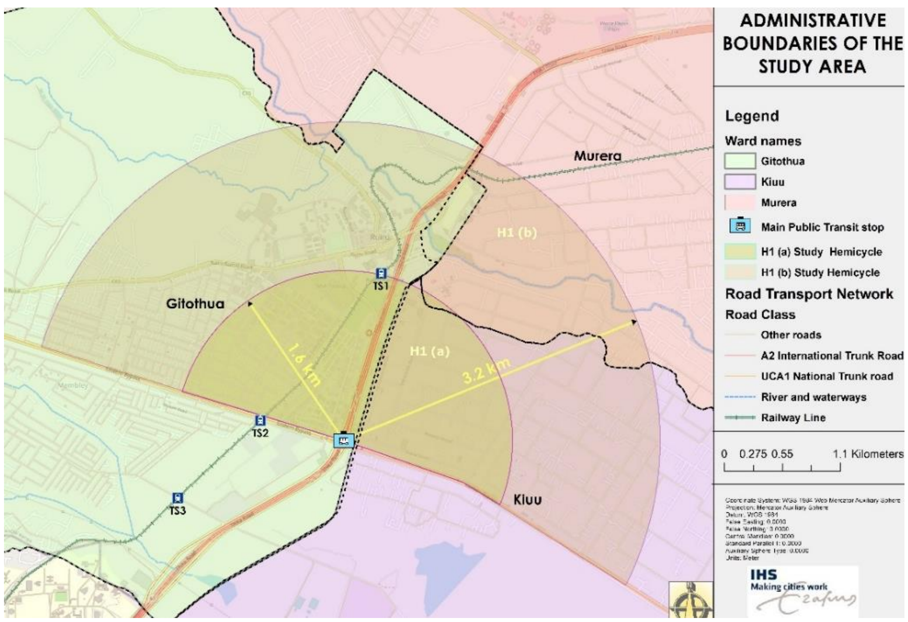
	nature of streetscape, street infrastructure, traffic composition, safety (both from traffic and crime) (Park, 2008).	**Street Safety** – Score on sense of personal security – Score on the perception of traffic safety for pedestrians – Score on the perception of traffic safety for cyclists – Score on the perception of traffic safety for motorists	Commuter Questionnaire
	Modal environment variables		
	✦ **Modal variability** Defined as the availability of multiple alternative transportation modes within a commuter's weekly travel (Heinen and Chatterjee, 2015)	**Travel modes** – All modes available in the FMLM	Manual Traffic Count Survey Commuter Questionnaire
	✦ **Travel time** The absolute time (expressed in minutes) required to cover the first and last miles, which is further expressed as a proportion of the entire trip time (Krygsman et al., 2004)	**Time spent (minutes)** – Average time spent to cover the first mile – Average time spent to cover the last mile – Average time spent for the line haul and the whole trip	Commuter Questionnaire
	✦ **Perceived costs** Economic travel cost, which typically characterizes the ease of travel by different modes, expressed by a cost function (Liu et al., 2018)	**Average costs (Ksh)** – The average cost incurred to cover the first/last mile – The average cost incurred for the line haul and the whole trip	Commuter Questionnaire
SOCIAL ENVIRONMENT **(Moderating Variables, Z)**	✦ **Socio-demographic variables** Commuter's personal and household profile (Demographic characteristics of the traveler and characteristics of the household)	**Age** in years, **Gender, Marital status** **Average income** in Ksh **Household size** – number of children **Auto ownership**	Commuter Questionnaire
MOTORIZATION PATTERNS **(Dependent Variable, Y)**	✦ **Modal Split/ Modal share** The percentage share of each mode of transport within a selected geographic boundary (Zuo et al., 2020).	**FMLM modal behaviors** – Modal choice for the First mile – Modal choice for the Last mile **Line-Haul modal choices** – Modal choice for the main segment of the trip **Transfers** – Number of and ease of transfers to the final destination	Commuter Questionnaire Manual Traffic Count Survey
	✦ **Public transport (PT) ridership** (The use of a given public transportation system)	**Public transport Usage** – Public transport modal share in all journey segments – Frequency of PT usage	Informant in-depth interviews: > Kiambu County department of transport >Nairobi Metropolitan Services (NMS)

Source: Author, 2020

3.6 Sampling

The target population for this research was commuters who reside within the boundary of Ruiru Bypass Zone Kenya. To get the proportion of residents to be engaged in the research, 3 sampling techniques were applied complementarily; purposive, quota, and random sampling. Purposive sampling technique was used as the initial approach to delineate the spatial extent within which the target population was distributed. Here, the maximum walkable and cyclable distances of 1 mile and 2 miles respectively were used to define the study's catchment area. Only commuters within the set boundary were interviewed. Additionally, quota sampling highlighted the administrative boundaries from which the sample was sourced. With the A2 superhighway traversing the target zone, all settlements on the right side of the highway were within Gitothua ward while the majority of those on the left were in Kiuu ward and a few in Murera ward as shown on map 3 below. Sample distribution was hereby a function of the ward area and spatial distribution of the population therein. Based on this, a ratio of 3:2:1 of the sample size was used to get the exact number of respondents within Gitothua, Kiuu, and Murera wards respectively.

Map 3: Administrative boundaries within the case study



Source: Author, 2020

Having identified the spatial extent encompassing the target population, computation of the required sample size was requisite. The population of the extensive Ruiru sub-county is 371,111 persons with an average population density of 2,119 persons/km^2 (Kenya National Bureau of Statistics, 2019). The target population however just sits on 14.72km^2 which at the aforementioned population density represents 8.4% (0.084) of the total population (14.72 * 2,119) /371,111 = 0.084). This value was likened to the prevalence ratio of the target population that was expected to reside within the scope of the study. To get the sample size from this population therefore, the Cochran's formula of sample size was used as shown below:

$$\eta_0 = \frac{Z^2 \rho q}{e^2}$$

Where:

- η_0 - Sample size
- Z^2 - Confidence level, 95% confidence level with a standard score of 1.96 is used here
- ρ - Estimated proportion of the population within the study scope (0.084)
- q - $1 - \rho$
- e - Tolerable margin of error/level of precision (5% if the desired here)

The calculation (rounded off to the nearest tenfold) yielded a target sample size of **120 respondents**. To reach out to these respondents, simple random sampling was used. However, the exclusion criteria for participation was the consideration of the study zone as the first mile i.e. the respondent lives within Ruiru Bypass. Additionally, the study assumed that the demographic composition of the neighbourhood was comparable to the current sub-county demographics where the ratio of males to females is 1: 1.03 (Kenya National Bureau of Statistics, 2019). Questionnaires were thus distributed randomly and evenly across gender within the selected sample size as shown in table 4.

Table 4: Sample distribution

Ruiru neighbourhood (Ward section)	Respondents from sample size of 120 (3:2:1)	F	M
Gitothua	60	30	30
Kiuu	40	20	20
Murera	20	10	10
TOTAL	**120**	**60**	**60**

Source: Author, 2020

Target respondents for the in-depth interviews were selected using purposive and snowball sampling. The goal was to acquire information regarding the position of FMLM in the transport planning domain of the city. The target respondents were; Nairobi Metropolitan Services (NMS) under policy and planning, transport planning department of the Kiambu local government, 2 transport planning experts (1 individual practitioner and 1 in academia), and transport planning organizations who have engaged in planning for public transportation in the Metropolitan region. This would yield **5 in-depth interviews.**

3.7 Data collection methods and instruments

To understand how the FMLM phenomenon manifests in the selected area and further reveal how it affects the other components of transportation; specifically modal share and emerging motorization patterns, it was increasingly important to employ mixed-methods of research in this study. The multi-methodology approach systematically integrated qualitative and quantitative research methods to allow for more synergistic acquisition and utilization of data. Quantitative research methods used a more structured system to acquire measurable data to formulate facts and uncover patterns. These methods included:

Questionnaires: Comprised of a set of close- and open-ended questions that were derived from the variables of the study (Van Thiel, 2014). Consistent with the operationalization framework, the questionnaire was structured into four major parts; socio-demographic attributes, physical environment/mobility route attributes, travel mode-related attributes, and modality attributes.

Traffic counts: Involved full day recording of traffic composition and volumes. This was mainly a triangulation method aimed at validating the modality information acquired from commuter questionnaires and further illustrated the current traffic demand in the TAZ. A traffic count schedule was prepared to fill in the manual traffic counts.

It was also imperative that the study provides an in-depth description and analysis of the study subject. Qualitative information defined by textual data was thus requisite to comprehend the complex relationships between the independent variable (X) and the dependent variable (Y), and how the nature of this relationship is influenced by the moderator (Z). Qualitative research methods could take different forms ranging from; review of existing documents, or general outline of topics to be discussed in an exhaustive interview, or open questions lacking pre-categorized responses, or structured observations to acquire first-hand data of the research phenomena in natural settings (Verschuren and Doorewaard, 2010). The following qualitative methods were used complementarily:

Content analysis: To better position and characterize the findings from the Ruiru Bypass Zone, the researcher analysed existing documents and data sets that contained investigations about the FMLM problem. Content analysis was also applied to acquire geographic/spatial, socio-economic, and other contextual data characterizing the study area, FMLM transport planning provisions, and to acquire data on possible key informants.

Semi-structured Interviews: This method gathers remarkably in-depth information through guided questioning and conversing with respondents, often called key informants. Semi-structured interviews were used to clarify and augment information acquired from other sources and responded to the "hows" and "whys" related to the research subject (Yin, 2018). An interview manual containing key topics of discussion was developed to guide the conversations. This method also allowed the researcher to ask supplementary questions to clarify or expound further on answers given.

Direct observations: Keen on-ground observations were made on the character of the mobility routes, major activity zones, road use behaviours, route profiles among other elements.

The research instruments used in this study are provided in Annexes 1a, 1b, 1c, and 1d attached.

3.8 Research deployment

An intensive 9-day primary data collection process was initiated, complemented by a series of in-depth interviews. The illustration below gives a sneak peek of the research activities undertaken to accumulate the requisite data to respond to the principal research question:

Figure 5: Snapshot of the data collection process

Source: Author, 2020

For the commuter questionnaire, online data capture techniques via Qualtrics[3] were applied. The digitized survey tool was administered both physically through enumerators and virtually on social media platforms. Three research assistants were recruited, trained on the FMLM concept, methods of data capture, and introduced to the research tools. The online tool underwent 2 days of piloting with the research assistants and a few residents to provide an objective review of the viability and consistency of the tool whilst acquainting the RAs with the tool. This member-check approach revamped the structure of the questionnaire and measurement approaches designed for different variables. On the reconnaissance day, physical reference points signifying the study boundaries were set. Additionally, authorization for academic research from the administrative authorities was sought. In the subsequent 7 days, commuter intercept surveys were issued out to 123 commuters accessed along the transport corridors, at major transportation nodes, and at prime economic hubs.

[3] Qualtrics – A web-based survey tool that contains in-built dynamic tools for formulating, distributing and even analyzing basic and advanced surveys.

Thereafter, a couple of main access routes were shortlisted for manual traffic counts and 1 selected through a participatory process. The initial plan was to undertake a 2-day traffic survey but due to financial constraints, only 1 weekday (7am-7pm) was possible. The survey sufficiently covered peak and off-peak hours. The entire research process was highly participatory, inclusive, and manifested effectual integration of citizen science in urban mobility research. Area residents were not only engaged as respondents but also as research assistants and elite informants in key stakeholders mapping.

In-depth interviews engaged transportation stakeholders from diverse backgrounds as indicated in figure 5 above; 5 key players in transportation planning, urban mobility research, and decision-makers. Highly illuminating 40-60 minute discussions were undertaken virtually via Zoom application due to the restrictions presented by the COVID-19 pandemic. The discussions not only focused on the place of FMLM in the context of paratransit but also in the context of the proposed City-wide BRT system. More stakeholders especially from the Nairobi Metropolitan Services (NMS) were targeted and meetings requested but were unsuccessful.

3.9 Data analysis methods

The multiple sources of evidence produced a detailed FMLM inventory which was a compound of qualitative and quantitative data distinguished by different levels of measurements. Quantitative and qualitative analysis methods were used to interpret the data to get a more panoramic view of this research.

3.9.1 Quantitative analysis

This involved analysis of quantifiable data acquired from commuter questionnaires and manual traffic counts. Notably, the research instruments as much as possible assigned scores to variables to facilitate logical, precise, and unambiguous responses (Van Thiel, 2014). Various data ordering steps as summarized in Figure 6 below were followed for quantitative analysis in SPSS:

Figure 6: Organization of quantitative analysis

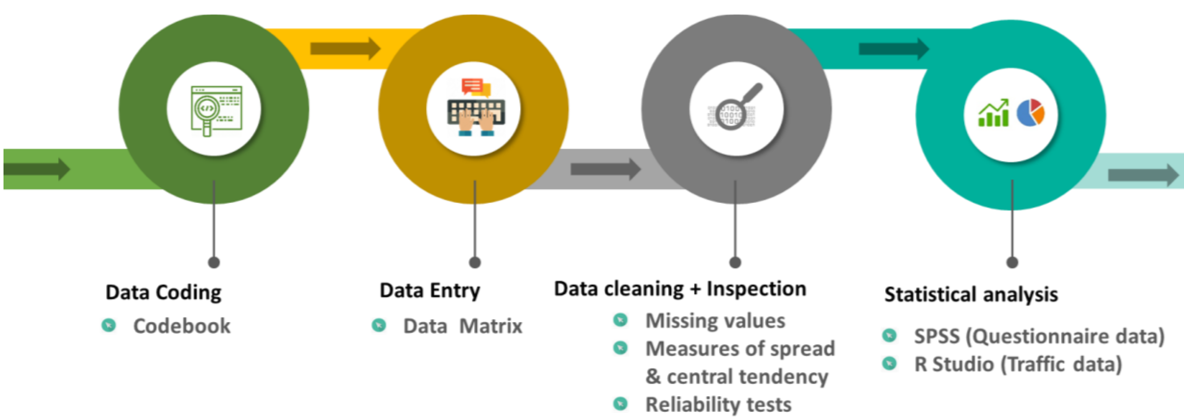


Figure by author; data sourced from (Van Thiel, 2014)

The commuter questionnaire measured the social, physical, and modal environments in categorical variables which were coded in SPSS as ordinal or nominal level measurements. Some indicators were analysed individually while those measured on Likert scales were aggregated into scale variables educed from the research questions. Indicators forming latent constructs were tested for reliability using Cronbach's alpha test. Rules of thumb regarding the Cronbach's Alpha (α) are: "$\alpha \geq 0.9$ – Excellent, $0.9 > \alpha \geq 0.8$ – Good, $0.8 > \alpha \geq 0.7$ – Acceptable, $0.7 > \alpha \geq 0.6$ – Questionable, 0.6 > α ≥ 0.5 – Poor and 0.5 > α – Unacceptable"(Keith, 2017, p.6). However, a scale variable with less than 10 items, >.6 is an acceptable α (van Griethuijsen et al., 2014). Therefore, factors whose alpha coefficient (α) was ≥ 0.6 for scales with less than 10 items were acceptable while the recommended minimum of 0.7 was adhered to for the other scales. It was further confirmed through this study that Cronbach's alpha (α) is sensitive to the number of items in the scale, the wording order, and language as used in the questionnaire (Pallant, 2016).

In some instances, the variables were transformed into 0/1 dummy variables to assign a numerical value to categorical data. Variables were then analysed descriptively through frequency distribution and contingency tables. For grouped data where the means were essential, class marks and class frequencies were used to estimate the mean based on the following formula:

$$\bar{x} = \frac{\sum mf}{n}$$

Where:

$\bar{x}$ – Estimated sample mean

$\sum mf$ – Sum of (Midpoint/class mark of each interval (m) × Frequency for the class (f))

n – Total number of sample values/data

Descriptive analysis was succeeded by correlation tests that preceded inferential statistics. The decision on the appropriate statistical test was heavily reliant on the normality curves and the levels of measurement. Since the data gathered was characterized by nominal and ordinal scales, non-parametric statistics were requisite. Additionally, the basic assumptions for a parametric test were not met e.g. homogeneity of variance, normality, and interval scale (Field, 2009). Non-parametric Spearman rank correlation test was thus applied in testing for correlations and significant relationships between dependent and independent variables. From the correlation contingency tables, independent variables that were highly correlated with each were omitted in the subsequent modelling steps to eliminate the multicollinearity problem. Inferential statistics were then used to respond to the main research question which probed the researcher to establish the relationship between FMLM accessibility (X) and Motorisation patterns (Y). Causality was investigated through a multivariate regression analysis whose model is typically expressed as follows:

$$\gamma = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots\ldots + \beta_n X_n + \varepsilon$$

Source: (Uyanik and Güler, 2013)

Where:

γ - Predicted/expected value of the dependent variable

β_0 - Intercept, (constant representing the value of γ when all predictors $X_1 \ldots X_n$ are zero)

$X_{1\ \text{through}}\ X_n$ – Distinct predictor/independent variables

$\beta_{1\ \text{through}}\ \beta_n$ – Estimated regression coefficients

ε - Random error.

Data acquired from manual traffic counts was analysed quantitatively in R statistical software. Traffic data statistics were predominantly used as descriptive statistics to augment and validate the modal split outcomes from the commuter survey.

3.9.2 Qualitative analysis

By contrast, textual variables that could not be quantified were analysed through qualitative methods (Van Thiel, 2014). The non-quantifiable interview data was accumulated through 5 transcriptions which were systematically coded in ATLAS.ti. The data units were classified using assigned codes and grouped into **categories** at variable level as derived from the research questions. Trends and patterns were identified and interpreted to define relationships between variables. The output largely supported the commuter survey outcomes and was used to shed light on observations made during preliminary analysis. Figure 7 summarizes the qualitative analysis process:

Figure 7: Organization of qualitative analysis

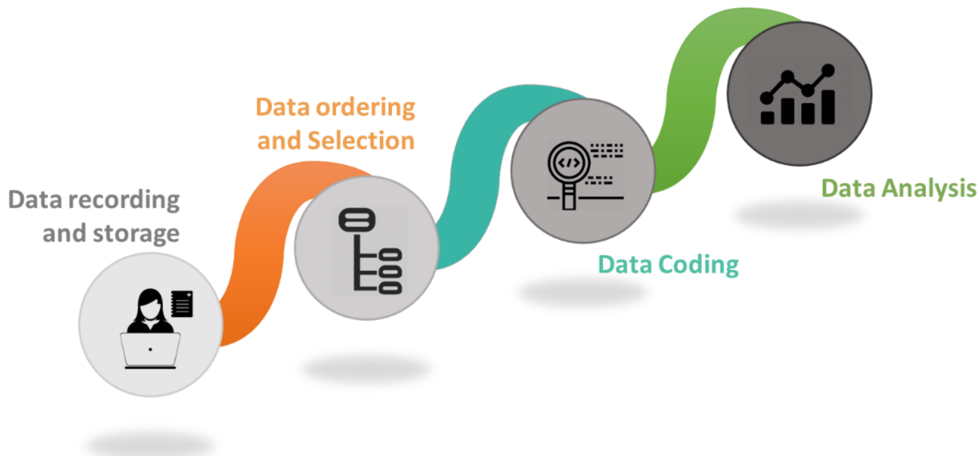


Figure by author; data sourced from (Van Thiel, 2014)

3.10 Reliability and validity

Reliability in social research refers to the degree to which the study variables are measured accurately and consistently (Van Thiel, 2014). The measures used are considered reliable only if they produce similar and systematic results when applied on the same variable several times. Accuracy refers to the precision of the research instruments while consistency refers to replicability; the possibility of the measurements to produce analogous results under similar circumstances. Firstly, the research design developed in this chapter to a great extent ensured that the methodology is coherent, with a lucid connection between theory, concepts, variables, and indicators. The operationalization framework provided was detailed ensuring that the study variables were accurately described with a maximum explicit meaning of the concepts captured, and was rooted in theory to enhance consistency in translating the variables to clear and measurable indicators.

In cognizance of the ambiguity that could surround some variables which assume different values, the study conceptualized each variable based on the scope and theme of the study and made a clear distinction between the values assumed. It further disaggregated the variables to a great level of detail; from variable – sub variable – indicator – measurement unit e.g. FMLM accessibility – physical environments – travel distance – first-mile distance – distance in meters. This procedure was adopted for all variables which ensured that the research instruments captured the variables correctly and precisely. This was further supported by the frequent consultations made with other researchers and experts in the field who provided objective scrutiny and sound assessment of the methodologies and units of measurement. Additionally, all procedures, activities, and choices made throughout the research were recorded in a log which makes the research transparent and highly replicable by other researchers. This substantially increases the reliability of the study.

Validity on the other hand makes reference to if the researcher has measured what (s)he intended to measure; intention versus reality (internal validity) and if the results can be generalized to a larger population (external validity) (Verschuren and Doorewaard, 2010). Operationalizing all variables to a great level of detail based on the theoretical construct ensured there was no room for ambiguity or confusion in measurement. Further, the research instruments adopted i.e. questionnaires, semi-structured interview manual, were designed in close relationship with the theoretical underpinnings of the study. This aimed at producing stable and consistent results, characterized by valid arguments that cogently explain that the change in the dependent variable (Y – motorization patterns) can be attributed to the change in the independent variable (X – FMLM accessibility). This was also supported by data triangulation; where different methods were used to gather data. In this case, content analysis complemented primary data collection methods. Also, manual traffic counts were used to affirm/verify the modal share information acquired from the commuter questionnaires. External validity was however constrained because case study findings are not generalizable to larger populations. Nonetheless, these results can be used to make theoretical propositions.

Lastly, the choices made in the selection of the study scope and respondents were not based on the researcher's intuition but rather based on the standard mobility provisions i.e. 1 mile and 2-mile buffers were created around the main transportation node. These distances reflect the maximum catchment areas acceptable for walking and cycling to access transit respectively. This further increases the reliability and validity of the research.

Chapter 4: Case study, data analysis and presentation

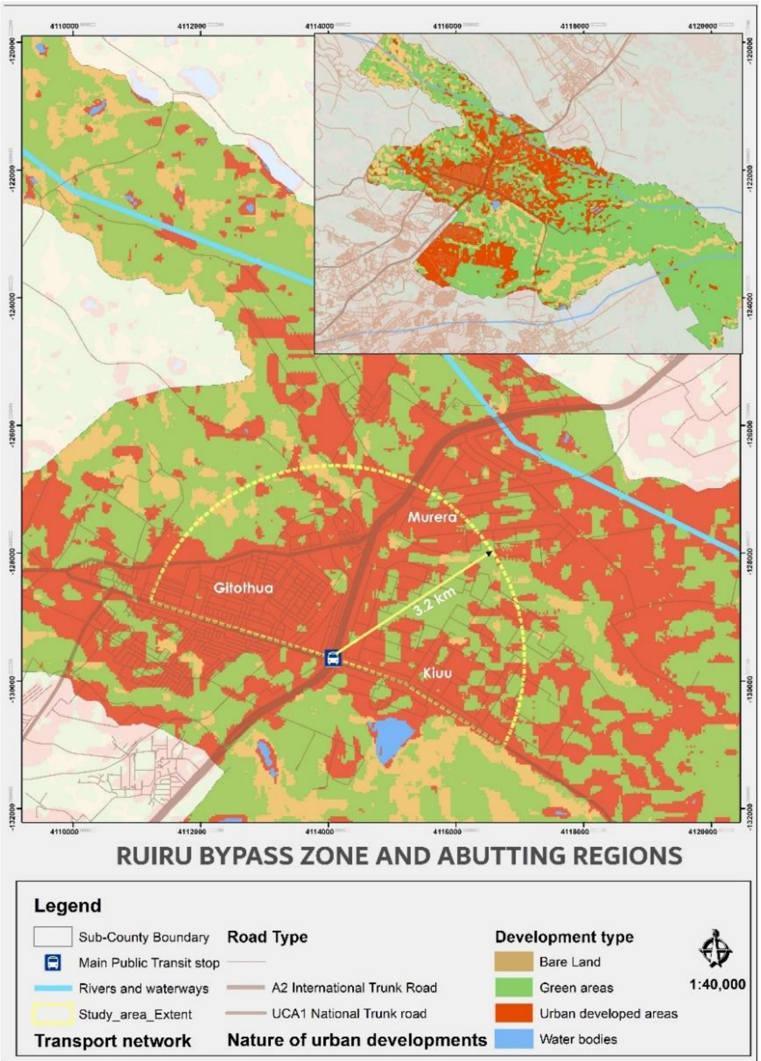
This chapter sets forth the findings of the study on the basis of the research methods outlined previously. Section (4.1) kicks off by giving a synopsis of the unit of analysis and elucidates the context within which the phenomenon manifests. The following section discloses the findings of the research through descriptive statistics presented in narratives, charts, maps, graphs and tables (4.2 and 4.3). The findings are organized consistently with the operationalization table which is also in congruence with the research sub-questions. The outcomes of the commuter intercept survey are described first, succeeded and supported by qualitative information from in-depth interviews. Finally, the statistical analyses which scrutinize the impacts of FMLM accessibility on motorization are presented and later discussed (4.4 and 4.5).

4.1 Description of the case studied

Understanding an individual's trip necessitates a critical comprehension of the entire journey from origin to destination which thus underscores the prominence of the FMLM. The quest of this study to assess the role of this journey segment in shaping the motorization patterns of a city points us to Ruiru Bypass Zone as the unit of analysis. The case was conscientiously selected within the context of a developing country and a rapidly urbanizing city region. The zone covers 14.72km^2 which partially includes 2 wards in Ruiru sub-county and 1 ward in Juja sub-county (Gitothua, Murera and Kiuu wards). The scope incorporates the bustling Ruiru town, which is the 6th largest urban centre in Kenya. It lies between Nairobi City and Thika town at 27km and 22km respectively.

Owing to its proximity to the country's capital, the zone absorbs Nairobi's urban overspill and has been characterized by an influx of middle-income households and high levels of commuting. Due to this locational advantage, Ruiru Bypass has been identified as a potential secondary center to decongest the capital city, and which may even become the "Future Centre of the Metropolis" (County Government of Kiambu, 2018). Consequently, the area has urbanized rapidly from an agricultural district into one of the most populous dormitory towns. Multifarious **urban developments** have been established in the zone, particularly along major infrastructure developments as shown on map 4 below:

Map 4: Urban development of Ruiru Bypass zone at a glance

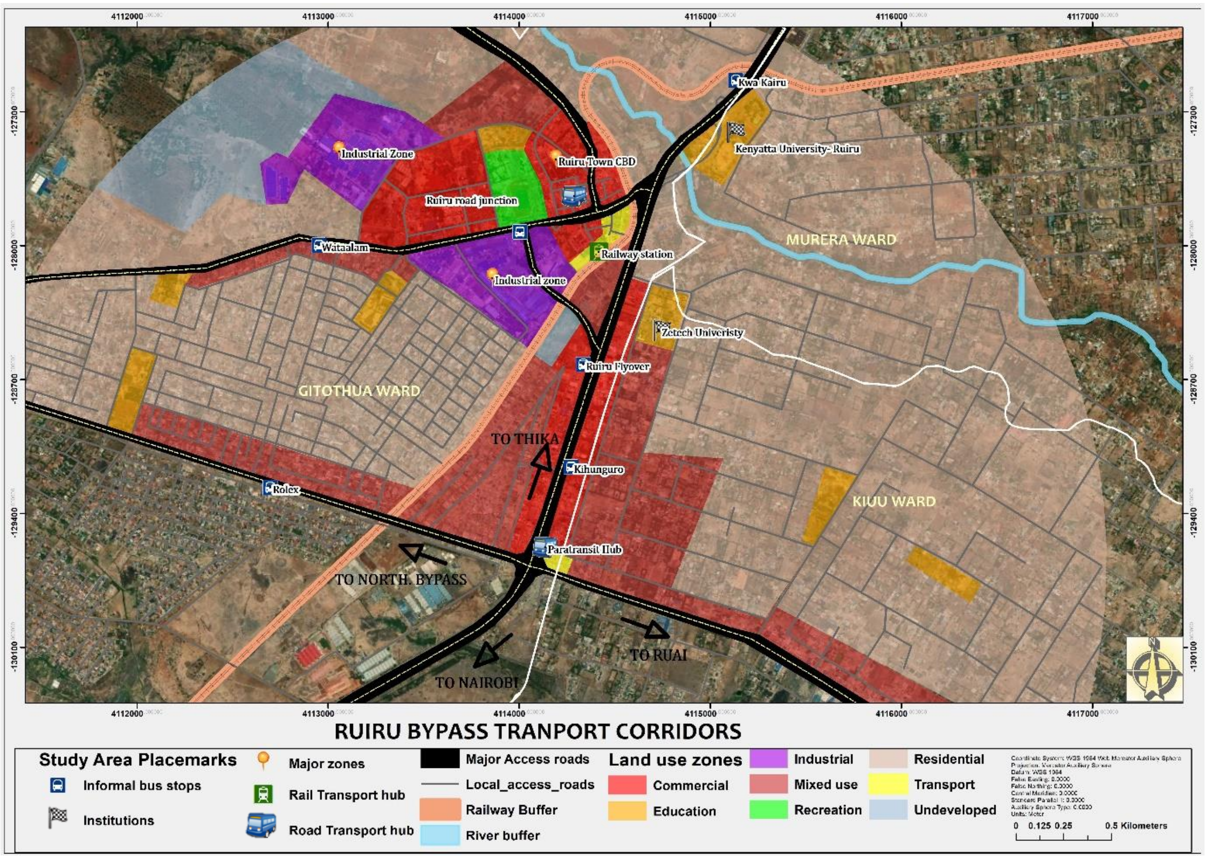


Source: Author, 2020

The industrial zone hosting major factories such as NKG Coffee Mills Kenya, Devki Steel Mills Limited, European Foods Africa Limited, Nairobi Clay-Works, Hotpoint appliances Limited inter alia have also attracted working-class families to this zone. Likewise, major academic institutions such as Kenyatta University, Zetech University and Ruiru College have added a fair share of low-middle cost housing and student accommodation. The density of developments illustrated on map 4 further typifies the demand for mobility both within and outside the settlement.

The fast-paced urban growth of this zone has also been fuelled by the improvements of the Nairobi-Thika Superhighway, A2 and opening up of the Eastern and Northern Bypass roads. Consequently, the settlement has become a renowned transportation hub. Mobility needs are served by A2 as the primary arterial corridor and Eastern bypass as the secondary arterial road. Few sub-arterials such as the Ruiru-Kamiti road feed traffic into these arterials while collector streets provide local access in the settlement. A single-track commuter train from Ruiru –Nairobi with 7 intermediate stops and offering 2 services per day also traverses the zone. A spatial glance of these inter- and intra-settlement transport corridors is provided in map 5 below:

Map 5: Ruiru Bypass Zone transportation network



Source: Author, 2020

Despite being populous, geographically advantaged, socially and economically vibrant, accessibility in this zone remains a salient challenge. Efforts to repress unsustainable mobility patterns have been traced through initiatives such as the Ruiru Sustainable Urban Mobility Plan (SUMP) which sought to integrate NMT with other modes. Howbeit, commuters lack connectivity to origins and final destinations which has gravely compromised urban mobility. The zone is however set to benefit from Strategic transport enhancements in the NMR such as the Bus Rapid Transport system (BRT) that has been proposed along A2. Given this, the study proves to be quite instrumental and timely. It not only captures the existing FMLM accessibility scenario in the context of paratransit but also instigates forward-thinking into accessibility to the proposed mass transit system. This offers a unique opportunity for simultaneous empirical and ex-ante research.

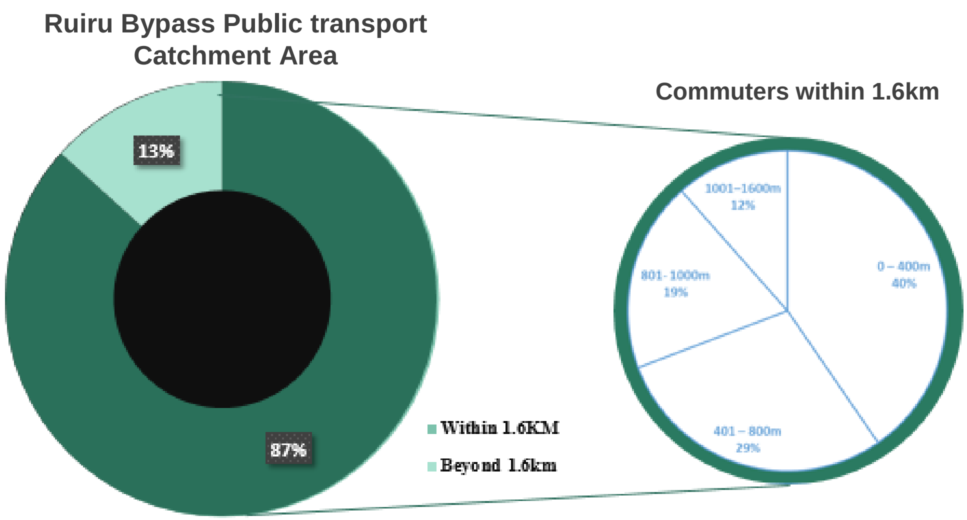
4.2 Accessibility to the first and last mile in Ruiru Bypass

The research process generated a detailed commuter inventory from which different forms of descriptive analysis were performed. Foremost, FMLM accessibility which is a latent construct was measured through a synergy of social, physical and modal environment factors:

4.2.1 Social environment profile of the sample size

The sample population engaged in this study represented commuters within a 3.2km buffer from the Ruiru Bypass transport node. As shown on chart 2, a sizeable percentage (86.7%) access public transportation within the 1.6km maximum walkable distance while the rest (13.3%) cover more than 1.6km. Therefore, public transport services are spatially accessible within a mile for the larger share representing more than ¾ of the sample commuters.

Chart 2: Spatial accessibility to public transportation



Source: Author, 2020

4.2.1.1 Commuters' socio-demographic attributes

The commuter survey yielded a 1:1.2 gender ratio with 54.2% male and 45% female respondents. A notable age polarity was observed, with young-middle aged adults (19-45 years) dominating at a cumulative 93.3%. Senior adults were few representing 6.6% of the sample population. Additionally, a critical observation was that middle-aged and senior citizens mainly resided within the 1-mile catchment area. Young adults on the other hand were distributed within the 1 mile and 2 miles buffer. Respondents had medium-sized families of 1-2 and 3-4 children (33.3% and 10% respectively). Larger families with 5-8 children were few but present (2.5%). Children-ages suggested that most respondents (45.5%) had children of the primary and secondary school-going age, which in the Kenyan education system is between 5-17years. The contingency table 5 below details out these observations:

Table 5: Individual attributes of commuters

Indicator	Full Study sample *(n=120)*	Public transport Catchment area		Gitothua ward *(n=60)*	Kiuu ward *(n=40)*	Murera ward *(n=20)*
* Notable observations		Within 1.6km *(n=104)*	> 1.6km *(n=16)*			
Sex	*N (%)*			*N (%)*	*N (%)*	*N (%)*
Male	**65 (54.2)** *	56 (86.2)	9 (13.8)	33 (50.8)	13 (20.0)	19 (29.2)
Female	54 (45.0)	47 (87.0)	7 (13.0)	26 (48.1)	7 (13.0)	21 (38.9)
Other	1 (.8)	1 (100.0)	0 (.0)	1 (100.0)	0 (.0)	0 (.0)
Age (yrs.)						
19-25	**48 (40.0)** *	41 (85.4)	7 (14.6)	20 (41.7)	8 (16.7)	20 (41.7)
26- 35	45 (37.5)	37 (82.2)	8 (17.8)	27 (60.0)	4 (8.9)	14 (31.1)
36- 45	19 (15.8)	19 (100.0)	**0 (.0)**	9 (47.4)	6 (31.6)	4 (21.1)
46- 55	**7 (5.8)**	6 (85.7)	**1 (14.3)** *	4 (57.1)	1 (14.3)	2 (28.6)
Above 55	**1 (.8)**	1 (100.0)	**0 (.0)**	0 (.0)	1 (100.0)	0 (.0)

Marital status						
Single	**66 (55.0)** *	55 (83.3)	11 (16.7)	29 (43.9)	10 (15.2)	27 (40.9)
Married	50 (41.7)	46 (92.0)	4 (8.0)	29 (58.0)	10 (20.0)	11 (22.0)
Divorced	1 (.8)	1 (100.0)	0 (.0)	1 (100)	0 (.0)	0 (.0)
No response	3 (2.5)	2 (66.7)	1 (33.3)	1 (33.3)	0 (.0)	2 (66.7)
Children Age						
0-4 years	22 (25.0)	19 (86.4)	3 (13.6)	14 (63.6)	4 (18.2)	4 (18.2)
5-9 years	**27 (30.7)** *	23 (85.2)	4 (14.8)	14 (51.9)	5 (18.5)	8 (29.6)
10-14 years	13 (14.8)	13 (100.0)	0 (.0)	9 (69.2)	1 (7.7)	3 (23.1)
15-17 years	8 (9.1)	7 (87.5)	1 (12.5)	4 (50.0)	2 (25.0)	2 (25.0)
18 years	14 (15.9)	13 (92.9)	1 (7.1)	7 (50.0)	2 (14.3)	5 (35.7)
No response	4 (4.5)	2 (50.0)	2 (50.0)	2 (50.0)	0 (.0)	2 (50.0)

Notably, families with young school-going children 5-14 years predominantly settled much closer to transit stop <800m = 55.5- 69.3%). This concurs with Krygsman et al. (2004) that commuters with young children chose minimal access distances to minimize the burden of accompanying young children to transit. The presence of school-going children within a traffic analysis zone stresses the criticality of efficient planning of the first and last leg from transit. In support of this, an excerpt from the in-depth interviews highlights:

> *"……regarding the movement of vulnerable groups, if many schools are locked out, then you've basically locked out everybody else apart from young males between 18-35 years but for the rest, it becomes a bit of an issue."* - Rd1

4.2.1.2 Household economic attributes

The prevalent household size was 1-2 (53.3%), followed by 3-5 at 39.2% as shown below in table 6. This was supported by the previous findings on the number of children which indicated that respondents have small and medium-sized families. The commuters' incomes were highly dispersed across the poor, floating class, lower middle class, upper-middle-class, and upper-class income groups as stipulated by the AFDB's income thresholds for Kenya (Neubert, 2019). This affirms that the sample is highly representative of the city's population.

Table 6: Household economic profile

No. of household members			**Average income per month (Ksh)**			
	N	*%*			*N*	*%*
1-2	***64***	***53.3***		*0 – 2000 (Poor)*	*5*	*4.2*
3-5	*47*	*39.2*		*2001 – 5000 (Poor)*	*5*	*4.2*
6-8	*4*	*3.3*		*5001 – 10,000 (Poor)*	*13*	*10.8*
More than 8	*1*	*.8*		***10,001 – 20,000** (floating)*	***35***	***29.2***
No response	*3*	*2.5*		***20,001 – 30,000** (Lower middle)*	***27***	***22.5***
				***30,001 – 50,000 (**Upper middle)*	***7***	***5.8***
				More than 50,000 (Upper class)	*15*	*12.5*
Own any automobile?			**$Type of auto owned**			
	N	*%*		*AutoOwned[a]*	*N*	*%*
Yes	*26*	*21.7*		***Own Car***	***19***	***73.1%***
No	*94*	*78.3*		*Own Motorcycle*	*7*	*26.9%*

From the data presented in table 6 above, it can be said that automobile ownership is not very domineering as only 21.7% of the respondents own automobiles. Out of this, however, a majority own private cars (73.1%). The auto-ownership count is closely comparable to the income thresholds of the upper-middle and upper-class categories.

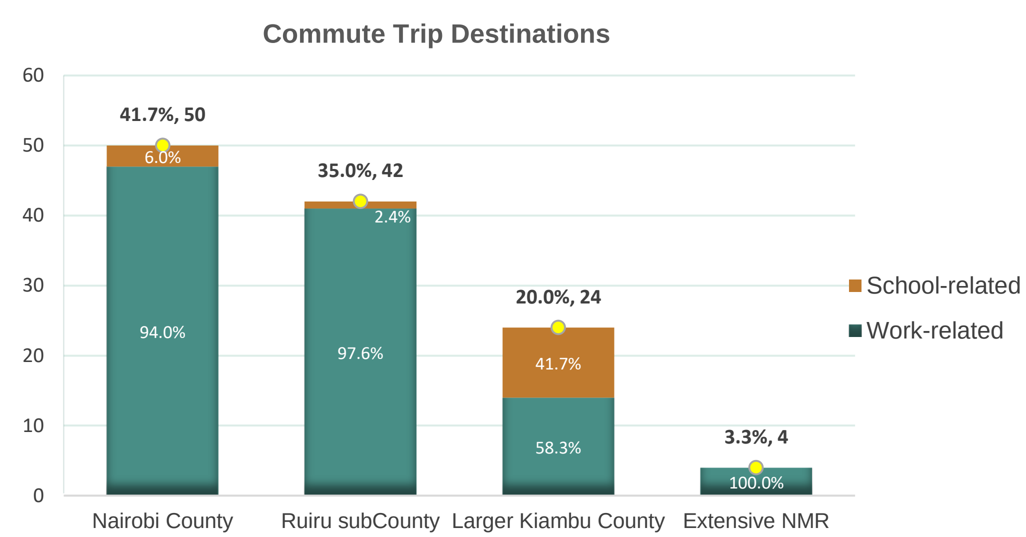
4.2.2 Physical environment profile of mobility

Commuters are rational decision-making entities who will put into consideration the street design, quality and condition of the network and travel distance before making modal decisions (Park, 2008; Tilahun et al., 2016). In this vein, the physical environment in this study embodied 2 variables; travel distance and character of the mobility networks which was a composite index defined by infrastructure provision and attractiveness of streetscapes.

4.2.2.1 Travel distance

The respondents were frequent commuters characterized by work-related trips (88.3%) and school-related trips (11.7%) which occurred 4-7 times a week. Commute trips were mainly inter-settlement represented by 65% of the responses distributed across Nairobi City County (41.7%), Kiambu County (20%) and other areas of the metropolitan region (3.3%). The juxtaposition of journey purpose to trip destination revealed high interdependence with the nation's capital-Nairobi and other regions of the metropolitan area as shown in graph 1:

Graph 1: Commute destinations and journey purpose



The routine travel from home to school or work substantiated the dormitory nature of the study area and suggested a high demand for inter-settlement mobility.

FMLM travel distance

Commuters mainly covered 0-400m in the first and last mile, with a notable share (70%) covering shorter distances in the last mile as opposed to the first mile (35%). This suggested that first mile distances are fundamentally longer and more dispersed across the 5 travel thresholds as indicated in table 7 below:

Table 7: First and last-mile travel distances

	Distance (meters) house to Ruiru Bypass transit stop			
	First Mile		Last Mile	
	N	*%*	*N*	*%*
0 – 400m	**42**	**35.0**	**84**	**70.0**
401 – 800m	**30**	**25.0**	**18**	**15.0**
801- 1000m	20	16.7	4	3.3
1001 – 1600m	12	10.0	4	3.3
Beyond 1600m (I.6Km)	**16**	**13.3**	**9**	**7.5**

To reinforce that, the calculated mean indicated that the average travel distance in the first mile was 820m which is almost twice the last mile average distance (487m). The recommended transit catchment area for walking is 400m on the lower threshold and 800m on the upper threshold (Tilahun et al., 2016; Zuo et al., 2020). Hereby, 60% of the commuters in the first mile and 85% in the last mile were within the upper threshold catchment area. However, it was also observed that a higher number of commuters (13.3%) travel beyond the extreme walkable distance (1 mile-1.6km) in the access as opposed to the egress from transit (7.5%). Longer first mile distances revealed low penetration of public transportation compared to the last mile and further insinuated neglect of this journey segment. Various key informants substantiated this with comments:

> "*So the first and last mile ends up being a lot more than a mile and a lot of cases in the Kenyan cities, is because our public transport grid is not fine enough, you know*." – Rd2

> "*So from that point of view, there is some thought of how people now if they are dropped out of the CBD, how they will access it. What we've not heard is how people will access this public transport from their homes. That I have not heard anywhere. It's not just about Matatus, even when you look at the access to the railway station, it is like they don't want you to go there*" – Rd1

Additionally, travel distance was not equally apportioned across gender. A majority of the women (68.5%) were within the walking threshold (<800m) while only a small share of the men (32.3%) was within this threshold. This was supported by literature which highlights that men travel longer distances to access transit compared to females (Krygsman et al., 2004).

4.2.2.2 Road network character

This was assessed through street attractiveness (multiple indicators measured on a Likert scale) and street infrastructure (0/1 dichotomy to measure the provision of infrastructure).

4.2.2.2.1 Attractiveness of streetscapes

Street attractiveness was measured through 8 qualitative indicators scored on a 0-5 Likert scale as summarized below:

Table 8: Applied measures of active streetscapes

S.no	Indicator	Minimum	Maximum	Mean	Std Deviation	Variance
1	**Vitality/activeness of the street**	**1**	**5**	**3.8**	1.2	1.4
2	A feeling of personal security	0	5	3.2	1.2	1.6
3	Safety of pedestrians from traffic	0	5	3.5	1.3	1.6
4	Safety of cyclists from traffic	0	5	3.4	1.4	1.9
5	Safety of motorists from traffic	0	5	3.6	1.1	1.2
6	**Sanitation (solid waste management and drainage)**	0	5	2.6	**1.5**	**2.2**
7	Condition of the road surface	0	5	1.8	1.3	1.7
8	Frequency of road maintenance	0	5	1.1	1.1	1.3

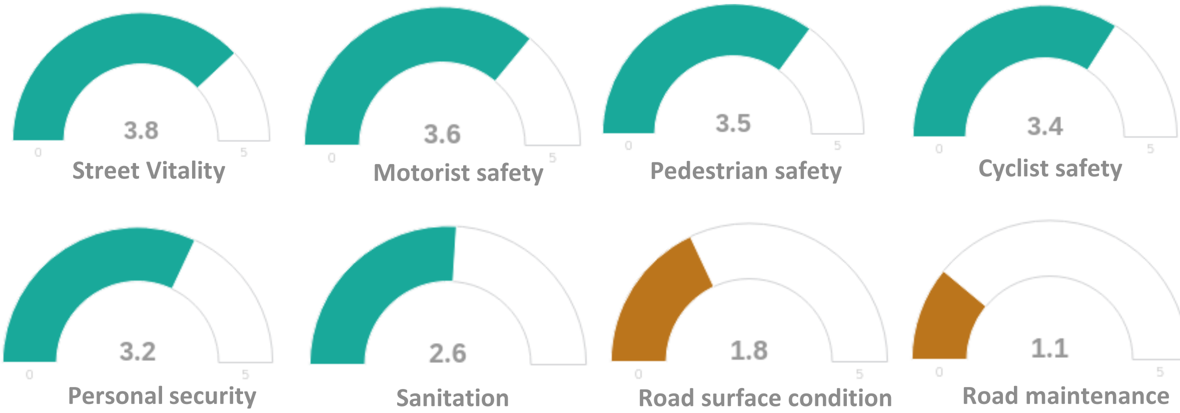
As table 8 shows, the distribution of all the scores indicated a deviation of a little over 1 point away from the mean. The standard deviation (σ) of sanitation was however the highest indicating that the responses for this particular element were more polarized. This could mean that on a larger share of streets, solid and liquid waste is not managed at all while on other small, but significant share, it is fairly managed. Further, the condition of the road surface and road maintenance accounted for the lowest scores. This was also apparent from the study area images as shown below:

Photograph 1: Road conditions in Ruiru Bypass Zone

Image A represents a striking downgrade of street infrastructure from the main highway located only a few meters away from this access road. The highway is characterized by drainage, lighting, pedestrian and cycle infrastructure which are suddenly cut off as you exit the highway. Image B further exemplifies the mobility challenges on the FMLM access roads.

As illustrated in chart 3 below, street vitality had the highest mean score (3.8) which suggested that streets used to access public transportation are fairly active. The discussion with the County Engineer however revealed chaotic vitality; "….*here is also another problem; in Kenya, whenever a new road is done, there are so many uncontrolled developments which crop-up. Bus stops attract people to do business at the hubs and maybe during the design, this was not foreseen. The* *uncontrolled developments take up the space that would otherwise be used for NMT and intermodal transfers*."- Rd3

Chart 3: Average score on street perceptions



It was also apparent that commuters feel safer while using motorized modes (3.6) to access transit as opposed to walking or cycling. This is consistent with literature which links safety concerns of pedestrians and cyclists to different motorization patterns (Tilahun et al., 2016). This was substantiated by in-depth interviews:

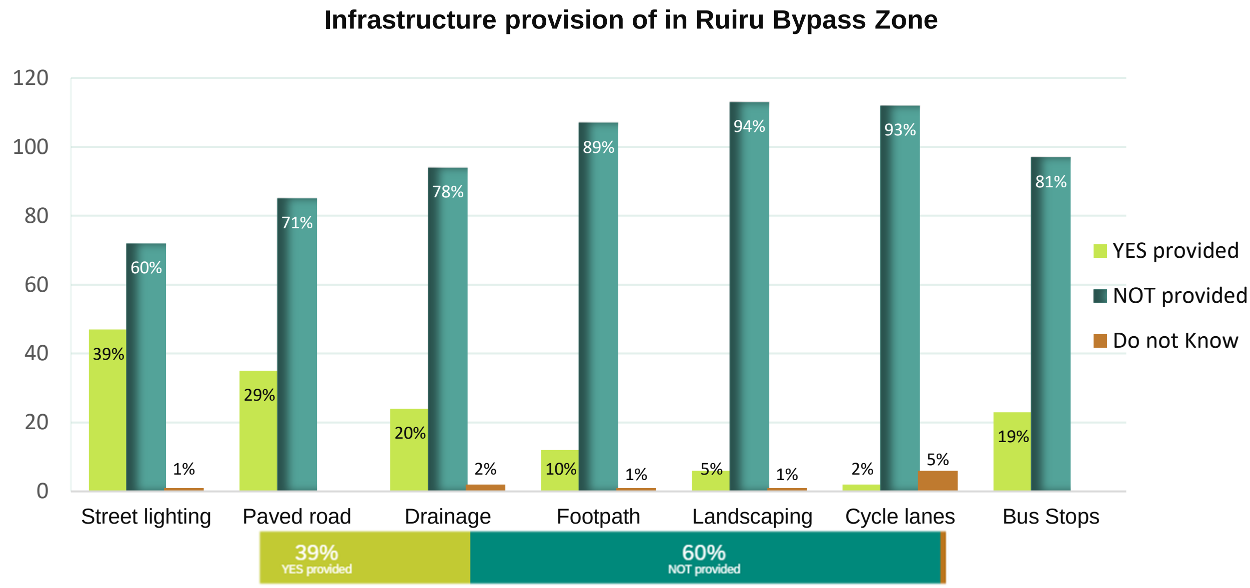
> *"…if today you asked me to cycle along Ruiru Bypass, I will not simply do that because it is very risky. If we can have safe NMT facilities, I can be encouraged to do so. I can even forgo my personal vehicle if when I alight from the bus park, I can connect to other areas conveniently via other modes. If not, the car seems like a better choice."- Rd3*

To compute cumulative street attractiveness, the Cronbach's reliability test was applied on the 8 indicators to test the internal consistency; variance within the indicators and covariance between each indicator and any other item on the scale. A Cronbach's alpha (α) value of 0.682 was produced. Although the mainstream Cronbach's alpha value for a reliable scale is > .7 (Field, 2009), a threshold of > 0.6 is deemed reasonable and acceptable for a scale of fewer than 10 items (Pallant, 2016; van Griethuijsen et al., 2014). The result of the test was therefore acceptable and the 8 elements were reliable to be computed into a scale variable (refer annex: table 18). The calculated mean score on the resultant scale variable (street attractiveness) was 2.8625. Although this value is slightly above the range midpoint, it indicates that the general attractiveness of the streets for all road users is low. In this regard, Rd2 reflected on commuter experiences: "*Then, you know, the sidewalks don't have universal access. So you're always jumping over curbs and things. So you're trying not to get squeezed between the two Matatus*"

4.2.2.2.2 Infrastructure provision

This was measured through a 0/1 dichotomous indicator; where 0 means the infrastructure listed was not provided and 1 where the infrastructure was provided. The infrastructure assessed were street lighting, road pavement, drainage facilities, landscaping, bus stops, segregated footpaths and cycle lanes. The general consensus was that street infrastructure was deficient. Roads used in the first mile by 60% of the respondents lacked basic street infrastructure while 39% had a few facilities. The (un)availability of various street infrastructure is as shown in graph 2 below:

Graph 2: Level of infrastructure provision in Ruiru Bypass zone



Paucity in public transport infrastructure and alternative non-motorized transport infrastructure was apparent as established by 93% lack of segregated cycle lanes, 89% dearth of segregated footpaths and 81% scantiness of bus stops. Rd3 brings out a concerning revelation of FMLM accessibility in the light of deficient infrastructure: *"….so they are dropped at the highway yet there is no connectivity for pedestrians to Ruiru town. From Thika Highway to Ruiru Town is a big challenge. People have to walk over and along the railway line, some bushes, very dangerous."*

Landscaping which according to Tilahun et al. (2016) improves aesthetics and therefore the road users experience was lacking in significant numbers (94%). This was practical because road infrastructure was also unavailable; it is impossible to provide landscaping before infrastructure. Some respondents also expressed a lack of knowledge on cycling and footpath infrastructure as shown in the graph above. It may be stated therefore that sufficient awareness of NMT mobility is markedly low, particularly on cycling; where lack of knowledge on cycle lane provision was the highest (5%). Additionally, the available infrastructure is not evenly distributed throughout the study area (refer to annexes: chart 7). Image analysis of the street layout provided a presumption that the carriageway is paid greater attention as compared to the other street elements. This was evidenced by photograph 2 below where ample space is delineated for the carriageway but no provision for non-motorized transport infrastructure such as footpaths or cycle lanes. Pedestrians were observed to add their own enhancements to adapt the street infrastructure to their mobility. These amendments include informal footpaths on the edge of the road reserve and stepping stones where roads were impassable.

Photograph 2: A glance at street infrastructure in Ruiru Bypass zone

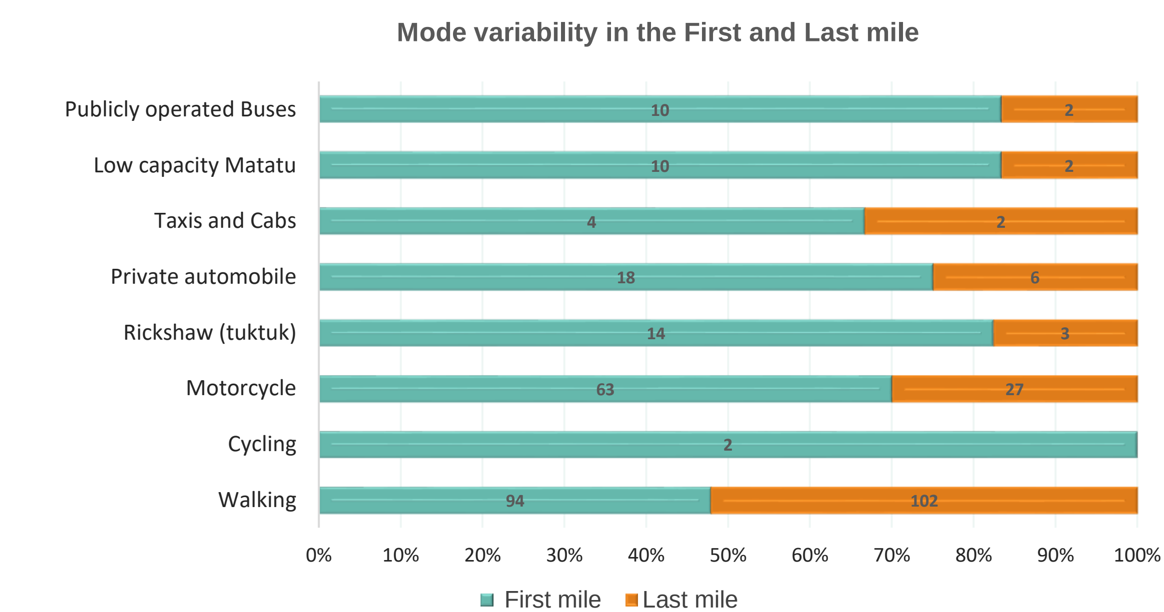
To define the network quality from street attractiveness and infrastructure provision discussed above, the Cronbach's alpha test was run to create the scale variable of network quality. The test on all the items (15 in total) yielded (α) value of 0.687. However, it was observed that "provision of paved roads, designated bus stops, landscaping and street vitality" had a very low correlation with the other variables on the scale and were thus removed from the computation. The recalculated (α) value was 0.704 which confirmed the reliability of the remaining 11 items.

4.2.3 Modal environment profile

4.2.3.1 FMLM modal variability

As shown in graph 3 below, modal variability was assessed by documenting the variety of travel modes available for commuters in the initial and final leg of their journey.

Graph 3: FMLM modal variability



The analysis was premised on the logic that the higher the number of travel modes availed to an individual, the more prevalent modal variability will be. The survey indicated that 8 travel alternatives were available for use in the first mile and 7 in the last mile. Availability of some modes such as cycling was significantly low and completely unavailable in the last mile, while motorcycle and walking were readily available. The total count of first-mile multiple modal choices (59.89%) outweighed the total count of last-mile modal choices (40.11%) which suggested that modal variability was higher in the first mile as compared to the last mile. To substantiate this, the total number of travel modes available to each respondent was computed and averaged. It was observed that residents have access to a minimum of 1 travel mode and a maximum of 5 in the first mile, while in the last mile they have access to 0-3 modes as tabulated in table 9 below:

Table 9: Modal variability in the First and last mile

Modal Variability – modes available per respondent

	N	Minimum	Maximum	Mean	Std. Deviation
FM modes available	120	1	5	**1.79**	0.888
LM modes available	120	0	3	**1.20**	.460
Valid N (listwise)	120				

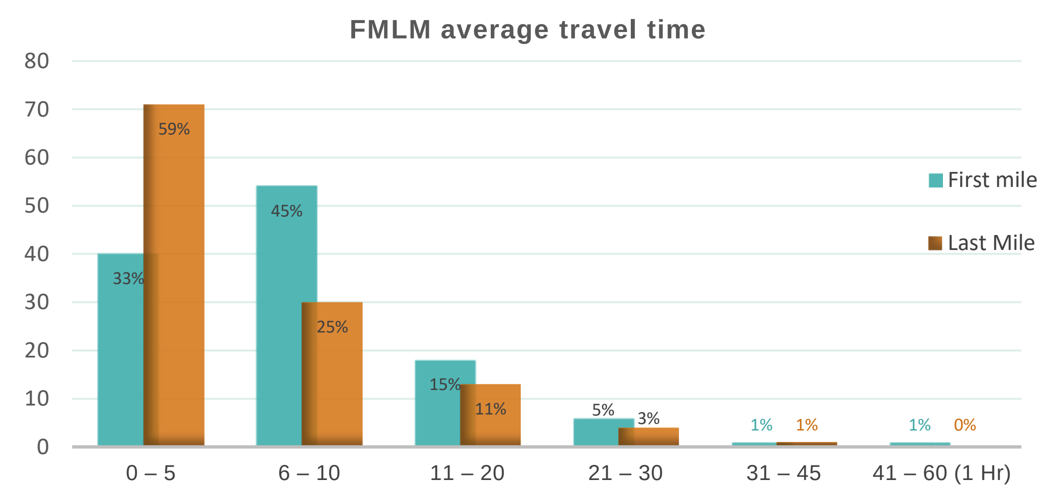
*FM - First mile
*LM - Last mile

Modal variability was thus higher in the first mile than the last mile.

4.2.3.2 Travel time

The temporal thresholds of the respondents suggested that last mile journeys were generally faster than first mile journeys. This was based on the 0-10 minute threshold for the majority of last-mile trips and 0-20 minutes for the majority of first mile trips as graph 4 shows:

Graph 4: FMLM travel time

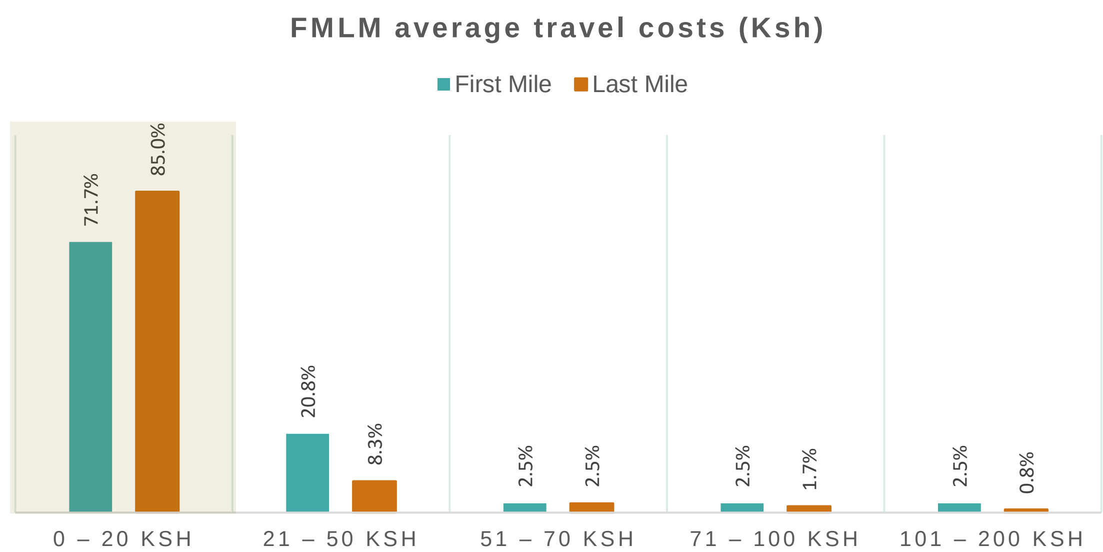


The average travel time for different journey segments was as follows: first mile - 8.8 minutes (21.64% of the entire trip), last-mile - 6.4 minutes (15.74% of total trip time) and Line haul – 25.4 minutes (62.62% of the entire trip). The interconnectivity ratio (IR_i) was computed to reflect the proportion of first and last mile travel time as a share of the total trip time. This yielded IR_i value of 0.16 - 0.22. As opposed to some prior studies, in this study interconnectivity ratio was disregarded as an index of temporal quality of multi-modal trips because according to theoretical underpinnings, it excludes wait and transfer times (Krygsman et al., 2004). The average travel times were therefore emphasized here.

4.2.3.3 Travel cost

The perceived cost of FMLM travel was averaged at 18.9Ksh while the average cost of the entire trip was 101.3Ksh. First-mile travels were seen to cost 23Ksh per kilometre while the last-mile costs were 38.8Ksh per kilometre. Therefore, although first mile distances are longer than the last mile, they cost considerably less for each kilometre travelled. To explain this, Liu et al. (2018) highlight that the perceived financial cost of travel is a function of travel modes. Linking to modal variability, commuters have access to more options in the first mile (maximum of 5) than in the last mile (maximum 3) which thus explains the lower travel costs in the first mile.

Graph 5: FMLM travel cost



4.3 Motorization patterns

The proximal location of Ruiru Bypass zone to the bustling Ruiru town, major employment areas, prime economic hubs, major transport corridors, education centres, recreation areas, low-middle-high income residential areas was observed to elicit anarchic demand for mobility and generated myriad motorization patterns.

4.3.1 Modal share

The primary transport modes used by the respondents for each segment of the journey is shown in table 10 below. The commuter survey revealed patronage to active transportation in both the first (64.1%) and last-mile (76.6%), while motorized modes accounted for the largest share (85.1%) in the line haul.

Table 10: Modal share of the 3 journey segments

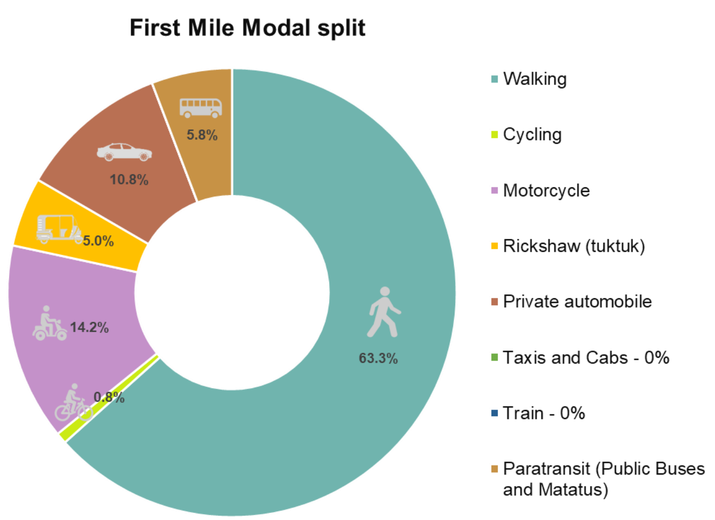
Frequently used mode of travel	First Mile (% share)	Line Haul (% share)	Last Mile (% share)
Mode shares			
Walking*	**63.3%**	15.0%	**75.8%***
Cycling	0.8%	0.0%	0.8%
Motorcycle	14.2%	14.2%	13.3%
Rickshaw (tuktuk)	5.0%	1.7%	2.5%
Private automobile	10.8%	11.7%	5.0%
Taxis and Cabs	0.0%	0.8%	0.8%
Train*	**0.0%***	**0.0%***	**0.0%***
Paratransit (Publicly operated Buses and Matatus)	5.8%	56.7%	1.7%
Summary stats			
Share of non-motorized modes	64.1%	15.0%	76.6%
Share of all motorized modes	35.8%	85.1%	23.3%
Share of low-capacity motorized modes*	**30.0%***	28.4%	21.6%
* Notable observation			

The general observation was that although walking is used by a considerable number of respondents on all the journey segments, its prevalence is salient in the last mile. Public transportation was seen to be very unpopular in the first and last miles. Additionally, the failure to use the train (0%) in any of the journey segments was perplexing despite the existence of a train station within the study area and a railway line that traverses the settlement.

First mile:

Despite the observed dearth in infrastructure, walking dominated this journey segment as shown in chart 4 below. A significant number of respondents (35.8%) were also seen to rely on motorized modes as their primary access mode.

Chart 4: Modal share in the first mile



Reasons for First Mile modal choice

	Percent (%)
Distance/Proximity *	34% *
Physical exercise	7%
Convenience	13%
Costs *	26% *
Time and speed	6%
Availability	4%
Safety	2%
Ownership of an automobile	8%
Total	100%
* Notable observation	

A further striking observation was that low-capacity, highly polluting modes were most prevalent in the first mile (30%) as compared to other journey segments. This was revealed by the share of private cars, motorcycles, and 3-wheelers (rickshaws). To substantiate this, the manual traffic count data was analyzed and discrete values plotted in graph 6 below. The data recorded even higher motorization levels than revealed by the commuter survey. The traffic volumes indicated 77.4% use of low capacity automobiles, 18.1% use of NMT modes, and 4.5% use of paratransit transport modes. This finding was consistent with previous studies which indicated that motorized modes in Ruiru dominate at 75-76%, while non-motorized mobility only accounts for 23-25% (UN-Habitat, 2018). The statistics further confirmed the unavailability of public transportation modes, which were observed to record the least values.

Graph 6: Motorization patterns evidenced by traffic volumes

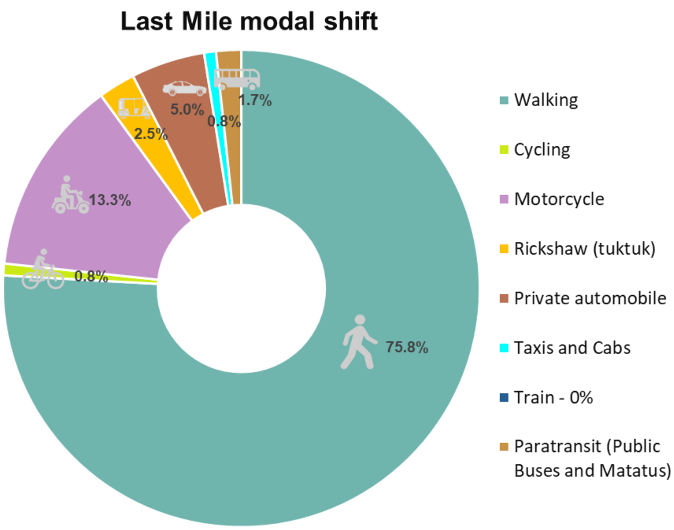
As illustrated by the trend line in graph 6, the plotted traffic volumes revealed a positive, moderate non-linear relationship between out-bound and in-bound modality. Although the relationship between the two cases cannot be interpreted as a causal relationship, increases in outbound volumes can be associated with the volumes in the inbound; except for NMT volumes whose most points are far off the trend line. During the morning peak hours (7am-9am), the outbound traffic recorded lower volumes (40%) than inbound traffic volumes (60%), while in the evening peak hours (5pm-7pm) the outbound had slightly higher volumes (53%) than the inbound (47%). This reveals that the demand for mobility towards the transportation node outweighs the outbound demand during the morning peak hours, while in the evening peak hours mobility demand is almost balanced. In both directions, however, low capacity auto-mobility dominated at 454-580 vehicles per hour (70% of total volume), succeeded by NMT at 97-221 people per hour (19.5%), and least paratransit at 22-55 per hour(4.5%) during the peak hour periods.

The first mile recorded a high consistency between modal variability and modal split; the higher the modal variability per travel mode, the greater the modal share recorded. An intriguing observation was that despite the reasonably high modal variability of taxis and cabs, their modal split was 0%. This indicated that although these modes were supplied, commuters did not patronize them in the first mile. This can be explained by the reasons highlighted for modal choice; distance and the financial cost associated with the travel mode.

Last-mile:

Just like in the first mile, travel modes that had a high score on variability also had a high score in the modal split. Similarly, taxis and cabs remained unpopular on this journey segment despite their high level of availability. Walking and motorcycles dominated as shown in chart 5:

Chart 5: Modal share in the last mile



Reasons for Last Mile modal choice

	Percent (%)
Distance/Proximity *	**53% ***
Physical exercise	1%
Convenience	16%
Costs	15%
Time and speed	4%
Availability	6%
Ownership of an automobile	5%
Weather	1%
Total	100%

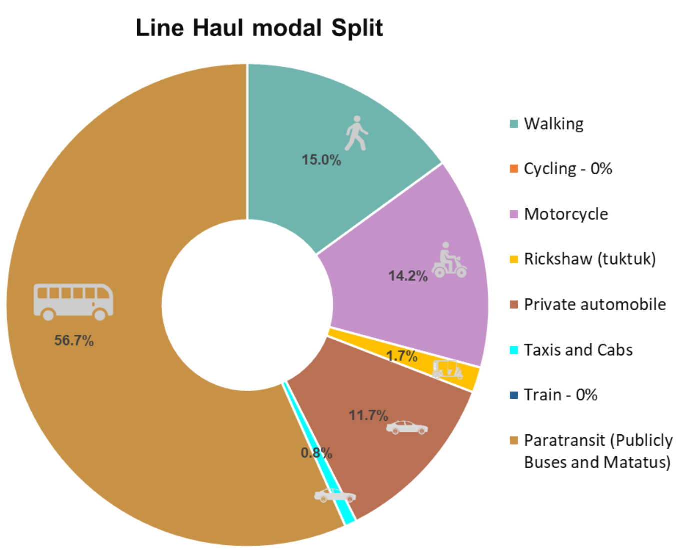
* Notable observation

Notably, the use of private automobiles in this journey segment (5%) reduced by half from the value in the first mile (10.8%). This is attributable to the short travel distances and higher travel costs associated with the last mile. Besides, 53% of the respondents underscored distance as the principal reason for which they selected their preferred travel mode.

Line Haul:

Paratransit (vans: 14-seater Matatus and 25-seater buses) dominated the main segment of the commuter's journey as shown in chart 6.

Chart 6: Modal share in the main segment of the journey



Reasons for Line Haul modal choice

	Percent
Proximity/Distance	15%
Convenience and Availability *	**49% ***
Costs	28%
Time and speed	3%
Ownership of an automobile	5%
Total	100%

* Notable observation

The frequency of use however illustrated irregular patterns; 41.7% of commuters used paratransit daily, 30.8% weekly, 10% monthly, 6.7% yearly and 10.8% did not use them at all. It was highlighted that when paratransit is not in use, commuters opt for low capacity autos. High use of automobiles was observed since the share of private cars and motorcycles was higher than in any other segment of the journey. As shown on the chart, the train remained unpopular (0%) despite the availability of a train station and a train which services the area twice a day. Public transport ridership was fairly low accounting for only half (56.7%) of the modal split. The in-depth interviews shed light on the contributors of this scenario by citing inaccessibility to the available road and rail public transportation:

> *"…you find that Ruiru town has a Bus Park and Railway station but you find the area is highly populated. So although the town has this infrastructure, the population does not live within the town CBD and are unable to reach this infrastructure."*-Rd3

Additionally, respondents cited convenience and availability (49%) as the main reasons which determine their line haul modal choice. In an open-ended question, one respondent mentioned:

> *"…..on the highway public Matatus are readily available, the challenge is just getting to that Matatu"*- R21

The chart further illustrates high usage of low capacity automobiles (28.3%). More than 2/3 of the private auto users (71.4%) opted for this travel mode due to its convenient access from the doorstep to the final destination.

4.4 Statistical analysis

Having fully assessed FMLM accessibility and motorization patterns in succession, it was crucial to evaluate the causal relationships between the two variables.

4.4.1 Correlation

The initial step in defining these relationships was undertaking a non-parametric correlation analysis to establish and weigh the strength of associations among variables. Apropos of that, the bivariate Spearman rank Correlation Test was conducted. Scientifically, correlation coefficients of +1 indicate that the variables tested are perfectly positively correlated, 0 indicates no relationship while a coefficient of -1 signifies a perfectly negative correlation (Field, 2009). By screening through the correlation matrix, it was observed that some variables such as the number of children, household size, age, marital status, catchment area, and travel distance had very high correlations (Spearman's rho (ρ) >= 0.8). This indicated a potential for collinearity which prompted the execution of a collinearity test by generating the Variance Inflation Factor (VIF) and the tolerance statistic. These statistics indicate to what extent a particular predictor is contributing to multicollinearity within the dataset. VIF values of >10 indicate that the predictor variables are highly correlated and pose a multicollinearity concern (Bowerman & O'Connell, 1990 cited in Lavery et al., 2017). Tolerance on the other hand indicates serious problems if it is < 0.1 and potential problems when < 0.2 (Field, 2009). From the collinearity diagnostics, (refer annex: table 21) number of children and catchment area raised multicollinearity concerns (VIF >10) and were thus discarded. Although the VIF values for marital status and household size were not >10, their tolerance statistics were below 0.2 highlighting potential collinearity problems. They were therefore also discarded. The other variables had significant correlations amongst each other but not too strong as to divide up the explanatory power of coefficients among them. The final tabulation of relevant variables is as shown in table 11 below:

Table 11: Spearman's correlation output

		Correlation Coefficient: Spearman's rho (ρ)										
		V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**IdV11**
V1	Gender	1.000	.148	-.121	-.027	-.126	.042	-.109	-.182*	-.114	.007	**-.146**
V2	Age	.148	1.000	.221*	.499**	.081	.167	-.091	.076	-.114	-.012	**.201***
V3	Auto ownership	-.121	.221*	1.000	.388**	.095	-.043	-.186*	.177	.130	.147	**.625****
V4	Income	-.027	.499**	.388**	1.000	.255**	.071	-.052	.100	.160	-.037	**.398****
V5	Travel Distance	-.126	.081	.095	.255**	1.000	.135	.207*	.242**	.202*	-.205*	**.276****
V6	Modal variability	.042	.167	-.043	.071	.135	1.000	.117	.296**	-.063	-.103	**.177**
V7	Travel Time	-.109	-.091	-.186*	-.052	.207*	.117	1.000	.322**	.073	-.224*	**-.066**
V8	Travel cost	-.182*	.076	.177	.100	.242**	.296**	.322**	1.000	.150	-.092	**.472****
V9	Infrastructure provision	-.114	-.114	.130	.160	.202*	-.063	.073	.150	1.000	.094	**.278****
V10	Street attractiveness	.007	-.012	.147	-.037	-.205*	-.103	-.224*	-.092	.094	1.000	**.102**
IdV11	Modal share	**-.146**	**.201***	**.625****	**.398****	**.276****	**.177**	**-.066**	**.472****	**.278****	**.102**	**1.000**
	Sig. (2-tailed)	.111	.028	.000	.000	.002	.054	.475	.000	.002	.266	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The above correlation matrix authenticated significance of most relationships ($p < 0.05$) while gender, travel time, and street attractiveness recorded statistically insignificant relationships (p of 0.111, 0.475, and 0.266). These three were hereby omitted in the subsequent modelling steps.

4.4.2 Logistic regression

Motorization trends as defined by modal share were predicted through logistic regression which allowed prediction of a categorical outcome (Field, 2009). The modal share comprised of 8 nominal categories which were recorded into 3 categories based on the level of motorization (low/no motorization to high motorization) as shown on table 12 below:

Table 12: Recorded nominal categories of motorization

Modal split as in the commuter survey inventory	Modal split as recorded in the model
Walking	1. Active transport
Cycling	
Low capacity Shuttles (Matatu)	2. Paratransit (public transport)
Train and Publicly operated Buses	
Motorcycle	3. Low capacity automobiles
Rickshaw (Tuktuk)	
Private car	
Taxis and Cabs	

Four predictors and three moderating variables that had significant correlations in antecedent analyses were used in modelling. The variables were measured at scale, ordinal and nominal scales. Accordingly, to predict membership into one of the 3 modal categories**, multinomial logistic regression** was applied. The data fulfilled the basic minimums of multinomial logit modelling i.e.

nominal dependent variable, continuous/ordinal/nominal independent variables, category independence, and non-multicollinearity. Due to the availability of more detailed data for the first mile, and high correlation between First and Last mile physical and modal environment parameters, only first mile statistics were applied in the models. Additionally, the moderating effects of social environment variables were added to the models through interaction predictors (product of the predictor and its moderator). To generate the interaction predictors, moderators were recoded into dummy variables as indicated in table 13 below:

Table 13: Dummy coding of logistic regression moderators

Moderating variable	**Dummy variable**
Age	0= < 45 years (*young and middle aged*), 1= others (*Above 45yrs*)
Income	0= Floating class and below, 1= above floating class (*Middle and upper class)*
Auto ownership	0= no auto owned 1= owns an automobile

In predicting the FMLM motorization, an initial base model containing the 4 predictors without any moderating effect was created. The subsequent models factored in moderation by introducing the interaction effects of the 3 moderators progressively. The statistically significant interaction terms were identified and used to produce the final model together with the main effects of the predictors. The same process was followed in predicting Line Haul motorization. Although many models (29) were produced during the regression analysis, in-depth discussions focus on 5 relevant models (3 in FMLM motorization and 2 in Line haul motorization). In all the models, low capacity automobiles was used as the reference category.

FMLM Assessment models: Modality in the FMLM

The regression analysis process of the FMLM modality produced 15 models. The initial model used travel distance, modal variability, travel cost, and infrastructure provision without any moderation effects while the subsequent 12 models progressively introduced 12 interaction terms. From this, only 5 models indicated statistically significant interaction effects (refer to annexes: table 22). Based on the outputs of the progressive regression analysis, 2 final models were produced. This section thus details out 3 models: the initial model without moderation and 2 final adopted models with moderation.

Table 14: Summary of the relevant FMLM models

Pseudo R-Square	.267
Initial Model - Without Moderation	
Effect	Sig.
Intercept	.000
Travel distance	.137
Modal variability	.188
Travel cost	.004
Infrastructure provisions	.023

Pseudo R-Square	.578
Final Model (a) - With significant moderation	
Effect	Sig.
Intercept	.000
Travel distance	.468
Modal variability	.027
Travel cost	.000
Infrastructure provision	.009
Auto Ownership	.000
Average income	.254
Age	.700
Age * Travel cost	.011

Pseudo R-Square	.584
Final Model (b) - With significant moderation	
Effect	Sig.
Intercept	.000
Travel distance	.343
Modal variability	.028
Travel cost	.000
Infrastructure provision	.007
Auto Ownership	.000
Average income	.379
Age	.707
Age * Infrastructure	.005

As shown in Table 14 above, the main effects of **travel cost and infrastructure provision** were significant in the initial model with $p < 0.05$, while travel distance and modal variability were insignificant $p > 0.05$. Notably, the Cox and Snell R^2 which measures how well we can predict the dependent variable from the predictors yielded 0.267 which means the variables in the initial model accounted for 27% explained variance in modal share which is substantially low. The explained variance however increased progressively as the interaction effects were added to the models one after another. The interaction effects of **age * travel cost** and **age * infrastructure provision** as revealed by models 8 and 9 were statistically significant. By contrast, all the moderating effects of **auto ownership and income** were insignificant but their **main effects** were significant in models 3, 5 and 13 (refer annexes: table 22). This finding indicates that auto ownership and income should be treated as predictors (main effects) as opposed to moderators in FMLM assessment. The impact of travel distance on modal share in all the models remained insignificant.

<u>Predicting FMLM motorization with moderation</u>

Two final models (FMLM 14-15) which incorporated: main effects + age * travel cost, and main effects + age * infrastructure provision were produced. The explained variance of the final models (both 58%) revealed a sizeable effect on the selected travel mode in the FMLM. This was significantly high as compared to the initial model (27%), which substantiates the criticality of moderation and the additional main effects. Through the significant interaction terms, the final models accentuate that although the main effects of travel cost and infrastructure provision are significant, their probability to influence the mode of transport adopted will be dependent on the age of the commuter. Strikingly, by adding interaction effects, **modal variability** which was insignificant in the base model ($p = 0.188$) gained significance in the final models ($p = 0.027$, $p = 0.028$). Parameter analyses of both models were used for in-depth inferential analysis. This specified the one-to-one relationship between the predictors, interaction terms and the dependent variables as summarized in table 15 below and further detailed out in annexes: table 24 and 25:

Table 15: Parameter estimates of the final FMLM models

Final models: FMLM Modal share/motorization patterns								
Modal Choice	Model FMLM14:				Model FMLM15:			
	Cox and Snell R2	*0.578*		*N= 117*	*0.584*			*N= 116*
FMLM motorization[a]		B	Sig.	Exp(B)		B	Sig.	Exp(B)
Active transport	Intercept	5.116	.004		Intercept	5.072	.003	
	Travel distance	-.266	.337	.766	Travel distance	-.256	.358	.774
	Modal variability	-1.092	.015	.336	Modal variability	-.972	.027	.378
	Travel cost	-1.905	.002	.149	Travel cost	-2.089	.001	.124
	Infrastructure provision	-.375	.154	.687	Infrastructure provision	-.409	.124	.665
	Average income	-.584	.107	.558	Average income	-.527	.144	.590
	Age	-.315	.546	.730	Age	-.325	.520	.723
	Age * travel cost	1.858	.013	6.411	Age * infrastructure	4.816	.032	123.473
	[No auto owned=0]	4.531	.000	92.808	[No auto owned=0]	4.510	.000	90.960
	[Auto Ownership=1]	0[b]			[Auto Ownership=1]	0[b]		
Paratransit	Intercept	-23.365	.000		Intercept	-23.254	.000	
	Travel distance	.156	.719	1.169	Travel distance	.167	.703	1.181
	Modal variability	-.127	.814	.881	Modal variability	-.125	.816	.882
	Travel cost	.447	.441	1.564	Travel cost	.424	.461	1.529
	Infrastructure provision	.548	.118	1.730	Infrastructure provision	.522	.130	1.685
	Average income	-.209	.676	.811	Average income	-.180	.720	.835
	Age	.339	.713	1.404	Age	.247	.777	1.280
	Age * travel cost	-14.493	.998	0.000	Age * travel cost	-10.033	.999	4.391E-05
	[No auto owned=0]	20.594		8.79E+08	[No auto owned=0]	20.577		8.64E+08
	[Auto Ownership=1]	0[b]			[Auto Ownership=1]	0[b]		

a. The reference category is: Low capacity autos.

As tabulated above, model FMLM14 indicates that modal variability, travel cost, auto ownership and the interaction effect of age*travel cost were significant in predicting whether a commuter chose active mobility (NMT) over low capacity automobiles in the FMLM. It is observed that while holding all the other predictors constant, a unit-increase in modal variability (*Exp(B) = .336*) results to 66.4% less likelihood of a commuter to select active transport over low capacity automobiles in accessing transit (*1.00- Exp (B) * 100*). Interestingly, the effect of travel cost (Ksh) on the selection of NMT changes direction based on age. Adjusting for other factors, a unit increase in travel cost reduces the probabilities of selecting NMT by 85.1% (*Exp(B) = .149*). However, when the interaction effect with age (0= < 45 years, 1= > 45yrs) is introduced, a unit increase in travel cost makes it 6 times more likely for young and middle-aged commuters (<45 years) to select NMT over automobiles. It is further observed that commuters who do not own automobiles are 92 times more likely to select active mobility over automobiles while holding other predictors constant. In model FMLM15, with a unit increase in modal variability (*Exp(B) = .378*) and travel cost (*Exp(B) = .124*), a commuter is 62.2% and 87.6% less likely to opt for NMT over low capacity automobiles holding other factors constant. Not owning an automobile (*Exp(B) = 90.96*) makes commuters 90 times more likely to select NMT over automobiles. Lastly, the model reveals that with a unit increase in infrastructure provision moderated by age, a young/middle aged commuter is 123 times more likely to choose active transportation modes over low capacity autos. The effect of all the predictors and interaction effects on the use of paratransit over low capacity automobiles in this journey segment was insignificant which can be explained by the desuetude of paratransit in the FMLM as reflected by 5.8% modal share outlined in section 4.3.1

FMLM Assessment models: Modality in the Linehaul

Unlike the previous models, here the predictors and moderators were used to define motorization patterns in the line haul. Model Lh1 applied the four predictors without moderation effects, while Lh2-Lh13 introduced interaction terms of the moderating variables with each predictor. Notably, on this journey segment, the social environment moderators did not have any statistically significant interaction effects. However, their main effects proved to be statistically significant as revealed by models Lh2, Lh3, Lh5 (auto ownership); Lh9 (age) and Lh10, Lh12, L13 (average income) - (refer annexes: table 23). Model Lh14 applied the initial predictors and the additional significant main effects from the preceding models. Detailed discussions hereby focus on the initial model without moderation and the final model with additional main effects as summarized in table 16 below:

Table 16: Summary of the initial and final Line haul models

Pseudo R-Square	.079
Initial Model Lh1 - Without moderation	
Effect	Sig.
Intercept	.010
Travel distance	.057
Modal variability	.245
Travel cost	.878
Infrastructure provision	.404

Pseudo R-Square	.431
Final Line Haul model - Initial predictors + Sig. main effects	
Effect	Sig.
Intercept	.002
Travel distance	.394
Modal variability	.001
Travel cost	.684
Infrastructure provision	.532
Auto Ownership	.000
Age	.240
Average income	.006

As observed in table 16 above, the predictors with main effects on modal share were interestingly fewer than in the access and egress prediction. Here, only **modal variability** in the final model had a significant main effect on line haul modal share (p= 0.001). The other main effects in the final model are associated with the social environment variables which proved to have insignificant moderating effects but significant main effects. The final model predicted a sizeable variability in the line haul modal share (43.1%) and was thus a substantial upgrade from the initial model which had only 7.9% explained variance. The parameter analysis of the final model as tabulated in Table 17 below was used to analyse the prediction effect of each variable on the selection of active mobility or public transportation over low capacity automobiles in the main journey segment.

Table 17: Parameter estimates of the final Line haul model

Final model: Line Haul Modal share/motorization patterns						
Model LH14:	*Cox and Snell R2 = 0.431*		*N= 115*			
LHmotorization[a]		B	Std. Error	Wald	Sig.	Exp(B)
Active transport	Intercept	5.689	1.798	10.012	.002	
	Travel distance	-.324	.265	1.487	.223	.724
	Modal variability	-.721	.621	1.349	.245	.486
	Travel cost	-.490	.601	.664	.415	.613
	Infrastructure provision	-.276	.259	1.143	.285	.759
	Age	.204	.488	.175	.676	1.226
	Average income	-1.246	.440	8.014	.005	0.288
	[No auto owned=0]	19.823	.000			406313669.8
	[Auto Ownership=1]	0[b]				
Paratransit	Intercept	2.017	.991	4.144	.042	
	Travel distance	-.247	.203	1.475	.225	.781
	Modal variability	.732	.327	5.032	.025	2.080
	Travel cost	-.149	.317	.220	.639	.862
	Infrastructure provision	-.078	.178	.189	.664	.925
	Age	.547	.381	2.066	.151	1.728
	Average income	-.680	.280	5.879	.015	0.507
	[No auto owned=0]	2.450	.645	14.424	.000	11.586
	[Auto Ownership=1]	0[b]				
a. The reference category is: Low capacity autos.						

Table 17 highlights that the average income of a commuter plays a significant role in predicting whether a commuter would select active mobility over low capacity automobiles in the line haul. It was observed that while holding other factors constant, a one-unit increase in average income (Ksh) of a commuter (*Exp(B) = 0.288*) results to 71.2% less likelihood of the commuter selecting active mobility over automobiles. Additionally, the same increase was seen to cause a 49.3% less likelihood of selecting public transportation over low capacity automobiles (*Exp(B) = 0.507*). By contrast, increasing mode-variability in transit access by one-unit makes it 2 times more likely for a commuter to select public transport over low capacity automobiles in the main segment of their journey. While holding other factors constant, commuters who do not own automobiles are 11 times more likely to use paratransit in the line haul as opposed to those who own automobiles.

4.5 Discussion of the findings

Statistical analyses provided evidence of relationships between FMLM accessibility variables and motorization patterns (modal share). A significant difference was observed in the effect of the predictors on FMLM modal share and the line haul modal share. In the access and egress; **modal variability, infrastructure provision, travel cost and auto ownership** were significant in determining FMLM motorization patterns. This was further supported by a rigorous interpretation of correlation tests where the "coefficient of determination" was computed by squaring the r-value of each variable and expressing it as a percentage. This helps explain how much variability in one factor can be associated with its relationship to another (Pallant, 2016). The percentage of variance for infrastructure provision (r=.278) indicated 7.7% shared variance with modal share (r^2*100), modal variability 3.1%, travel cost 22.2% while auto ownership was 39.1%. Therefore auto ownership and FMLM travel costs explain a higher variance in commuters' modal choices. From the two final FMLM models, increasing **modal variability** by a unit has been seen to increase the odds of a commuter selecting active mobility over automobiles by 62.2-66.4%. It is observed that although commuters have access to a maximum of 5 modes in the first mile, 4 of those modes are mainly motorized while only 1 mode represents active mobility (walking). The provision of travel modes in the FMLM is demand-driven which explains the dominance of two- and three-wheelers whose motivation is profits and high returns. With the low availability of public transport (evidenced by 5.8% in descriptive analysis), the intermediate motorized modes are bound to increase to bridge the connectivity gap. Although this increases modal variability, it reduces the probability of using active modes. This trend can however be intercepted by specifically increasing commuters' exposure to walking and cycling in the FMLM. This means targeted investment into more kilometres of footpaths and cycle lanes.

To support this, the models suggested that **infrastructure provision** increases the attractiveness of active mobility. This is consistent with previous studies which highlight that access to the first and last mile is substantially positively weighted by infrastructure availability (Zuo et al., 2020). Interview excerpts added to this by emphasizing the potential of infrastructure to reduce motorization:

> *".....if provided the right infrastructure, I think a lot more people would go for walking and cycling, I think especially because the perception is that it's just too unsafe right now, a lot of people who recognize the benefits and even would want to do it for fitness reasons are just staying away because they're really scared of the roads"*-Rd2

> "*Due to the bad experience people have on different roads, when an opportunity comes to go to a different travel mode of transport particularly a private car, they jump on to it. And it is not like I blame them because it is not like I enjoy walking there either. Sometimes it's muddy, crowded, vehicles speeding. In fact I think this is one of the biggest factors affecting the increase in motorization. The fact that people do not have proper access to public transport, not going into the fact that public transport itself is another whole issue on its own*" – Rd1

The final FMLM model, however, cautions that increasing infrastructure coverage does not directly maximize active mobility. Rather, the resultant effect is dependent on the **age of commuters**. To wit; commuters below 45years are 123 times more likely to adopt active mobility as compared to other adults (> 45years) when a unit of infrastructure is provided. This spotlights the need for people-centred infrastructure; that which responds to different commuter needs – in this case, based on age. It is also observed from past studies that each additional year of age reduces the probabilities of walking and cycling to transit by 1.8% and 4.4% respectively (Tilahun et al., 2016). Contributing to the discussion, Li et al.,(2019) highlight that condition of road infrastructure and traffic planning influence the ease of access for pedestrians of different age groups.

Age was also seen to moderate the impact of **travel costs** in the FMLM models. While the direct effect of an increase in travel costs resulted in 87.6% less likelihood to select active mobility, consideration of age revealed that young and middle-aged adults would still choose non-motorized modes; 6 times more likely than senior adults with all other factors held constant. This highly suggests that planning authorities can maximize active mobility by penetrating NMT infrastructure and the public transportation grid into areas where commuters pay high costs to access transit. In this context, the local (county) government bears the role over FMLM access roads although based on national road classification, KURA or KeRRA can assume responsibility. The effect of

automobile ownership on the travel mode adopted in the FMLM was also increasingly pronounced in both final models. The likelihood of commuters who do not own automobiles to use active transport over automobiles was to a large extent higher than that of auto owners.

In-depth discussions further enriched the study by bringing to light governance and structural parameters that have greatly influenced "when, where and how" infrastructure is provided. Some related limitations included; a multiplicity of road institutions who work in isolation, lack of intergovernmental linkages, financial constraints where infrastructure is designed based on financial availability rather than user needs, political influence interfering with prioritization of universal mobility, uncontrolled public transport anti-monopolism, poor public engagement and capacity building, road classification which has been overtaken by urbanization, prioritization of motorized modes in current road design manuals among others. These were apparent and supported by the interview responses:

> *"Our designs are based on funds availability not on needs and other considerations. You may need like 10 bus stops but due to funds available, you tend to minimize those stops to the doable amount based on the cost rather than the need. Vehicles are given priority, even in our design manuals"* – Rd3

It was observed that there wasn't enough evidence to associate the previously discussed predictors with the selection of paratransit over low capacity automobiles in FMLM final models. The substantially low modal share of paratransit in the FMLM could be one of the explanatory factors. The commuter inventory supported by the traffic count data had a very low response for this particular category. Based on the typical multiple regression equation ($\gamma = \beta_0 + \beta_1 X_1 + \beta_2 X_{2....} + \beta_n X_n + \varepsilon$), the final regression models for the FMLM modal choice of commuter *k* on access route *j* is represented as follows:

$$Y_a = 5.116 + 0.336MVj + 92.808Am[0]k + 6.411Ak{*}TCj + 1.756$$

$$Y_a = 5.072 + 0.378MVj + 0.124TCj + 90.960Am[0]k + 123.473Ak{*}IPj + 1.694$$

> Where; Y_a is the predicted modal category for active transport (with low capacity autos as the reference category), MV*j* is modal variability on route *j*, Am[0]*k* is automobile ownership representing category 0 (no auto owned by commuter *k*), A*k**TC*j* is the cost of travelling on route *j* moderated by age of commuter *k*, TC*j* is travel cost on route *j*, A*k** IP*j* is infrastructure provision on the same route moderated by commuter's age.

The line haul motorization patterns were significantly different from the FMLM as revealed by descriptive statistics in section 4.3.1 and the regression analysis. The final line haul model (Lh14) underscored that **modal variability, auto ownership and income** materially influence modal split in the line haul without any significant moderation effects. By increasing access **mode-variability** by one-unit, a commuter will be 2 times more likely to select public transport over low capacity automobiles in the main segment of their journey. The practical relevance of this finding is substantiated by studies which reveal that increasing modal variability through mobility enterprises, Mobility-as-a-Service (MaaS), shared-mobility and other innovative feeder services induces significant modal shifts from private auto-mobility to public transportation (Kanuri et al., 2019; Scheltes and de-Almeida-Correia, 2017). It can hereby be said that providing a mix of modes to access transit makes public transportation more accessible and attractive to commuters

The **average income** of the commuter was observed to be one of the major drivers of automobile use in the Linehaul. Statistics reveal that with a one-unit increase in the income of a commuter, the odds of using active mobility and public transport are reduced by 71.2% and 49.3% respectively. Commuters with higher incomes have more transport service demands and often a wider range of factors to consider before selecting a particular travel mode (Fan et al., 2019). This is particularly interesting because, in cities, income is used as an index to signify growth. Often, this growth is not linked to impacts on the city's mobility patterns, yet single upward mobility in income comes with a demand for improved standards of transport services. Where the standard is not met, then low capacity automobiles are selected over public transport and active mobility. It can hereby be interpreted that modal shifts are instigated by the individual's willingness to pay for a transportation service which is affected by the individual's income.

Auto ownership was also seen to have a significant direct effect on the modality in the line haul. Commuters who do not own automobiles are 11 times more likely to use paratransit in the line haul as opposed to those who own automobiles. To corroborate this, respondent R7 cited:

"Ownership of personal car makes it convenient to use my car on the trip"-R7

The regression equation for the line haul modal choice is represented as follows;

$$Y_p = 2.017 + 2.080\mathrm{MV}j + 0.507\mathrm{I}k + 11.586\mathrm{Am}[0]k + 0.991$$

Where; Y_p is the predicted modal category for paratransit (with low capacity autos as the reference point), $\mathrm{MV}j$ representing modal variability on route j, $\mathrm{I}k$ representing average income of commuter k and $\mathrm{Am}[0]k$ representing commuter k who does not own an automobile

The statistical analyses have revealed that; physical environment factors as defined by infrastructure provision; modal environment factors as defined by modal variability and travel cost are critical in predicting motorization in both the FMLM and the line haul. The study has further brought to light the direct effect of social environment factors (auto ownership and average income) on the line haul travel mode and the interaction effect of age in the FMLM. The effect of these FMLM attributes was further supported by 69.2% of the commuters who indicated that FMLM has moderate to very high effect on their modal choice (refer annex: table 19).

Chapter 5: Conclusions and recommendations

The chapter uses evidence gathered in the previous chapter to draw conclusions on the subject of study. At the outset, it restates the purpose for which this study was conducted and highlights how the aim was achieved. Each research question is then addressed based on the study findings and in sync with theoretical underpinnings. The section not only illustrates how the study fits in answering the research questions but also how it augments the existing body of knowledge. In the end, the author puts forward suggestions on how FMLM planning can be used to shape urban mobility patterns. Areas of further research are also proposed to further enrich this theme of urban transportation.

5.1 Restatement of the study purpose

This study was premised on the comprehension that mere provision of mass transit is not sufficing to sustain urban transportation systems and to deter commuters from using private cars and other low-capacity automobiles. Further, access and egress from transit was perceived as a neglected segment of the journey which substantially affects the modal choices of a commuter. In this regard, the study purposed to assess the accessibility of the first and last mile in its different facets and to evaluate how it affects modal share and motorization. To achieve this, a highly representative case study was selected in the context of a rapidly urbanizing metropolitan region in Kenya.

The case study was grounded on the view that commuters are rational utility-maximizing individuals who make modal decisions based on various distinct attributes (Tilahun et al., 2016). Through complementary research methods and several data triangulation techniques, the study assessed how physical environment factors (travel distance, network character, catchment area) and modal environment factors (modal variability, travel time, cost) in the FMLM affect the adoption of different modes of travel. The study was cognizant that this effect may be moderated by social environment factors (age, income, gender, household size, and automobile ownership).

5.2 Summary of the research findings

Inferences were drawn from the data through a series of descriptive and regression analyses. The overarching discovery is that FMLM accessibility indeed affects mobility behaviours in the FMLM largely and moderately in the main segment of a commuter's trip. Among the multi-fold factors assessed, infrastructure provision, modal variability, travel cost, auto ownership and average income were found to be significant in predicting motorization in both journey segments, with pronounced moderation by the commuter's age. The effect of these variables was quantified through FMLM assessment models which indicated 58% explained variance of the travel mode adopted in transit access and egress, and 43.1% variance of the line haul modal share. The explained variances for both journey segments were sizeable thus contrasting with previous studies which suggest that prediction of modality in different stages of transit is prominently difficult and explains low variance (Krygsman et al., 2004). This instructive finding discounts the erroneous assumption that access and egress are short-mile distances and thus barely shape urban mobility patterns. Conversely, the study demonstrates how different physical, social and modal environment conditions of the first and last mile result in the use of automobiles over active mobility and public transport in the short trips and the main commute trips. This study hereby pioneers a systematic strategy for FMLM assessment which is a low-hanging fruit in instigating holistic multimodal transportation, enhancing seamless end-to-end connectivity, suppressing auto dependency, and reducing greenhouse gas emissions in cities. The study further answered to the main research question by sequentially addressing 5 sub-questions as detailed out below:

5.2.1 Response to the research sub-questions

Sq.1: What share of population can public transport services reach within a Mile (1.6Km) and 2 miles (3.2km) radius and what is the character of these households?

- PT catchment areas and travel distances
- Socio-demographic attributes

The action area of public transport was dominantly within a mile (1.6km). It was however observed that the first-mile average distance is twice the last mile average distance which reveals poor permeability of the public transportation grid in the first mile. In global transport planning, the recommended distance for walking to transit is 400m (0.25 miles). Planning practice in Kenya has also standardized 400-500 meters as the buffer distance for regular bus service and 1km for rapid transit - BRT or commuter rail (ITDP, 2011). Although this is not explicitly stated in transport policy documents, it is consistent with previous studies recommending 400-1600m (Daniels and Mulley, 2013; Zuo et al., 2020). In light of this, only 35% of the commuters were located within the bus service walking distance in the first mile and 70% in the last mile. This further exemplifies the connectivity gap in the first mile. As revealed by in-depth interviews, a key limitation to upholding the standardized catchment areas in both segments was the failure to rationalize the recommended distances in transport policy documents and road design manuals. Despite the apparent incongruity, travel distance was found to be insignificant in predicting motorization.

The socio-demographic attributes of commuters within the stated catchment area were diverse and portrayed distinctive mobility behaviours. Male commuters were observed to cover long access distances compared to their female counterparts. Also interestingly, families with school-going children predominantly settled closer to transit stops. It was however observed that although gender, household size, number of children, and marital status are correlated to different FMLM attributes, they are not significant in predicting which travel mode a commuter would adopt. By contrast, average income and auto ownership portrayed significant effects where an increase in any of the two resulted in considerable use of automobiles and a declined use of NMT and public transport. Notably, the discussion on travel behaviours of different age groups has been accentuated in the contemporary urban mobility discussions with the young adults being associated with high auto dependency while middle-aged and senior adults are seen to prefer automobiles and short transit access distances (Fan et al., 2019). This study contributed to this discussion by revealing significant moderating effects of age. As travel costs increased, commuters < 45years were seen to be more likely to choose NMT over automobiles than those > 45years. Maximizing accessibility through infrastructure provision was also dependent on the age of the commuters.

Sq. 2: What is the network character and modal variability in the first and last miles in the selected Traffic Analysis Zone (TAZ)?

- Network character
- Modal variability

Network character assessment applied 2 scale variables; infrastructure provision and street attractiveness. Apart from being characterized by longer distances, first mile routes lacked the requisite infrastructure to facilitate mobility by different road users. NMT infrastructure recorded the highest paucity followed by public transport infrastructure. Notwithstanding this, walking recorded an appreciable modal share in the FMLM (63.35-75.8%). This portrays an auspicious trend which, if supported through well-equipped walking environments, can promote active mobility and simultaneously reduce auto dependence. Regression analysis authenticated this by highlighting that an increase in infrastructure provision results in high likelihoods of commuters walking or cycling to transit. The impact of this modal shift is however dependent on the age of the commuter. Street attractiveness on the other hand as defined by street vitality, personal security and safety, sanitation, road condition and maintenance was fairly low but its influence on modal choice was insignificant.

Modal variability assessed whether commuters access solely 1 mode of transport or a mix of modes with one frequent travel mode. Unimodal monopoly was highly uncommon as commuters had access to a maximum of 5 modes in the first mile and 3 modes in the last mile. Modal variability had contrasting effects in FMLM and line haul modality. In the access and egress, increasing modal variability intensified the use of automobiles. In the line haul, however, increasing modal variability simplified the access to public transportation and thus reduced the use of automobiles.

Sq.3: What is the average time spent and financial cost incurred in covering the FMLM and the line-haul?

Commuters spent an average 8.8 minutes in the first-mile travel which was higher than the average last-mile travel time (6.4 minutes). This was practical considering that first mile distances are also longer. In the line haul, commuters spent 25.4 minutes since the work- and school-journeys were mainly inter-settlement trips. FMLM travel times accounted for 37.38% (0.374) of the total trip time. The ratio of the access/egress travel time to total travel time in multi-modal trips ranges from 0.2-0.5 (Krygsman et al., 2004). The travel times assessed were hereby within the acceptable range, but were insignificant in predicting the travel mode to be used by a commuter.

The average travel cost was 18.9Ksh and 61.67Ksh in the FMLM and line haul respectively. An illuminating observation was that although the first mile distances are longer, more time-consuming and lack adequate infrastructure, the cost of travel on this journey segment is considerably cheaper than the last mile. This was substantiated by cost analysis which revealed that first-mile mobility costs 23Ksh per kilometer while last-mile costs 38.8Ksh per kilometer. Higher costs have been seen to instigate higher NMT usage in the last mile than in the first mile. The effect of travel costs is however moderated by age; with increased travel costs, young and middle ages commuters are 6 times more likely to choose NMT as opposed to senior adults.

Sq.4: How does the FMLM gap affect the first-mile, line-haul and last-mile travel mode adopted by commuters?

To address this question commuter responses were triangulated with manual traffic count data which further enhanced the study validity. Non-motorized modes dominated in the first mile mainly defined by walking. By contrast, public transportation was least used among the motorized modes which reiterates that public transport grids are not fine enough in the first mile. Low capacity automobiles were considerably high on this segment than the other trip segments. This was mainly attributed to the lack of infrastructure for alternative travel modes and the proliferation of 2-and 3-wheelers. In the last mile, walking and motorcycles dominated. It was observed that the bus service catchment area was upheld in the last mile ensuring that destinations were located close to public transport hubs. In support of this, more than half of the respondents underscored "proximity/short distances" as the main reason for their modal choice in the last mile. The line haul modality was substantially different from the FMLM. Here, paratransit (publicly operated buses and 14-seater Matatus) were commonly used, with its use being augmented by modal variability which simplified transit access. Low capacity automobiles were also popular here and facilitated by automobile ownership and an increase in commuter incomes. An interesting observation here was the unpopularity of the train as a travel option despite its availability.

Regression analysis further quantified the extent to which different FMLM attributes affect modal share in the FMLM and the line haul. Box 2 summarizes the key effects identified by the models:

Box 2: Effects of FMLM accessibility attributes on modal share

One-unit increase in:	**Moderating effect**	**Reference category : Low capacity automobiles**	**Journey segment**
Modal variability	--------	62.2 - 66.4% less likely to choose active mobility	FMLM modal share
Auto ownership [0]	--------	90-92 times more likely to choose NMT (active mobility)	
Infrastructure provision	*Age*	Commuters < 45yrs 123 times more likely to choose NMT (active mobility) than those > 45yrs	
Travel cost	*Age*	Commuters < 45yrs 6 times more likely to choose NMT (active mobility) than those > 45yrs	
Modal variability	--------	2 times more likely to choose paratransit	Line Haul modal share
Auto ownership [0]	--------	11 times more likely to choose paratransit	
Average income	--------	49.3 % less likely to choose paratransit 71.2 % less likely to choose active mobility	

As box 2 shows, modal variability, auto ownership, travel cost and infrastructure provision largely influenced FMLM modal share with age moderating travel costs and infrastructure provision. The line haul modal share on the other hand was influenced by modal variability, auto ownership and average income without any significant moderation effect.

Sq.5: What motorization patterns have FMLM choices induced in the City Region and how can they be controlled?

The mobility patterns defined the zone as internally vibrant (intra-settlement mobility) and to a large extent externally inter-dependent with the neighbouring counties (inter-settlement mobility). It was observed that although active transport is patronized in the access and egress, only a significantly small share of commuters access transit within the recommended bus service catchment area. This unveils long transit access distances which indicates that the conventional 5-minute walk catchment area to transit (Andersen and Landex, 2008) is an understatement of actual catchment areas in developing cities. The walking population was mainly characterized by commuters aged below 45 years. Drawing evidence from the FMLM models, lack of infrastructure provision and high, oscillating travel costs have discouraged senior adults (above 45 years) from adopting active mobility and instead persuaded them to substitute it with private cars and motorcycles. This is aggravated by the apparent poor permeability of the public transportation grid in the first mile. These findings suggest prevailing inequalities in FMLM accessibility which can be termed as “mobility age-discrimination” where; mobility of different age groups is limited based on the commuter’s financial and physical capacity.

It was also observed that low capacity automobiles account for approximately a third of the modal share in all journey segments. Highest motorization was observed in the first mile caused by increased modal variability (supply of low capacity automobiles), high travel costs (induces auto dependency among senior adults), poor infrastructure provision (discourages active mobility among senior adults) and auto ownership. In the line haul, motorization is heightened by low modal variability (minimal options available for commuters in the first mile) and increased auto ownership and income. As average income and automobile ownership increases, the use of low capacity automobiles increases tremendously. Considering the interdependencies with other counties as earlier revealed, these motorization effects will be felt not only at the TAZ level but also at the City region level. This can however be countered through increased modal variability which subsequently enhances transit accessibility. This requires innovatory actions to ensure that the alternative access modes provided are responsive to the needs of all commuters, available on-demand, and have neutral or low carbon emissions.

The unpopularity of train transport was noticeable notwithstanding the provision of an upgraded train station and a commuter train that services the area twice a day. In-depth interviews associated the unattractiveness of this mode to poor accessibility to the train station. In support of this, previous plans highlight that FMLM gaps deter active and potential transit users from using the system because public transport stations are inaccessible (City of Richmond, 2019). This research thus echoes that basic provision of public transport infrastructure on the mainline corridor without consideration of how the users access it dissuades commuters from using public transportation.

5.3 Recommendations

To conclude the study and respond to part b of the previous sub-question, the researcher floats some suggestions to intercept unsustainable motorization patterns. The suggestions are based on the study findings and existing best-case scenarios. The significant predictors of modal share as identified in this study can serve as the points of departure in shaping sustainable mobility in urban areas. Firstly, with proper infrastructure provision, commuters are more likely to adopt active transport modes over automobiles in accessing transit. The study underscores the need for infrastructure that is responsive to the mobility needs of all age groups. Transport authorities, therefore, need to enlarge the reach of transit through safe, universally accessible, people-friendly NMT infrastructure. Seamless and congruous interconnectivity calls for inter-actor collaboration and standardized design standards to ensure that all classes of roads attain the ideal NMT benchmark. An NMT docket under the County department of roads, whose role would be to ensure intergovernmental links, undertake studies on how to improve NMT, facilitate public engagements for people-centered mobility inter alia is essential. Additionally, adjusting the economic costs of travel strategically and judiciously can discourage the use of automobiles and increase active transport patronage and public transport ridership (Kanuri et al., 2019).

Modal variability is critical in facilitating multi-modal transportation. The study suggests that no one modal-strategy can fully address the FMLM challenges. To persuade commuters to use active mobility and to increase transit access, a variety of solutions ought to be modelled as an ecosystem of complementary options that are aided by information technologies. Options could include bicycle, pedestrian, ride-sharing, Mobility-as-a-Service (MaaS) Schemes among others. Modal variability also discards modal monopoly and thus controls travel costs and reduces the likelihoods of commuter exploitation. Increasing modal variability however should be cognizant of people with mobility difficulties (PWD), gender, senior adults (> 45years), frequency of commute, household income, size of the settlement, and car ownership (Heinen and Chatterjee, 2015).

Although the study accentuates myriad benefits that can accrue from enhancing FMLM accessibility, proper FMLM cannot independently shape sustainable mobility patterns in a city. Rather, the solution needs to be coupled simultaneously with fast and efficient public transportation in the line-haul, which then provides an optimal, well-integrated multimodal transportation network (Fan et al., 2019). Adopting the suggested measures to increase FMLM accessibility in Ruiru Bypass will not only improve access to the existing paratransit system but will also improve access and ridership of the proposed BRT system. The City Region will further benefit from multiple synergistic effects and superlinear benefits as highlighted in section 2.7.

5.4 Further research

This research is the first of its kind to be conducted in Kenya. It paves the way for deliberate focus on end-to-end connectivity of commuter journeys. The assessment of FMLM and its impact on modal choice on different journey segments has proved to be complex; characterized by person-, place- and mode-based evaluation. A large and comprehensive dataset has been utilized here to make inferences about motorization patterns. In other cities, evaluation of first/last mile connectivity has substituted such datasets through simulation modelling. Therefore, to replicate this research, the Monte Carlo simulation-based model can be applied at the micro-scale while at the city and regional scales, other advanced statistical methods can be applied.

Additionally, the assessment revealed that the first and last mile attributes not only shape mobility patterns in the routine short-mile trips in the neighbourhood context (by more than half), but also the line haul mobility patterns in the city context (by almost half). Exploratory research on which other factors can explain the remaining modal variance would highly enrich this field of study.

The research also raised the question of governance, public engagement, and policy in shaping motorization patterns. Political processes have been seen to influence where and how infrastructure is implemented. In a hunt for political mileage, large scale infrastructure has been prioritized while FMLM garners little attention. The role of citizens on the other hand seemed low in mobility planning. It was highlighted that commuters see "NMT as a privilege not as a right". Institutional cohesion and policies to guide the FMLM planning framework were also described as scanty. These parameters provide projections for further research which could bring in new practical insights.

<u>Author's reflection</u>

The current motorization patterns as observed in cities are a reflection of the transportation cultures that are being adopted by urban residents. It has been substantiated that without end-to-end connectivity; public transportation fails, low capacity high polluting travel modes proliferate and auto-dependency is instigated. In the strive towards meeting global targets on sustainable universal mobility, energy efficiency, and carbon reduction, developed countries have grasped the significance of first and last-mile accessibility as a key to sustainable urban transport.

Developing countries by contrast still struggle in providing efficient, equitable, reliable, healthy, and environmentally-friendly mobility. With upward mobility in income levels, auto ownership may be expected to increase which further aggravates the mobility challenges. Developing cities, therefore, need to pick up the pace by integrating first and last-mile planning strategies into the current mass transit systems which are gradually gaining momentum. The significant predictors as discussed in this research can serve as instrumental starting points. This will not only increase the attractiveness of active transport and public transport ridership but will also provide sustainable options for short-mile trips, coupled with other super-linear positive outcomes. The FMLM is hereby an indispensable part of an efficient sustainable urban transportation system.

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Annexe 1: Research Instruments

Annex 1a: Commuter questionnaire

Data Collection tool for FMLM Accessibility in Ruiru Neighbourhood

This questionnaire aims at acquiring information pertaining to first and last mile accessibility of daily work or school-related trips. Your support is requested in gathering this information which will feed into a planning research done in partial fulfilment of the requirement for the award of a Master degree (MSc in Urban Management and Development).

Declaration: This questionnaire is meant for academic purposes only and the information obtained will be confidentially used for this purpose only.

* Optional questions

Name of interviewer: ____

Date of interview: ____

Questionnaire number: ____

COMMUTER SOCIO-DEMOGRAPHIC ATTRIBUTES

1. **Area of residence (ward):**

   ☐ Gitothua ward ☐ Murera ward ☐ Kiuu ward

2. **Name of respondent:** * ____

3. **Gender of respondent:**

   ☐ Male ☐ Female

4. **Age of the respondent:**

   ☐ 19-25yrs ☐ 36- 45yrs ☐ Above 55yrs

   ☐ 26- 35yrs ☐ 46- 55yrs

5. **Marital status of the respondent***

   ☐ Single ☐ Widowed

   ☐ Married ☐ Divorced/separated

6. **Number of children (number according to ages)**

   ☐ 0-4yrs __________

   ☐ 5-9yrs __________

   ☐ 10-14yrs _________

   ☐ 15-17yrs __________

- ☐ Above 18yrs ___________

7. **What is your average income per month (Ksh)?**
   - ☐ 0 – 2000
   - ☐ 2,001 - 5000
   - ☐ 5,001 – 10,000
   - ☐ 10,001 – 20,000
   - ☐ 20,001 – 30,000
   - ☐ 30,001 – 50,000
   - ☐ More than 50,000

8. **Do you own any automobile?**
   - ☐ Yes
   - ☐ No

9. **If yes, which type of automobile do you own?** *
   - ☐ Car
   - ☐ Motorcycle

TRAVEL CHARACTERISTICS

First Mile

10. **What is the journey purpose of your daily trips?**
    - ☐ Work-related
    - ☐ School-related

11. **What is the distance (meters) from your house to the Ruiru Bypass transit stop?**
    - ☐ 0 – 400m
    - ☐ 401 – 800m
    - ☐ 801- 1000m
    - ☐ 1001 – 1600m
    - ☐ Beyond 1600m (1.6km), specify distance: __________________

12. **What mode of transport do you use frequently from trip origin TO the transit stop? (first mile)**
    - ☐ Walking
    - ☐ Cycling
    - ☐ Motorcycle
    - ☐ Low capacity Shuttles (matatu)
    - ☐ Rickshaw (tuktuk)
    - ☐ Private automobile
    - ☐ Taxis and Cabs e.g. Uber, rideshare

13. **How much time on average (minutes) to do you spend from origin TO transit station?**

    ____

14. **How much money (Ksh) does it cost from origin TO transit station?**

    ____

Last Mile

15. **What is the final destination of daily trips (area name)?** _________________________________

16. **What is the distance (meters) from the final transit stop to your daily destination?**
    - ☐ 0 – 400m
    - ☐ 401 – 800m
    - ☐ 801- 1000m
    - ☐ 1001 – 1600m

- ☐ Beyond 1600m (1.6km), specify distance: ________________

17. What mode of transport do you use frequently <u>FROM</u> the final transit stop to destination? (Last mile)

- ☐ Walking
- ☐ Cycling
- ☐ Motorcycle
- ☐ Low capacity Shuttles (matatu)
- ☐ Rickshaw (tuktuk)
- ☐ Private automobile
- ☐ Taxis and Cabs e.g. Uber, rideshare

18. How much time on average (minutes) to do you spend <u>FROM</u> final transit station to Destination?

____

19. How much money (Ksh) does it cost <u>FROM</u> final transit station to Destination?

____

Line-Haul Mile (Main Trip)

20. What modes of transport do you use for the <u>MAIN</u> part of the trip? (multiple choices)

- ☐ Walking
- ☐ Cycling
- ☐ Motorcycle
- ☐ Rickshaw (tuktuk)
- ☐ Paratransit (Publicly operated Buses and Matatus)
- ☐ Private automobile
- ☐ Taxis and Cabs e.g. Uber, rideshare
- ☐ Train

21. How much time on average (minutes) to do you spend for the <u>MAIN</u> part of the trip?

____

22. How much money (Ksh) does it cost for the <u>MAIN</u> part of the trip?

____

23. How many transfers do you make on one trip before getting to your final destination:

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ More than 3, specify ________________

24. On a scale of 0-5 how easy is it to transfer from one mode to another?

- ☐ Very Easy
- ☐ Easy
- ☐ Moderate
- ☐ Difficult
- ☐ Very difficult

25. How frequent do you use public transportation on the MAIN segment of the trip?

- ☐ Daily
- ☐ A few times a week
- ☐ A few times a month
- ☐ A few times a year
- ☐ Never

MOBILITY ROUTES ATTRIBUTES

26. Which of the following facilities are provided on the road used in the first mile route?

Infrastructure/facility provided	√	X
Street lighting		
Paved road (cabro/tarmac)		
Drainage facilities		
Segregated sidewalks		
Landscaping		
Segregated cycle tracks		
Bus Stops		

27. On a scale of 0-5 how would you rate the following attributes of the first mile route?

Road network attribute (1=very low level, 5=very high level)	**1**	**2**	**3**	**4**	**5**
Vitality of the street (activeness)					
Feeling of personal security					
Safety of pedestrians from traffic					
Safety of cyclists from traffic					
Safety of motorists (car and motorcycle users) from traffic					
Sanitation (solid waste management and drainage)					
Condition of the road surface					
Frequency of road maintenance					

28. What is your general perception on ease of accessing the first and last mile?

- ☐ Very Easy
- ☐ Easy
- ☐ Moderate
- ☐ Difficult
- ☐ Very difficult

28. To what extent does this “ease” affect your travel mode choices?

- ☐ Very high effect
- ☐ Moderate effect
- ☐ No effect
- ☐ High effect
- ☐ Low effect

29. What important factors/elements should be considered to improve your experience in accessing the first and last mile?

a. ……………………………………………………………………………………………….

b. ……………………………………………………………………………………………….

c. ……………………………………………………………………………………………….

d. ……………………………………………………………………………………………….

e. ……………………………………………………………………………………………….

THE END

Thank you very much. I highly appreciate your support!

Annex 1b: Interview manual

Interview manual for FMLM Accessibility in Ruiru Neighbourhood

This interview aims at acquiring information pertaining to first and last mile accessibility in Ruiru Neighbourhood (within Gitothua, Murera and Kiuu Wards) and its impacts on motorization patterns in the Nairobi Metropolitan Region. The main goal of this is to explore ways of enhancing mobility within Ruiru neighbourhood and between the city and everyday destinations throughout the NMR. Your support is requested in gathering this information which will feed into a planning research done in partial fulfilment of the requirement for the award of a Master degree (MSc in Urban Management and Development).

***Declaration: The information obtained will be confidentially used for academic purposes only*.**

....

Name of interviewer: ____

Date of interview: ____

Name of respondent: ____

Respondent's Occupation: ____

Organization: ____

* **FMLM =** First Mile Last Mile from public transit
* **NMR** = Nairobi Metropolitan Region

FMLM PLANNING REGULATIONS

1. **How is planning for the first and last mile guided, controlled and integrated within the transportation planning framework of the city?**
2. **What legal and/or policy provisions are adhered to in Kenya with regards to the following FMLM elements?**
   - Maximum access and egress distances (FMLM distances)
   - Transit catchment area for : Cycling _________________
     : Walking _________________
3. **Under whose mandate (institutions) is the planning of FMLM placed?**
   - Preparation of transport plans
   - Implementation of the plans (infrastructure)
   - Service delivery
   - Maintenance of infrastructure

FMLM CURRENT STATUS WITHIN THE NMR AND STUDY AREA

4. **How would you describe the current status of FMLM within the Nairobi Metropolitan Region?**
   - Is this put into key consideration in the Region's transportation plans?
   - To what extent do the Infrastructure and services implemented cover the FMLM?
   - Is there a mismatch between "what is planned" and "what is implemented"? If yes, please explain……

5. **What challenges do commuters face in accessing transit and final destinations within the region?**
6. **How have these challenges affected the general mobility behaviors in the region?**
   - Modal choices
   - Transportation expenditure
   - Public transport patronage
   - Use of active transport modes (walk/cycle)
   - Are there any other sector affected?
7. **How does the FMLM affect the achievement of the Nairobi Metropolitan Area Transport Authority's vision on sustainable integrated mobility?**
   - What challenges do the institution(s) in addressing the FMLM challenge?
   - Survey by NAMATA indicate 53.3% of traffic is caused by private cars, is this in any way related to FMLM accessibility?
8. **What strategies would potentially curb the FMLM challenge in the region?**
   - Strategies/solutions according to urgency and practicality
     - ✓ Technological
     - ✓ Infrastructural
     - ✓ Laws/policies/governance
     - ✓ Service providers
   - Who should be responsible?
9. **What potential does FMLM hold in enhancing sustainable transportation in the city and the region at large?**
   - Attaining the city Region's mobility goals
   - Curbing increased motorization
   - Options for short mile trips
   - Resilience of the transportation system
   - Physical and environmental health

<u>THE END</u>

Thank you very much. I highly appreciate your support!

Annex 1c: Traffic count manual

Snapshot of Page 1 of the morning shift sheet *(Survey were done from 7Am to 7Pm)*

IHS
Making cities work

IHS, Institute for Housing and Urban Development Studies_ Erasmus University Rotterdam

*MORNING

ENUMERATOR :

STRETCH NAME:

WARD NAME:

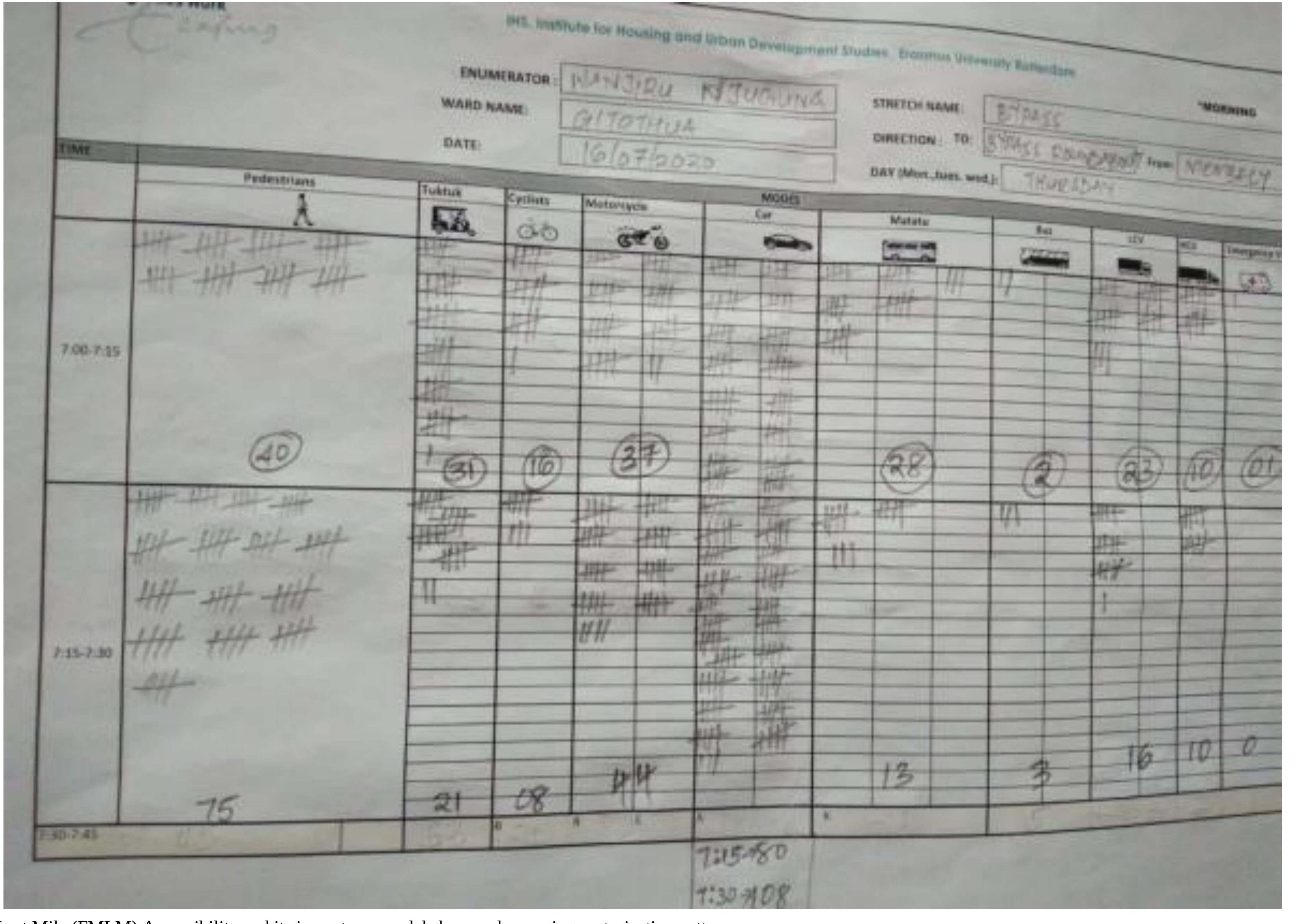
DIRECTION : TO: From:

DATE:

DAY (Mon.,tues. wed,):

TIME	MODES									
	Pedestrians	Tuktuk	Cyclists	Motorcycle	Car	Matatu	Bus	LCV	HCV	Emergency V.
7:00-7:15										
7:15-7:30										
7:30-7:45			B	R E	A	K				

Annex 1d: Snapshot of the manual traffic count output



Annexe 2: Additional study findings

Reliability Analysis

Table 18: Reliability test for street attractiveness indicators

Reliability Statistics

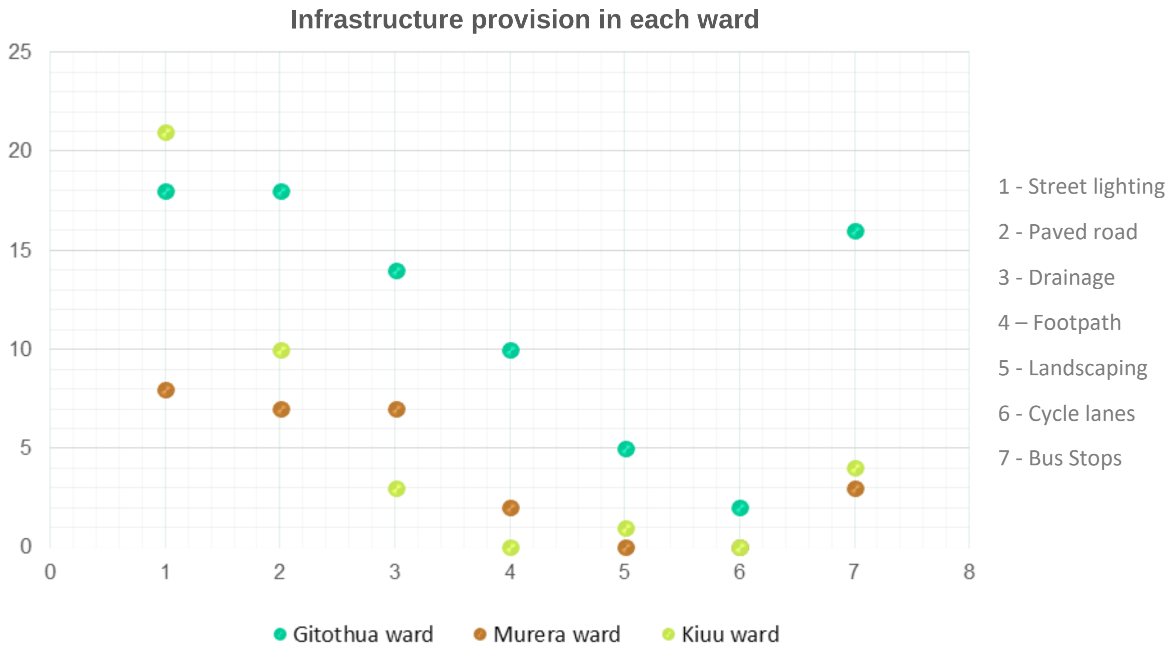
Cronbach's Alpha	N of Items
.682	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Rating Vitality of the street (0 = very low, 5 = very high)	19.13	28.671	.166	.696
Rating Feeling of personal security	19.67	25.922	.365	.654
Rating Safety of pedestrians from traffic	19.44	23.022	.627	.590
Rating Safety of cyclists from traffic	19.54	23.780	.483	.623
Rating Safety of auto- users from traffic	19.29	24.746	.554	.614
Rating Sanitation (solid,liquid waste management)	20.28	24.659	.357	.658
Rating Condition of the road surface	21.10	26.982	.251	.681
Rating Frequency of road maintenance	21.84	28.134	.223	.684

Infrastructure provision

Chart 7: Infrastructure provision by ward



Effect of FMLM on modal choice

Table 19: Effect of FMLM accessibility on modal choice

FMLM effect on modal choice

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No effect	8	6.7	6.7	6.7
	Low effect	27	22.5	22.5	29.2
	Moderate effect	29	24.2	24.2	53.3
	High effect	19	15.8	15.8	69.2
	Very high effect	35	29.2	29.2	98.3
	No response	2	1.7	1.7	100.0
	Total	120	100.0	100.0	

Number of transfers

Table 20: Trip transfers

Number of transfers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	43	35.8	35.8	35.8
	1	19	15.8	15.8	51.7
	2	33	27.5	27.5	79.2
	3	20	16.7	16.7	95.8
	4	3	2.5	2.5	98.3
	5	2	1.7	1.7	100.0
	Total	120	100.0	100.0	

Multicollinearity test

Table 21: Collinearity Diagnostics

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Gender of respondent	.802	1.247
	Marital status	.110	9.060
	Age of the respondent:	.433	2.309
	No. of children	.086	11.672
	Household members/size	.132	7.548
	Own any automobile?	.638	1.568
	Income per month (Ksh)	.642	1.558
	Catchment area	.082	12.238
	Travel distance (meters)	.317	3.153
	Travel time (minutes)	.457	2.187
	Travel cost in Ksh	.558	1.793
	Infrastructure provided	.757	1.321
	Street attractiveness	.639	1.564
	Modal variability	.555	1.802

a. Dependent Variable: Modalshare/Motorization

List of Models

Significant moderation effects

Table 22: Significant effect of interaction terms in the FMLM

Progressive models where Moderating variables had significant influence					
Model 3		Model 5		Model 13	
Cox and Snell R2	*0.463*	*0.467*		*0.424*	
	Sig.		Sig.		Sig.
Intercept	.000	Intercept	.000	Intercept	.000
Travel distance	.196	Travel distance	.170	Travel distance	.199
Modal variability	.016	Modal variability	.014	Modal variability	.599
Travel cost	.008	Travel cost	.005	Travel costs	.006
Infrastructure provision	.019	Infrastructure provision	.004	Infrastructure provision	.004
Auto Ownership	.029	Auto Ownership	.000	Average Income	.000
Auto * modal variability	.821	Auto * infrastructure	.145	Av. Income * Infrastructure	.062
Model 8		Model 9			
Cox and Snell R2	*0.463*	*0.467*			
	Sig.		Sig.		
Intercept	.000	Intercept	.000		
Travel distance	.106	Travel distance	.131		
Modal variability	.335	Modal variability	.491		
Travel cost	.000	Travel cost	.000		
Infrastructure provision	.014	Infrastructure provision	.008		
Age	.027	Age	.023		
Age * Travel cost	.023	Age * Infrastructure	.002		

Table 23: Significant effect of social environment variables in the Line Haul

Progressive models where Moderating variables had significant influence					
Model 2		Model 3		Model 5	
Cox and Snell R2	*0.376*	*0.368*		*0.376*	
	Sig.		Sig.		Sig.
Intercept	.012	Intercept	.039	Intercept	.017
Travel distance	.066	Travel distance	.130	Travel distance	.135
Modal variability	.011	Modal variability	.023	Modal variability	.007
Travel cost	.854	Travel cost	.863	Travel costs	.834
Infrastructure provision	.467	Infrastructure provision	.482	Infrastructure provision	.273
Auto Ownership	.004	Auto Ownership	.036	Auto Ownership	.000
Auto * travel distance	.475	Auto * modal variability	.970	Auto * Infrastructure	.487
Model 10		Model 12		Model 13	
Cox and Snell R2	*0.463*	*0.467*		*0.467*	
	Sig.		Sig.		Sig.
Intercept	.001	Intercept	.004	Intercept	.000
Travel distance	.646	Travel distance	.664	Travel distance	.597
Modal variability	.001	Modal variability	.001	Modal variability	.000
Travel cost	.431	Travel cost	.595	Travel cost	.503
Infrastructure provision	.336	Infrastructure provision	.294	Infrastructure provision	.107
Average income	.002	Average income	.019	Average income	.000
Income * travel distance	.916	Income * Travel cost	.804	Income * Infrastructure	.162

FMLM Motorization: Final model (a)

Table 24: Model FMLM14 further details

Model FMLM14 Fitting Information

Model	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC	BIC	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	231.140	236.715	227.140			
Final	191.396	235.996	159.396	67.744	14	.000

Final model (a) FMLM 14		FMLM motorization Parameter Estimates				
N		117				
Pseudo R^2 Cox and Snell R^2		0.578				
FMmotorization[a]		B	Std. Error	Wald	Sig.	Exp(B)
Active transport	Intercept	5.116	1.756	8.484	.004	
	Travel distance	-.266	.278	.921	.337	.766
	Modal variability	-1.092	.448	5.944	.015	.336
	Travel cost	-1.905	.606	9.887	.002	.149
	Infrastructure provision	-.375	.264	2.027	.154	.687
	Average income	-.584	.362	2.603	.107	.558
	Age	-.315	.522	.364	.546	.730
	Age * travel cost	1.858	.744	6.236	.013	6.411
	[No auto owned=0]	4.531	.953	22.581	.000	92.808
	[Auto Ownership=1]	0[b]	.	.	.	.
Paratransit	Intercept	-23.365	2.710	74.323	.000	
	Travel distance	.156	.434	.129	.719	1.169
	Modal variability	-.127	.540	.055	.814	.881
	Travel cost	.447	.581	.594	.441	1.564
	Infrastructure provision	.548	.351	2.447	.118	1.730
	Average income	-.209	.501	.174	.676	.811
	Age	.339	.921	.135	.713	1.404
	Age * travel cost	-14.493	5066.383	.000	.998	5.077E-7
	[No auto owned=0]	20.594	.000	.	.	878767544.053
	[Auto Ownership=1]	0[b]	.	.	.	.
The reference category: Low capacity autos.						

FMLM Motorization: Final model (b)

Table 25: Model FMLM15 further details

Model FMLM15 Fitting Information

Model	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC	BIC	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	197.410	202.985	193.410			
Final	124.083	174.258	88.083	105.327	16	.000

Final model (b) FMLM 15		**FMLM motorization Parameter Estimates**				
N		116				
Pseudo R^2 Cox and Snell R^2		0.584				
LHmotorization[a]		B	Std. Error	Wald	Sig.	Exp(B)
Active transport	Intercept	5.072	1.694	8.960	.003	
	Travel distance	-.256	.279	.844	.358	.774
	Modal variability	-.972	.438	4.921	.027	.378
	Travel cost	-2.089	.658	10.099	.001	.124
	Infrastructure provision	-.409	.266	2.362	.124	.665
	Average income	-.527	.361	2.134	.144	.590
	Age	-.325	.505	.413	.520	.723
	Age * Infrastructure	4.816	2.243	4.612	.032	123.473
	[No auto owned=0]	4.510	.962	21.973	.000	90.960
	[Auto Ownership=1]	0[b]	.	.	.	.
Paratransit	Intercept	-23.254	2.668	75.988	.000	
	Travel distance	.167	.437	.146	.703	1.181
	Modal variability	-.125	.540	.054	.816	.882
	Travel cost	.424	.576	.543	.461	1.529
	Infrastructure provision	.522	.345	2.289	.130	1.685
	Average income	-.180	.503	.128	.720	.835
	Age	.247	.874	.080	.777	1.280
	Age * Infrastructure	-10.033	6803.345	.000	.999	4.391E-5
	[No auto owned=0]	20.577	.000	.	.	863788428.695
	[Auto Ownership=1]	0[b]	.	.	.	.
The reference category: Low capacity autos.						

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