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Characterizing and Estimating Operational Cost Elements and Performance Metrics for Public Transport Modes in Sub-Saharan African Cities

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Abstract

Operation cost of public transport has been universally recognized as a vital consideration in its implementation, operation and management worldwide. The cost structure is even more complex in Sub-Saharan Africa (SSA), where the public transport system is dominated by paratransit, which is largely characterized by the private sector that owns, operates, maintains, and manages their vehicles separately. There is limited knowledge of paratransit cost structure, the extent to which they vary by mode, and their use in fare-setting and the design of regulatory policies. Accordingly, this study characterized and quantified several operational cost elements in the form of Key Performance Indicators (KPIs) for paratransit modes in two SSA cities: Accra-Ghana and Dar es Salaam-Tanzania. Vehicle-make in Accra-Ghana is mainly Mercedes Benz and Toyota, whereas those in Dar es Salaam-Tanzania are Toyota, Nissan, and Bajaji tricycles. Diesel is the most popular vehicle propulsion followed by petrol in both cities. Our findings show higher vehicle utilization and better fuel consumption in Dar es Salaam-Tanzania compared to Accra-Ghana. Findings further indicate higher economic and environmental efficiency in minibuses compared to taxis and three-wheelers, with Dar es Salaam-Tanzania achieving better outcomes than Accra-Ghana in revenue generation, fuel consumption, and safety conditions. Daily revenue generation is higher, 75.1USD in Dar es Salaam-Tanzania compared to 46.3USD in Accra-Ghana. The overall expenditure is higher, 0.41USD/km in Accra-Ghana than 0.28USD/km in Dar es Salaam-Tanzania. Safety-related KPIs including kilometers per accident, kilometers per mechanical breakdown, and kilometers per tyre carcase show favourable conditions in Dar es Salaam-Tanzania compared to Accra-Ghana. These insights provide essential data to inform fare-setting, regulatory policies, and operational management of paratransit services in SSA. Overall, this study has established the cost structure for paratransit modes in the study cities, making available vital data and knowledge to underpin practical engagement, operational management, and governance of paratransit services in SSA.

Keywords: public transport, paratransit, operational costs, transport costs, public transport pricing, urban transport

1. Introduction

The cost of public transport services is a crucial consideration in implementing, operating and managing public transport systems worldwide. Specifically, the operation cost of public transport relates to the production cost, the cost incurred in providing the service and managing the fleet of vehicles and personnel (Batarce, 2021; Verhoef, 2007; Walker, 2011). It has been linked to directly impact transport supply, efficiency, and various parts of the production process such as capital, user time, operator wages, public facilities, and other unintended spillovers to non-users (Batarce, 2016; Iles, 2005; Verhoef, 2007). That is, knowledge of the operation costs is relevant for the design of regulatory policies and procurement of public transport services by governments and public authorities (Batarce, 2021; Hörcher & Tirachini, 2021; Iles, 2005). In sub-Saharan Africa (SSA) where paratransit services dominate the public transport system, the cost structure and its estimation are even more complex. The paratransit system in SSA cities is largely characterized by the private sector, who own, operates, maintains, and manages its vehicles separately (Acheampong & Asabere, 2022; Behrens et al., 2016; Dumedah et al., 2022, 2023; Dumedah & Garsonu, 2021; Klopp & Cavoli, 2017; Poku-Boansi, 2022). This independent and characteristic setup means that the cost structure can vary widely for key component variables such as operator wages, vehicle maintenance, and purchase costs.

According to Walker (2011), the operating cost can be categorized into (a) time-based costs, (b) distance-based costs, (c) fleet-based costs, and (d) administrative costs. Time-based costs relate to costs which vary directly according to the number of operating vehicles, including the cost of owning each vehicle, interest on the purchase cost, insurance, license fees, and other costs which vary closely with the number of vehicles, such as operator wages, washing, and cleaning of vehicles (Iles, 2005; Walker, 2011). Distance-based costs correspond to the costs which vary directly with the number of kilometers operated, such as the costs of fuel, lubricants, tyres and maintenance materials. Fleet-based costs are costs associated with the number of vehicles owned, mainly including the cost of the vehicles and their maintenance. Administrative costs mainly include costs associated with manpower, stationery, public relations, and non-vehicle insurance (Iles, 2005; Walker, 2011).

Essentially, the cost structure is complex where some costs are fixed in the medium term regardless of the level of activity, others vary with the number of vehicles, and some with the number of kilometers operated. Accordingly, a comprehensive characterization and estimation of the various cost elements is crucial to establishing the cost of each activity, for example, the cost of running a route or the operator wage per hour. The viability of operating routes requires consideration of marginal costs in terms of how much it costs to provide one additional unit of service. Concerning the marginal cost, an additional journey on a route can be provided without increasing the number of vehicles by scheduling an existing vehicle to operate additional kilometers while incurring only kilometer-variable costs (Hörcher & Tirachini, 2021; Iles, 2005). However, if an extra vehicle is needed to provide a number of additional journeys, the additional costs incurred are limited to the kilometer-variable costs and the vehicle-variable costs with no changes in the fixed costs (Batarce, 2021; Hörcher & Tirachini, 2021; Iles, 2005; Verhoef, 2007).

Based on these conditions, the daily cost of operating a route is the summation of key components: (a) the number of vehicles needed to operate the route multiplied by the daily vehicle-variable cost, (b) the total daily kilometers operated on the route multiplied by the total cost per kilometer of all kilometer-variable costs, and (c) any route-related costs (Iles, 2005). So, a route is deemed viable to run on the condition that it earns sufficient fare revenue to cover these variable costs, or a single trip is considered feasible if it earns sufficient fare revenue to cover only the kilometer-variable costs incurred, provided that it does not require an additional vehicle to operate it (Iles, 2005).

However, knowledge of these cost elements is particularly limited for paratransit services in SSA, given their characteristic setup, operation, and management. Paratransit operations are not structured for data collection of their services, the operators rarely document their expenditures, and there are often limited requirements and monitoring from local governments to provide such information. Even in cases where this information is available for some vehicles, the extent to which they are spatially differentiated for different routes and modes is unknown. Accordingly, this study investigates key performance indicators needed to quantify the operating costs for paratransit modes in two SSA cities: Accra-Ghana and Dar es Salaam-Tanzania. To our knowledge, the literature on the operating cost of paratransit services in SSA is limited. Some studies examine travel fares for paratransit services in SSA cities (Iimi, 2023; Nkuah & Berko, 2018; Ocheni, 2015; Poku-Boansi & Asibey, 2022; C. J. Venter et al., 2014), but operating costs are almost nonexistent. A study by C. Venter (2011) examined the pattern of household expenditure on transport to inform pro-poor transport policies in South Africa. A related study by Dumedah et al. (2025) showed that fares for paratransit services are inconsistent in Kumasi-Ghana and are spatially differentiated by route, distance travelled, travel time, service type, economic status, and population density.

In addition, most SSA cities are examining ways to reorganize their public transport system with the introduction/integration of Bus Rapid Transit (BRT) and the formalization of the paratransit system (Asimeng, 2022; Boutueil et al., 2020; C. Venter, 2016). For example, Venter et al. (2018) examined equity impacts of BRT by investigating whether BRT systems achieve progressive benefits for poorer segments of the population in Africa and Asia. They found that BRT systems are hampered by insufficient spatial coverage and inappropriate fare policies. An essential ingredient to developing fare policies is good knowledge of existing operational costs. Thus, a critical component of public transport reorganization and BRT integration is a better understanding of the operational cost of existing paratransit systems.

It is crucial to emphasize the connection between establishing a consistent practical cost structure for paratransit services and the inherent socioeconomic and environmental goals of public transport. That is, through a competitive cost structure, paratransit services can enhance access to socioeconomic opportunities for populations and minimize the externalities or negative impacts of transport by reducing traffic-related pollution and emissions. Currently, some communities and routes are not properly served by paratransit because of prohibitive operating costs and a lack of structured fare-setting to guide their services (Dumedah et al., 2023; Ndibatya & Booysen, 2020). Structured fare-setting that is underpinned by objective operational cost can lead to more organized paratransit operation of routes, leading to reduced traffic congestion, thereby lowering traffic-related emissions. By establishing the cost structure for paratransit modes in the study cities, this study is making available critical data and knowledge to underpin meaningful engagement, operational management, and governance of paratransit services in SSA.

In addition, the comparative nature of this study is unique in using Accra-Ghana and Dar es Salaam-Tanzania. It is widely recognized that SSA cities face similar challenges concerning mobility and access to opportunities (Behrens et al., 2016; Klopp, 2021). However, mobility and access are always context-specific, requiring the need to interrogate the local underlying drivers that underpin the transport system. The selected cities, Accra-Ghana and Dar es Salaam-Tanzania, present compelling differences and commonalities, which imply that interesting findings are likely through a comparative analysis. Accra, the capital and largest city of Ghana, may be described as the quintessential rapidly urbanizing African city, being surrounded by sprawling peri-urban development. In Accra-Ghana, the public transport system is a mix of minibus (Trotro), shared taxis, three-wheeler (tricycles) and two-wheeler (motorcycles) taxis. Dar es Salaam is currently Africa's fifth most populous city, where about 70% of the population lives in informal settlements. Dar es Salaam also has a similar mix of public transport modes, mostly including minibuses, three-wheeler and two-wheeler taxis. Paratransit minibuses dominate the transport mode share in Dar es Salaam, where commuters travel as far as 30 km on the arterial roads, which connect the central business district and the residential areas at the fringes (Andreasen & Møller-Jensen, 2017; Kiunsi, 2013; Nkurunziza et al., 2012; Olvera et al., 2003). The mix of public transport modes and high population densities in both cities portend significant ramifications for urban transport accessibility, as evident through increased pressure on transport services and infrastructure (low speeds, high travel time, long queues, etc.), as well as elevated usage of motorcycle and tricycle taxis.

2. Material and Methods

2.1 Study Area

The study was carried out in two cities: Accra-Ghana and Dar es Salaam-Tanzania, where their basic mobility-related characteristics are presented in Table 1. The information in Table 1 include mobility-related variables: road connectivity index, Digital Adoption Index (DAI), and sustainable mobility index. The road connectivity index quantifies the connectivity of a transportation network, providing insights into how well-connected an area's road network is. It influences accessibility, travel options, and overall transport efficiency. DAI measures digital adoption across three dimensions of the economy in a country/area: people, government, and business. It provides insight into the spread and utilization of digital technologies, which can influence travel options. The sustainable mobility index assesses and compares the readiness and performance of cities or regions in adopting sustainable transportation systems such as public transport, active transport, etc.

In Accra-Ghana, the rapidly expanding areas of Accra Municipal Assembly (AMA) and Korle Klottey Municipality were selected as the study communities, as shown in Figure 1. According to the 2021 Ghana Statistical Services Population and Housing Census, the area has a combined population of 352,762 inhabitants, comprising 47.4% males and 51.6% females. The available paratransit modes in this area include minibus (Trotro), shared taxis, three-wheelers (tricycles) and two-wheelers (motorcycles) which are used by residents for their daily commute to access socioeconomic and other opportunities. The primary and widely used paratransit modes are minibuses and shared taxis.

Table 1. Basic characteristics for the two study cities: Accra-Ghana and Dar es Salaam-Tanzania

Item	Accra-Ghana	Dar es Salaam-Tanzania
Study area	Accra, and Korle Klottey Municipal	Kinondoni municipal
Population	352,762	982,328
Land area (kilometer sq.)	15.49	538.91
Average population density (2020)	46 persons per 100 square meters	64 persons per 100 square meters
Rate of population growth	2.5% per annum	4.95% per annum
Major public transport modes	Minibus, Taxi, Motorcycle	Minibus, Tricycle, Motorcycle
Number of registered vehicles (2016 – national). Source: Sustainable Mobility for All (2019).	2066.9	2163.6
Road Connectivity Index (0-100) – national. Source: Sustainable Mobility for All (2019).	73.4	70.0
Digital Adoption Index (0-1) – 2016. Source: Sustainable Mobility for All (2019).	0.5	0.3
Sustainable mobility index (2022 – national). Source: Sustainable Mobility for All (2019).	32.2	40.8

In Accra-Ghana, the provision of public transport is the responsibility of local government at the District or Municipal level, although national ministerial resources can be transferred to the local administrative levels. Despite this mandate, local governments have limited direct action within the sector, where operating permits are often used as a revenue-generating exercise, and there is limited consideration of network planning or the adequacy of service supply (IBIS Transport Consultants Ltd, 2005). Typically, the income taxes generated from public transport operations are not used to develop the sector (IBIS Transport Consultants Ltd, 2005). Also, the public transport network was not properly designed, where unrealistic price controls have led to a high proliferation of routes, breaking up of routes into shorter sections by operators to increase their revenue, and the emergence of several branches of transport unions. These are underpinned by piecemeal operating procedures that are set up to primarily maximize the operator revenue stream rather than prioritize passenger needs.

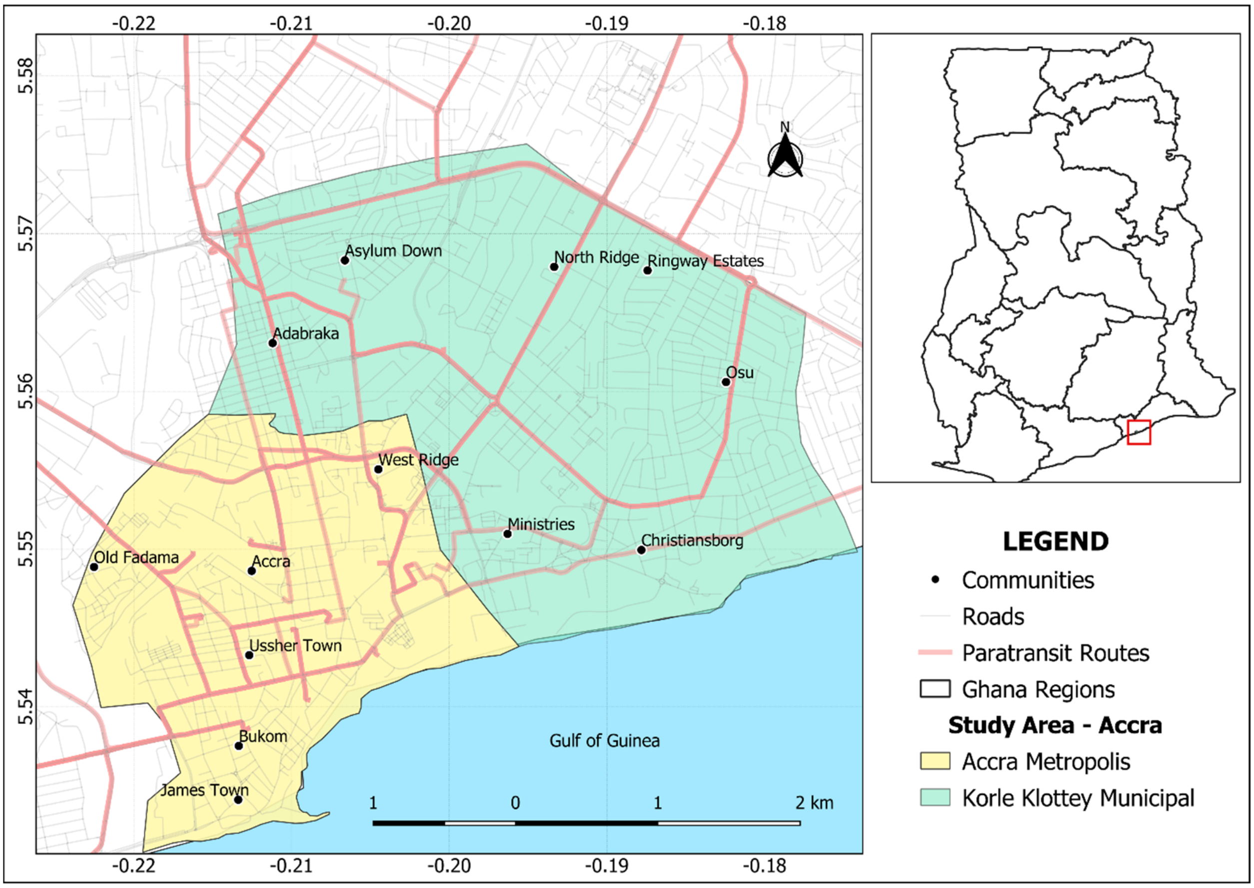


Figure 1. Study area in Accra, Ghana, showing road networks, major communities and paratransit routes

Officially, public transport fares are fully deregulated, with the government retaining pricing controls on a limited number of 'essential' products or services, such as road fuels. However, this has a very direct impact on vehicle operating costs and hence fare levels. In practice, fare regulation is exercised by the Ministry of Transport in 'negotiations' with the Ghana Road Transport Coordinating Council (GRTCC), representing operator interests. It is widely understood that these negotiations are based on a formula recognizing the unit costs of transport inputs and typical operating efficiencies in the sector, but this has not been disclosed to external parties. It is often claimed by the GRTCC and other transport unions that the fare increase allowed through these negotiations is considerably less than those arising from a strict application of the formula. Given the nonexistence of a consistent and transparent fare structure, fare increases relate to existing route-based fares rather than to an approved rate per kilometer across the network as would be implied by a formula (IBIS Transport Consultants Ltd, 2005).

In Dar es Salaam-Tanzania, the selected study community is Kinondoni municipality shown in Figure 2. Dar es Salaam-Tanzania is located at the country's eastern border, adjacent to the India Ocean. According to the 2022 Population and Housing Census for Tanzania Mainland, Kinondoni municipality has a population of about 982,328 people, comprising 48.3% males and 51.7% females. As the commercial and industrial capital of the country, Dar es Salaam-Tanzania has a high concentration of trade, services, manufacturing, and transportation hubs. The common paratransit modes in Dar es Salaam-Tanzania are minibuses (dala dala), three-wheelers (Bajaji), and two-wheelers (Bodaboda). Also, it has a Bus Rapid Transit (BRT) service that operates in dedicated lanes along the city's principal arteries.

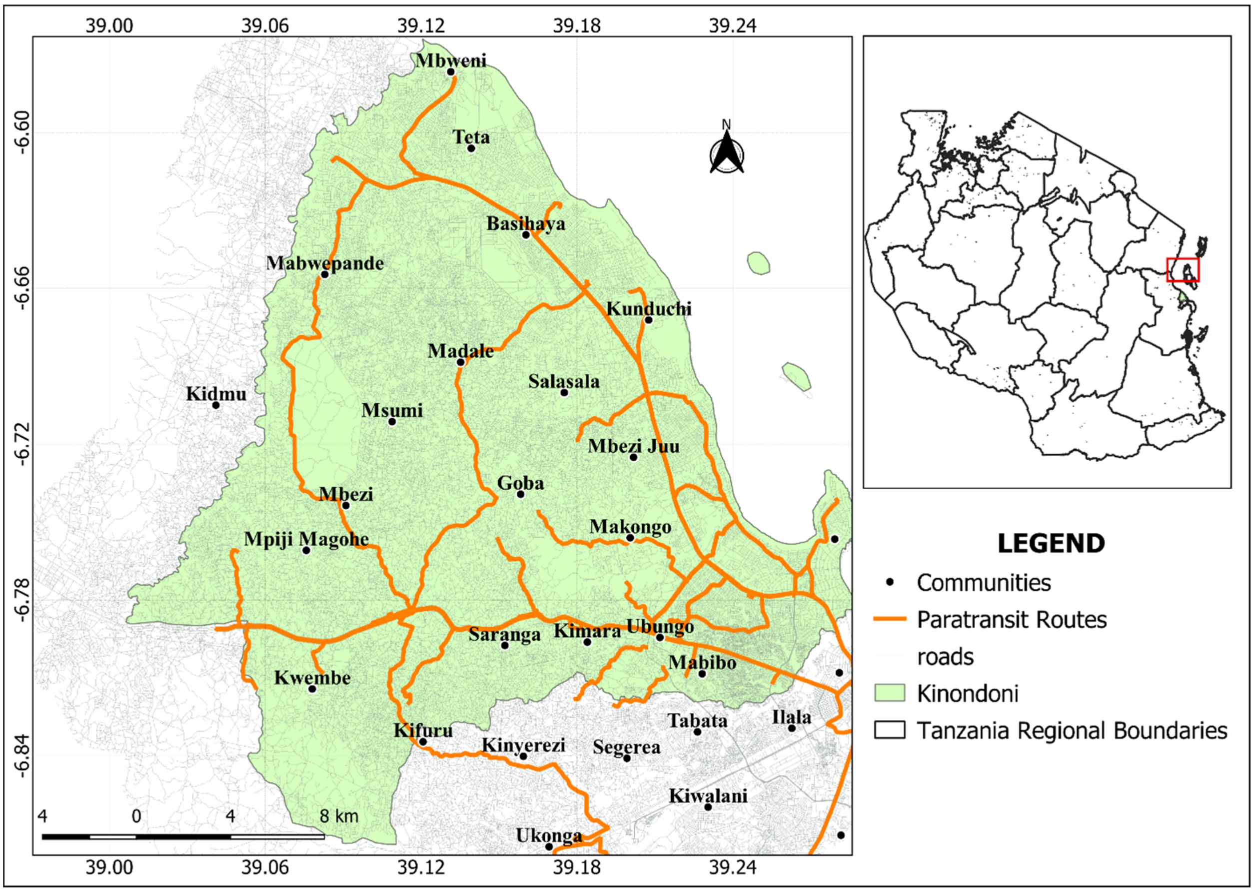


Figure 2. Study area in Dar es Salaam, Tanzania, showing road networks, major communities and paratransit routes

The land public transport in the form of the above modes is regulated by the Land Transport Regulatory Authority (LATRA), which was established under Section 4 of the Land Transport Regulatory Authority Act 2019 to regulate the land transport sector. Among its mandates, LATRA is responsible for assessing the supply and demand for passenger services, protecting the financial viability of efficient suppliers, and protecting the interests of consumers concerning costs, quality and standards of transport services. Based on this mandate, the formulation, development and implementation of fare policy and fare structure are the responsibility of LATRA. Specifically, under section 19(1) of the Land Transport Regulatory Authority Act of 2019, LATRA is mandated to set fare rates and charges for all land transport sectors.

A recent fare review for commuter buses in Dar es Salaam was carried out by LATRA in 2022 (Land Transport Regulatory Authority - LATRA, 2022). In the review, the factors taken into account included: (a) transport inputs such as fuel, capital cost, salaries and wages, repairs, maintenance and depreciation; (b) road conditions; (c) inflation and currency depreciation; and (d) affordability by passengers. The travel fares were categorized based on route travel distance where: (a) routes up to 10km attract 500TZS; (b) 11-15km routes attract 550TZS; (c) 16-20km routes attract 600TZS; (d) 21-25km routes attract 700TZS; (e) 26-30km routes attract 850TZS; (f) 31-35km routes attract 1000TZS; and (g) 36-40km routes attract 1100TZS. Discounted fares were specified for students, where a flat fare of 200TZS applies to all the above categories of routes. Also, a provision was specifically made for travel over unpaved roads where their fares are to be adjusted upward by 20% for the rates on paved roads. Essentially, a distance-based fare system is employed in Dar es Salaam-Tanzania, with a specific discount for only student populations. Given this fare structure, it is not known whether this fare structure is applied consistently for all paratransit modes in Dar es Salaam-Tanzania.

2.2 Data Sources and Study Approach

The public transport costs were obtained through on-site data collection at terminals and stops along the routes. The paratransit route selection process was based on all routes originating from each study area, whether their destinations are within or outside the study area. A Global Positioning System (GPS) device with a locational accuracy of 1-2 meters was used to record the locations of stops along the routes. The GPS-assisted mapping was based on a combination of being in a moving paratransit vehicle as a passenger and walking along the routes. Data from semi-structured questionnaires containing both quantitative and qualitative questions on vehicle operating costs, basic vehicle characteristics, and route information were obtained from drivers and station patrons at the various paratransit terminals. The instrument was administered through an in-person interview where clarifications were made to ensure transparency. In Accra-Ghana, the respondents were recruited through the Ghana Private Road and Transport Union (GPRTU) and the Cooperative Drivers Union (CDU). In the case of Dar es Salaam-Tanzania, all the respondents were recruited through the Land Transport Regulatory Authority (LATRA) of Tanzania. The respondents included both drivers and vehicle owners, with their proportions reported in the results section.

In Accra-Ghana, the onsite survey included 550 vehicles (420 minibuses and 130 taxis) across a total of 52 routes, 38 of which were minibus and 14 were taxi routes. Whereas in the case of Dar es Salaam-Tanzania, the onsite survey included 650 vehicles (386 minibuses and 249 three-wheelers) across a total of 57 routes, where 41 were minibuses and 16 were three-wheeler routes. In both cities, the sample sizes were disaggregated based on the proportion of vehicles at the various terminals and routes. The sample sizes are representative of the study communities since they each encompass all the routes originating from each study area, whether their destinations are within or outside the study area. Both weekdays and weekends were used to administer the instrument to ensure the representation of different operators and their vehicles.

It is recognized that self-reported vehicle operating data can be unreliable. This is partly because when public authorities set fares (i.e., the case for paratransit), operators often have an incentive to overemphasize their operating costs. In cases where operators are remunerated by a target system, they have an incentive to understate fare revenue and overstate vehicle operating costs. That is, operators have an incentive to overstate vehicle operating costs whether fares are set by public authorities or if a target system is used. Given this understanding, several steps were taken to ensure consistency in the self-reported data. For example, questions on some variables, such as fuel consumption, were asked in different ways using the cost spent on fuel used and the amount of fuel purchased. Other cost items such as insurance, wages, station charges and some maintenance-related items are common knowledge among the operators and station patrons, thus allowing for verification. Also, the self-reported data were combined with objective measurements such as fares and distance travelled based on route distance estimation in Geographic Information System (GIS). This approach for empirical data collection was used in both study cities: Accra-Ghana and Dar es Salaam-Tanzania. Institutional Review Board, the HuSSREC, Humanities and Social Sciences Research Ethics Committee, approved the study protocol (Ref: HuSSREC/AP/117/VOL. 2).

Vehicle operation cost characteristics for each route were formatted in a GTFS-like format, facilitating the estimation of Key Performance Indicators (KPIs) such as fare revenue per kilometer, expenditure per kilometer travelled, and fuel consumption in liters per kilometer. The resulting data were compiled electronically, coded, and analyzed using descriptive statistics to summarize the findings. At the time of data collection in Accra-Ghana in June 2023, the currency exchange rate was 1.0 USD equivalent to 11.29 GHS. In the case Dar es Salaam-Tanzania in July 2023, when the data collection was carried out, the exchange rate was 1.0 USD equivalent to 2439.02 TZS.

Paratransit routes connecting terminals, locations of communities, and road networks were sourced from OpenStreetMap (OSM). The population density data at a spatial resolution of 100m was obtained from the Humanitarian Data Exchange (https://data.humdata.org), serving as an indirect indicator for the demand of public transport. The paratransit routes were preprocessed and analyzed using GIS software called QGIS to spatially analyze the KPIs. To estimate the travel distances between certain key landmarks, preliminary geocoding was carried out to determine their geographical coordinates. The geocoding task and related structuring of the road network data were carried out using QGIS software. Statistical analysis software was used to compute descriptive statistics to summarize the operating cost KPIs for paratransit vehicles.

2.2.1 Route Travel Time and Distance Estimation

For each compiled paratransit route, its general travel time and distance were estimated using Openrouteservice (ORS). The travel time was based on the time spent travelling on the paratransit route from the origin terminal to the destination terminal using a car under typical traffic conditions. The travel distance was determined as the length of the travel path used. The coordinate values for origin and destination pairs were supplied as input into Openrouteservice (ORS) [https://openrouteservice.org/] to estimate the travel time along the route. ORS is a free web service that uses publicly available geographic data from OpenStreetMap to provide travel directions, travel time, and travel-related information. The estimated travel times were obtained in minutes for each route.

It is noted that the estimated travel distances match the paratransit routes used. However, the estimated travel times represent the time under typical traffic conditions in a car. Given the dynamic nature of travel time, these estimates are expected to be generally lower than the ones experienced by paratransit vehicles. Also, the operational nature of paratransit services means that their travel times vary widely, even among operators on the same route (Ukam et al., 2023). Nevertheless, the ORS data provides indicative travel time data for paratransit routes. It is worth noting that the travel distance and time provide distinct insights into a specified route. The travel distance for a specific route is fixed and not changeable. In contrast, travel time is dynamic and depends on the prevailing traffic conditions. Under typical traffic conditions, two routes with the same travel distances can be associated with different travel times.

2.2.2 Categories of KPIs

The KPIs were categorized into three groups, including operational variables, vehicle indicators, and personnel variables. The list of KPIs and their descriptions for operational variables is presented in Table 2, those for vehicle characteristics are in Table 3, whereas the personnel indicators are shown in Table 4. The KPIs were directly estimated from the survey data, focusing on themes such as vehicle operating costs, basic vehicle characteristics, personnel, and route information. Preprocessing of the survey data was carried out to determine intermediate variables used to estimate the KPIs. The total kilometers operated by a vehicle is the sum of dead kilometers and the product of the route travel distance and the number of times the route was operated. All of these variables were determined from the survey data except the dead kilometers. The dead kilometer was assumed to be the sum of the travel distances from home/garage to the station, vehicle washing, and maintenance travels. The home/garage to station travel is the travel distance from the driver's home/garage to the station where s/he starts operation. Because most respondents can rarely estimate these travel distances accurately, the locations of these activity points were obtained where they were geocoded and inputted into ORS to estimate their travel distances. A similar preprocessing was carried out to estimate fuel consumption, where respondents provided the total amount of money spent on fuel each day. This was combined with the total distance operated to estimate the fuel consumption.

Table 2. A list of key performance indicators and their descriptions for operational variables

KPI	Description	Estimation Procedure
Kilometers per vehicle per day (KPVPD)	It is a measure of the average number of kilometers driven by a vehicle in a single day. It is a vehicle use index or a measure of vehicle productivity where higher value indicates intense usage.	[Total kilometers traveled by vehicles] + [Dead kilometers operated].
Fare revenue per vehicle per day (RPVPD)	It is a measure of how much revenue a vehicle generates per day from fares. It is the same as **Revenue per vehicle per day by route**.	[Fares per day] * [Number of times route was run] * [Number of passengers carried by route].
Fare revenue per kilometer	It is a measure of revenue earned by a vehicle from fares per kilometer travelled. Fare revenue per kilometer is also known as Revenue Passenger Kilometers (RPK) or Revenue Passenger Miles (RPM) indicating the demand for transport service and the number of miles traveled by paying passengers. It is estimated as the number of revenue passengers multiplied by the total distance traveled. It is the same as **Revenue per kilometer by route**.	[Fares for all trips run] / [Total kilometers traveled]
Passengers per vehicle per day (PPVPD)	It is a measure of how many passengers are transported by a particular vehicle in a given day. It is an indicator of the level of passenger use of each vehicle in service. It is influenced by several variables such as the total passenger demand, vehicle capacity, length of operating day, length of route, average distance traveled per passenger, the extent to which demand varies between peak and off-peak periods, and the kilometers operated per bus per day. It is the same as **passengers per vehicle per day by route.**	[Total passengers carried] / [Total number of vehicles]
Average fare paid per passenger	It is a measure of the average amount of money that each passenger pays for a given type of transport service.	[Fare for all trips run] / [Total passengers carried]
Load factor	The load factor refers to the capacity utilization of public transport services - the average load on a vehicle as a percentage of its capacity. It is estimated by dividing the number of revenue passenger miles by the total number of available seat miles. A high passenger load factor indicates that a larger portion of available seats are being filled with paying passengers, which is favorable for the profitability of the service. The load factor is crucial to assessing the performance of any transport system, and it is used to calculate the break-even load factor.	[Total passengers carried] *100 / [Total capacity]
Vehicle utilization by kilometer	It is a measure of how efficiently a vehicle is used. It is typically expressed as a ratio of the vehicle's total hours in service (e.g. driving, loading/unloading, maintenance, etc.) to the total hours that it is available for use. It is an indicator of the productivity and efficiency of a vehicle in terms of the distance it travels.	[Total kilometers operated by all vehicles] * 100 / [Total scheduled kilometers]
Percentage of scheduled kilometers operated	It is a measure of how well a vehicle is meeting its planned schedule. It is calculated by dividing the total number of kilometers operated by the vehicle over a certain period by the total number of kilometers scheduled to be operated over the same period. It is a measure of the reliability and efficiency of the transport service, reflecting the extent to which operators adhere to their scheduled routes and distances.	[Actual kilometers operated for] * 100 / [Total scheduled kilometers]
Percentage of "dead" kilometers	It is a metric used to measure the total number of kilometers that a vehicle has travelled without any passengers or goods.	[Unscheduled kilometers traveled] * 100 / [Total kilometers operated]
Revenue by route	It is the amount of money generated from a particular route.	[Fare per route] * [Number of passengers carried by route]

Table 3. A list of key performance indicators and their descriptions for vehicle variables

KPI	Description	Estimation Procedure
Expenditure per kilometer on tyres, and maintenance materials	It is a measure of the total cost on tyres, and other maintenance materials per kilometer driven. It is calculated by dividing the total expenditure of each of the items by the total kilometers driven.	[Total expenditure on maintenance, tyres and other costs] / [Total kilometers operated]
Expenditure per kilometer on all expenses	It is a measure of the total cost of inputs such as fuel, tyres, and other maintenance materials per kilometer driven. It is estimated by dividing the total expenditure of each of the items mentioned by the total kilometers driven.	[Total expenditure on fuel, maintenance, tyres and other costs] / [Total kilometers operated]
Expenditure per kilometer on fuel	It is a measure of the total cost of fuel per kilometer driven. It is calculated by dividing the total expenditure on fuel by the total kilometers driven.	[Total expenditure on fuel] / [Total kilometers operated]
Vehicle availability at peak periods	It refers to the number of vehicles available to operate at a terminal during periods of high demand.	[Vehicles available at peak periods at all stations] / [Number of stations]
Fuel consumption per day	It is a measure of the amount of fuel used to operate a vehicle in a day.	Average of fuel consumption by all vehicles
Fuel consumption in kilometers per litre	It is the measure of kilometers of distance travelled per unit litre of fuel used by the vehicle.	[Total kilometers operated] / [Total litres of fuel used]
Fuel consumption in litres per kilometer	This is a measure of the amount (i.e., litres) of fuel used by a vehicle per kilometer travelled.	[Total litres of fuel used] / [Total kilometers operated]
Engine oil consumption	Refers to the amount of engine oil that is burned or used up by the vehicle engine during operation.	Average of the engine oil used by all vehicles
Kilometers per accident	It is a measure of safety that is used to measure the kilometers a vehicle drives before it is involved in an accident or a traffic crash. It is calculated by dividing the total number of kilometers driven by the number of accidents that occur during that time.	[Total kilometers operated] / [Number of accidents]
Kilometers per mechanical breakdown (KPMB)	It is a measure of how many kilometers a vehicle can travel before it experiences a mechanical breakdown. It is calculated by dividing the total number of kilometers travelled by the number of mechanical breakdowns experienced by the vehicle in a certain period.	[Total kilometers operated] / [Number of mechanical breakdowns]
Kilometers per tyre carcase	It is a measure of the amount of distance a tyre can travel before it needs to be replaced. It is determined by dividing the number of kilometers driven by a vehicle by the number of tyre replacements.	[Total kilometers operated] / [Number of tyre failure]
Average age of fleet	It is a measure of the age of vehicles within an organization. It is calculated by taking the total age of all vehicles in the fleet and dividing it by the total number of vehicles in the fleet.	Average age of all vehicles surveyed
Maintenance expenditure by vehicle	It refers to the amount of money spent on the maintenance and repair of a vehicle over a given period of time.	Average total cost of vehicle maintenance
Maintenance expenditure by vehicle per kilometer	It is the amount of money spent on maintenance and repair of the vehicle per kilometer over a given period.	[Total cost of vehicle maintenance] / [Total kilometers operated]

Table 4. A list of key performance indicators and their descriptions for personnel variables

KPI	Description	Estimation Procedure
Number of personnel per vehicle	It is a measure of the number of people needed to operate a vehicle. It is commonly used to measure the efficiency of a fleet and its personnel. It is calculated by dividing the total number of personnel by the total number of vehicles.	[Number of personnel for each mode (minibus, taxi)] / [Total number of vehicles]
Expenditure per kilometer on salaries and wages	It is a measure of the amount of money spent on salaries and wages for each kilometer travelled. It is calculated by dividing the total salary and wage expenditure for a given period by the total kilometers travelled during that period.	[Total wages of (driver /conductor)] / [Total kilometers operated]
Kilometers per employee per period	It is a measure of how many kilometers an employee travels during a specific period of time. It is a ratio of the total kilometers travelled to the total number of employees during that period.	[Total kilometers operated daily] / [Total employees]
Kilometers per driver per day	It is typically used to measure the total kilometers driven by a single driver over a given period, such as a day, a month or a year. It is estimated as the ratio of the total kilometers driven to the number of days.	[Total kilometers operated daily] / [Number of drivers used in a day]
Kilometers per man hour (KPMH)	It is a measure of productivity that is used to calculate the kilometers a worker can travel in an hour. It is estimated as the ratio of the kilometers travelled to the hours worked.	[Total kilometers operated] / [Working hours per day]

3. Results and Discussion

3.1 Summary Statistics on Paratransit Vehicles, Operation, and Operators

The information in Table 5 shows key statistics on paratransit vehicles in Accra-Ghana and Dar es Salaam-Tanzania. The distribution of the make of vehicles in Accra-Ghana shows widespread dispersion where Mercedes Benz and Toyota are the dominant vehicle makes accounting for about 32% and 22% respectively. The vehicle-make distribution in Dar es Salaam-Tanzania is particularly skewed towards specific types where Toyota has about 29%, Nissan about 26% and other vehicle types represent about 41%. It is noteworthy that the other (41%) vehicle-make in Dar es Salaam-Tanzania is dominantly three-wheelers (Bajaji). The distribution of vehicle years shows that vehicles in Accra-Ghana are relatively older compared to those in Dar es Salaam-Tanzania. The majority of about 51% in Accra-Ghana corresponds to the 2001–2010 period, whereas the majority of about 43% in Dar es Salaam-Tanzania was associated with the 2011–2020 period. There is a comparable representation of vehicle propulsion, with diesel being the largest in both cities, followed by petrol. There is a notable use of Liquefied Petroleum Gas (LPG) of 2% in Accra-Ghana.

Table 5. Information on paratransit vehicle and operational characteristics in Accra-Ghana and Dar es Salaam-Tanzania

Variable	**Percent – Gh.**	**Percent – Tanz.**	**Variable**	**Percent – Gh.**	**Percent – Tanz.**
Vehicle Make			**Rental Period**		
Toyota	21.5	28.5	Hourly	0.5	0.2
Nissan	12.5	25.6	Daily	52.0	99.8
Mitsubishi	0.6	5.24	Weekly	44.7	0.0
Honda	0.2	0.0	Monthly	2.7	0.0
Ford	3.2	0.0	Yearly	0.0	0.0
Hyundai	9.1	0.0	**Hours operated daily**		
Volkswagen	2.6	0.0	Less than 1 hour	0.0	0.2
Chevrolet	1.3	0.0	1 – 3 hours	0.2	0.3
Mercedes Benz	32.3	0.0	4 – 6 hours	0.0	0.0
Other	16.8	40.7	7 – 10 hours	2.4	0.2
Vehicle year			10 – 15 hours	62.9	53.7
Before 2000	27.5	24.0	above 15 hours	34.6	45.6
2001 – 2010	50.7	28.7	**Driver Age**		
2011 – 2020	21.0	42.8	18-24 years	0.5	3.7
2020 – 2023	0.7	4.5	25-34 years	12.5	38.9
Vehicle Propulsion			35-44 years	27.1	36.4
Petrol	20.7	42.8	45-54 years	38.4	19.8
Diesel	77.4	57.2	55-64 years	17.8	1.2
Electric	0.0	0.0	above 64	3.6	0.0
LPG	2.0	0.0	**Driver Employment Type**		
Vehicle type			Full-time	78.8	22.4
Motorcycle	0.0	0.2	Part-time	1.3	49.1
Three-wheeler	0.0	38.7	Contract	17.5	25.8
Salon – Taxi	22.8	0.0	Work-and-pay	2.4	2.8
Minibus	76.4	59.7	Other	0.0	0.0
Midibus	0.7	1.4	**Driver Has Formal Training**		
Other	0.0	4.4	Yes	20.5	97.4
Is vehicle insured?			No	79.5	2.6
Yes	98.9	98.8	**Driver Years of Experience**		
No	1.1	1.2	>> 1 year	0.5	0.6
Insurance type			1 – 2 years	0.9	8.2
Liability coverage	87.8	58.0	3 – 5 years	4.5	35.9
Collision insurance	10.4	2.3	6 – 10 years	22.1	42.2
Comprehensive insurance	1.5	37.4	<< 10 years	71.9	13.1
Medical payments coverage	0.2	2.2	**Valid Driver License**		
Personal injury protection insurance	0.0	0.0	Yes	98.9	97.2
Gap insurance	0.0	0.0	No	1.1	2.8
Other	0.0	0.0	**Driver License Type**		
Vehicle Owner			Type A – motorcycles, cruisers	0.0	19.2
Driver	34.4	5.6	Type B – minibus, pick-up	13.6	28.5
Private owner	64.1	80.9	Type C – buses, medium goods carrying vehicles	70.6	50.9
Transport union	1.5	11.7	Type D – buses, coaches, heavy goods vehicles	15.8	1.4
Corporate-Bank	0.0	1.8			

Similarly, for vehicle type, there is a proportionate use of minibuses that has been the highest in both cities with about 76% in Accra-Ghana, and 60% in the case of Dar es Salaam-Tanzania. Also, both cities have limited usage of motorcycles and midi-buses. However, there is a divergent usage of taxis and three-wheelers in both cities. Accra-Ghana has taxi and three-wheelers usage of about 23% and zero, respectively, whereas the usage is zero and about 39% in the case of Dar es Salaam-Tanzania. Relatedly, there is comparable seating capacity in both cities where the average is about 15 in Accra-Ghana, and about 16 in the case of Dar es Salaam-Tanzania. There is a relatively higher dispersion of seating capacity in Dar es Salaam-Tanzania, indicating that the seating capacity for vehicles there is more dissimilar in comparison to those in Accra-Ghana. It is noteworthy that the seating capacity statistics are in the context of the distribution of paratransit vehicles in each city. The average number of vehicles assigned to a route is relatively higher (about 46) in Dar es Salaam-Tanzania than the estimate (about 31) in Accra-Ghana.

There is a high proportion of about 99% of the respondents who have their vehicles insured in both cities. The category of insurance varies in both cities, where the largest proportion of about 88% of the respondents in Accra-Ghana and 58% in Dar es Salaam-Tanzania subscribe to liability coverage. Notably, about 37% of the respondents in Dar es Salaam-Tanzania subscribe to comprehensive insurance, which is indicative of a higher level of caution to road safety. In both cities, vehicle ownership by private owners is the largest ownership category, with about 64% in Accra-Ghana, and about 81% in Dar es Salaam-Tanzania. The high vehicle ownership by drivers of about 34% in Accra-Ghana is almost contrary to those in Dar es Salaam-Tanzania comprising about 6%. This characteristic variation in vehicle ownership can exert enormous influence on operational arrangements such as wages, employment conditions, operating hours, etc. The vehicle rental period in both cities is highest for the daily period, with 52% in Accra-Ghana and 99.8% in Dar es Salaam-Tanzania. The very high daily rental in Dar es Salaam-Tanzania is likely related to the high vehicle ownership by private owners and not by drivers. The number of hours of operations is very high in both cities, with the largest proportion associated with 10-15 hours followed by above 15 hours.

The findings on driver age show that there are relatively younger drivers in Dar es Salaam-Tanzania compared to Accra-Ghana. Based on these results, the average driver age in Accra-Ghana is about 47 years, whereas in Dar es Salaam-Tanzania it is about 37 years, indicating a 10-year gap in driver age. Concerning driver employment type, there is a clear distinction between the two cities that may be linked to vehicle ownership. Driver full-time employment is highest in Accra-Ghana, where it is associated with about 79%, followed by contract work of about 18%. In the case of Dar es Salaam-Tanzania, part-time employment is the highest category at about 49%, followed by contract (26%) and then full-time employment (22%). Driver formal training is distinctive in both cities, with Dar es Salaam-Tanzania associated with a high proportion of about 97% compared to about 21% in Accra-Ghana. This disparity may be linked to local government enforcement and vehicle ownership. Private owners are the largest category of vehicle ownership in Dar es Salaam-Tanzania; thus, they may be willing to rent their vehicles to only those with formal driver training. Another distinguishing variable is the years of experience of drivers in both cities. Relatively, the drivers in Accra-Ghana have more years of experience compared to those in Dar es Salaam-Tanzania. Based on these results, the average years for driver experience in Accra-Ghana is about 9 years, whereas in Dar es Salaam-Tanzania, it is about 6 years, indicating a 3-year gap in driver years of experience. Acquisition of valid driver's licenses by drivers in both cities is overwhelmingly high, more than 97%. Regarding driver license type, Type C – buses, and medium goods carrying vehicles are associated with the largest proportion in both cities, with about 71% in Accra-Ghana and about 51% in Dar es Salaam-Tanzania. Given the high usage of three-wheelers in Dar es Salaam-Tanzania, about 19% of the drivers own Type A – motorcycles, and cruiser licenses.

3.2 Paratransit Route Characteristics

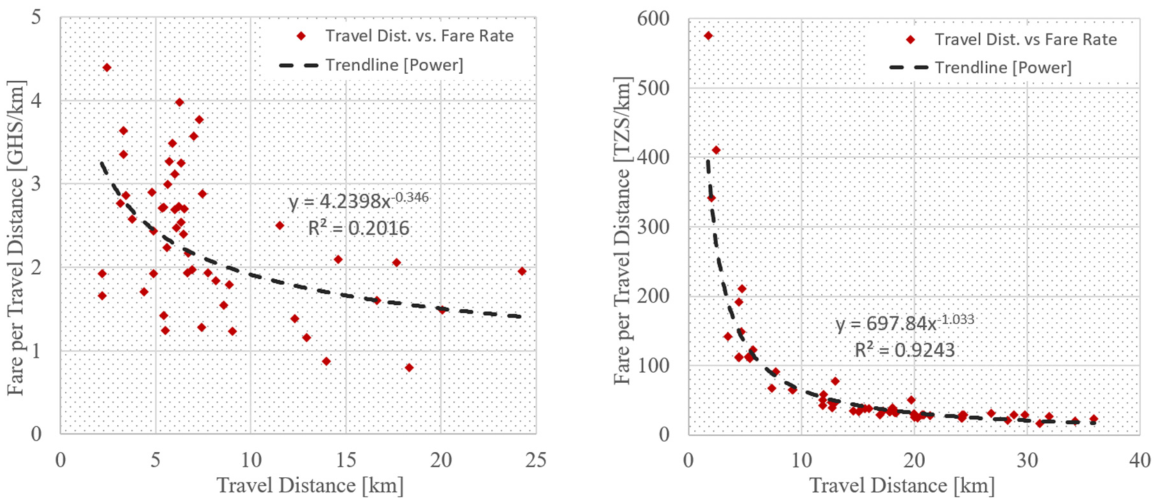
The information in Table 6 shows the basic characteristics of paratransit routes surveyed in both cities. The route characteristics include the mode of travel, the number of routes surveyed, travel distance (in km), and travel fares in Ghana Cedis (GHS) for Accra-Ghana and in Tanzanian shilling (TZS) for Dar es Salaam-Tanzania. The summary statistics for the routes are categorized into all modes of travel, minibus, taxis in the case of Accra-Ghana, and three-wheelers for Dar es Salaam-Tanzania. In Accra-Ghana, a total of 52 routes were surveyed where 38 were specifically minibus routes and 14 were taxi routes. All 38 minibus routes were operated under the Ghana Private Road and Transport Union (GPRTU), whereas the taxi routes were operated by either GPRTU or the Cooperative Drivers Union (CDU). In the case of Dar es Salaam-Tanzania, a total of 57 routes were surveyed where 41 were minibus routes and 16 were three-wheeler routes. All routes, including minibus and three-wheeler routes, are operated under the Land Transport Regulatory Authority (LATRA) of Tanzania.

A comparison of the travel distances for all routes in both cities shows that the average travel distance in Dar es Salaam-Tanzania is about double that of those in Accra-Ghana. Despite having the longest travel distance, the routes in Accra-Ghana are relatively shorter in comparison to those in Dar es Salaam-Tanzania. These findings are consistent when the travel distances are categorized by travel mode, where minibus routes in Dar es Salaam-Tanzania are about double that of those in Accra-Ghana. Similarly, the overall travel distance of three-wheeler routes in Dar es Salaam-Tanzania is about double that of taxi routes in Accra-Ghana. Notably, the overall travel distances of minibus routes in both cities are relatively longer in comparison to either taxi routes in Accra-Ghana or three-wheeler routes in Dar es Salaam-Tanzania. Typically, taxis and three-wheeler routes correspond to shorter trips that are used to connect to main or minibus routes and/or on routes not served by minibuses. The travel fares are indicative of the local currency where the overall average for all the routes is GHS6.59 (0.58USD) in Accra-Ghana, and TZS656.14 (0.27USD) in the case of Dar es Salaam-Tanzania. When segregated by travel mode, the fares for minibus routes in both cities are relatively lower in comparison to either taxi routes in Accra-Ghana or three-wheeler routes in Dar es Salaam-Tanzania.

Table 6. Summary of paratransit route characteristics in Accra-Ghana and Dar es Salaam-Tanzania

All Routes	**Accra**	**Dar es Salaam**	**Minibus Routes**	**Accra**	**Dar es Salaam**	**Taxi or Three-Wheeler Routes**	**Accra**	**Dar es Salaam**
Mode	All modes	All modes	Mode	Minibus		Mode	Taxi	Three-Wheeler
Number of routes	52	57	Number of routes	38	41	Number of routes	14	16
Travel Distance (km)			**Travel Distance (km)**			**Travel Distance (km)**		
Mean	8.74	16.04	Mean	9.57	17.89	Mean	6.47	11.28
Std. Dev.	8.31	8.81	Std. Dev.	9.42	7.57	Std. Dev.	3.27	10.17
Travel fares	GHS (USD)	TZS (USD)	**Travel fares**	GHS (USD)	TZS (USD)	**Travel fares**	GHS (USD)	TZS (USD)
Mean	6.59 (0.58)	656.14 (0.27)	Mean	6.27 (0.56)	625.61 (0.26)	Mean	7.46 (0.66)	734.38 (0.30)
Std. Dev.	2.60 (0.23)	146.71 (0.06)	Std. Dev.	2.51 (0.22)	116.79 (0.05)	Std. Dev.	2.73 (0.24)	186.83 (0.08)

In addition, the relationships between fare rate (fare per distance) against travel distance are illustrated in Figure 3 using a scatter plot and a power trendline. The plot shows diminishing returns of fare rates where increasing travel distance yields progressively smaller decreases in fare rates. That is, increasing travel distance yields progressively smaller increases in fare revenue. There is a distinct pattern for each city where the coefficient of determination R^2 for Accra-Ghana is 0.2016 and 0.9243 for Dar es Salaam-Tanzania. This shows a consistent distance-based fare structure in Dar es Salaam-Tanzania compared to those for Accra-Ghana, which is highly variable by distance. The results show that travel distance has a consistent diminishing return to fare rate in both cities. The relationships indicate that longer travel distances are associated with lower fare rates and vice versa. That is, it is expensive to travel for shorter distances. This finding is consistent with those found by (Brown, 2018) showing that low-income transit riders travel shorter distances, and rely disproportionately on local rather than longer-distance modes, where they pay far higher per-mile transit fares compared to more affluent riders.



(a) Accra-Ghana (b) Dar es Salaam-Tanzania

Figure 3. Scatter plots show the diminishing returns of fare rates against travel distance

3.3 Indicative KPIs for Paratransit Modes

3.3.1 Characteristics of Operational KPIs

The estimated values for the operational KPIs for paratransit modes in both cities are presented in Table 7. The KPVPD is distinctive in both cities, with more kilometers travelled in Dar es Salaam-Tanzania than Accra-Ghana. This is consistent with the average route distance in both cities, although KPVPD is influenced by other factors, such as the time the route is run. The RPVPD is subject to the local currency and economy of each country, but the variation by mode is insightful. Based on the fare revenue, minibuses in both cities generate a higher fare revenue per kilometer travelled, about double compared to taxis in Accra-Ghana or three-wheeler in Dar es Salaam-Tanzania. Concerning PPVPD, there are higher values in Dar es Salaam-Tanzania compared to Accra-Ghana. The difference by mode is considerable in both cities, where taxis carry only about 27% of the passengers carried by minibus in Accra-Ghana, and three-wheelers carry about 22% of the passengers carried by minibus in Dar es Salaam-Tanzania. While different travel modes perform distinct functions, the PPVPD by mode is crucial for policy formulation and action.

The average fare is subject to the local currency and economy of each country, but the variation by mode is noteworthy. In both cities, the minibus fares paid per passenger are more than those paid for taxi services in Accra-Ghana or three-wheeler services in Dar es Salaam-Tanzania. For the load factor, the overall results show that there is a relatively higher load factor in Accra-Ghana compared to Dar es Salaam-Tanzania. It is noteworthy that the load factor for three-wheeler services in Dar es Salaam-Tanzania is the highest, with more than 99%. The results for vehicle utilization by kilometer show that there is relatively higher vehicle usage in Dar es Salaam-Tanzania compared to Accra-Ghana. While there are distinct differences by country, the vehicle utilization by mode in both cities is almost the same, indicating that minibus usage is similar to taxi usage in Accra-Ghana or three-wheeler utilization in Dar es Salaam-Tanzania. The estimates for the percentage of scheduled kilometers operated show that there is a higher proportion of kilometers operated in Dar es Salaam-Tanzania compared to Accra-Ghana. Similarly, the percentage of scheduled kilometers operated by mode in both cities is considered to be almost the same, indicating that minibus operation levels are similar to those of taxis in Accra-Ghana or three-wheelers in Dar es Salaam-Tanzania.

Table 7. Operational key performance indicators and their estimated values for paratransit modes in Accra-Ghana and Dar es Salaam-Tanzania

KPI	Accra-Ghana			Dar es Salaam-Tanzania		
	Combined	Minibus	Taxi	Combined	Minibus	Three-Wheeler
Kilometers per vehicle per day (KPVPD)	76.67	81.93	60.07	166.64	223.27	79.77
Fare revenue per vehicle per day (RPVPD)	522.6GHS (46.3USD)	655.4GHS (58.1USD)	215.3GHS (19.1USD)	183234.3TZS (75.1USD)	228370.3TZS (93.6USD)	51872.5TZS (21.3USD)
Fare revenue per kilometer	6.8GHS (0.60USD)	8.0GHS (0.71USD)	3.6GHS (0.32USD)	1099.6TZS (0.45USD)	1022.8TZS (0.42USD)	650.3TZS (0.27USD)
Passengers per vehicle per day (PPVPD)	78	102.4	27.6	281.6	352.3	79.0
Average fare paid per passenger	6.7	6.4	7.8	650.7	648.2	657.0
Load factor (%)	96.57	93.74	95.59	73.86	79.96	99.24
Vehicle utilization by kilometer (%)	75.41	75.71	75.19	83.74	84.19	74.28
Percentage of scheduled kilometers operated (%)	71.74	71.70	71.92	83.17	83.72	80.85
Percentage of "dead" kilometers (%)	17.22	17.20	17.01	4.03	3.39	6.70
Revenue by route	80.4GHS (7.12USD)	102.4GHS (9.07USD)	31.2GHS (2.76USD)	14315.2TZS (5.89USD)	20742.1TZS (8.50USD)	3285.2TZS (1.35USD)

Concerning the percentage of dead kilometers, there is a higher proportion, almost four times higher, in Accra-Ghana compared to those estimated for Dar es Salaam-Tanzania. The variation by mode is fractional in Accra-Ghana, whereas it is considerable in Dar es Salaam-Tanzania, with the value for three-wheelers about two times that for minibuses. As noted, the fare is subject to the local currency and economy of each country, but the revenue by route for different modes is noteworthy and distinct for each country. In Accra-Ghana, the revenue by route for minibus is three times more than that for taxi services. In the case of Dar es Salaam-Tanzania, it is even higher, with the revenue for minibus being six times more than those for three-wheelers.

3.3.2 Characteristics of Vehicle KPIs

The estimated values for the vehicle KPIs for paratransit modes in both cities are presented in Table 8. The expenditure per kilometer on tyres and maintenance materials is also subject to the local currency and economy of each country. However, the variation by mode is insightful with fractional differences for modes in Accra-Ghana. For Dar es Salaam-Tanzania, the expenditure for three-wheeler services is about 1.5 times higher than that for minibus. In Accra-Ghana, there are similar values for expenditure per kilometer on all expenses and expenditure per kilometer on fuel. However, in the case of Dar es Salaam-Tanzania, the order has reversed, with minibus having higher values for both expenditure per kilometer on all expenses and expenditure per kilometer on fuel. The minibus expenditure relating to all expenses is about 1.4 times higher than those for three-wheelers, whereas it is two times higher than in the case for expenditure relating to fuel. This indicates that differences in fuel usage are the indicator with the largest impact on the disparities in expenditure values.

Table 8. Vehicle key performance indicators and their estimated values for paratransit modes in Accra-Ghana and Dar es Salaam-Tanzania

KPI	Accra-Ghana			Dar es Salaam-Tanzania		
	Combined	**Minibus**	**Taxi**	**Combined**	**Minibus**	**Three-Wheeler**
Expenditure per kilometer on tyres and maintenance materials	1.3GHS/km (0.11USD/km)	1.3GHS/km (0.11USD/km)	1.2GHS/km (0.10USD/km)	163.2TZS/km (0.07USD)	146.5TZS/km (0.06USD)	233.2TZS/km (0.10USD)
Expenditure per kilometer on all expenses	4.6GHS/km (0.41USD/km)	4.5GHS/km (0.40USD/km)	4.6GHS/km (0.41USD/km)	690.9TZS/km (0.28USD/km)	721.3TZS/km (0.29USD/km)	513.9TZS/km (0.21USD/km)
Expenditure per kilometer on fuel	3.3GHS/km (0.29USD/km)	3.3GHS/km (0.29USD/km)	3.4GHS/km (0.30USD/km)	527.7TZS/km (0.22USD/km)	574.7TZS/km (0.23USD/km)	280.7TZS/km (0.11USD/km)
Vehicle availability at peak periods	16	16	16	20.5	17.0	26.12
Fuel consumption per day (litres/day)	20.5	21.5	17.7	33.0	48.8	7.35
Fuel consumption per kilometer (litres/km)	0.27	0.26	0.29	0.20	0.22	0.09
Fuel consumption in kilometer per litres (km/litres)	3.7	3.8	3.4	5.1	4.6	10.9
Engine oil consumption (litres per day)	0.25	0.28	0.17	0.83	1.17	0.29
Engine oil consumption (km/litres)	302.4	292.6	336.2	201.1	190.6	276.4
Kilometers per accident (km)	2848.6	2640.5	13245.4	3180.9	3507.4	2106.7
Kilometers per mechanical breakdown (KPMB) (km)	373.6	395.5	358.0	577.0	771.5	277.0
Number of days per mechanical breakdown	4.9	4.8	5.9	3.5	3.5	3.5
Kilometers per tyre carcase (km)	679.5	677.8	854.5	555.8	740.2	267.9
Average age of fleet	2004	2004	2005	2008	2002	2016
Maintenance expenditure by vehicle per day	40.8GHS/day (3.61USD/day)	43.4GHS/day (3.84USD/day)	32.5GHS/day (2.88USD/day)	22297.0TZS/day (9.14USD/day)	26850.3TZS/day (11.00USD/day)	15127.1TZS/day (6.20USD/day)
Maintenance expenditure by vehicle per kilometer	0.53GHS/km (0.04USD/km)	0.53GHS/km (0.04USD/km)	0.54GHS/km (0.05USD/km)	133.8TZS/km (0.06USD/km)	120.3TZS/km (0.05USD/km)	189.6TZS/km (0.08USD/km)

For vehicle availability at peak periods, the values are the same for all modes in Accra-Ghana. But in Dar es Salaam-Tanzania, there is a higher number of three-wheelers available than minibuses at peak periods. Fuel consumption was measured in three different units: litres/day, litres/km, and km/litres, where the last two units are more practical for operation purposes. Based on the fuel consumption results, the vehicles in Dar es Salaam-Tanzania have better consumption rates of about 5.1km/litres compared to 3.7km/litres in Accra-Ghana. Notably, there are relatively newer vehicles in Dar es Salaam-Tanzania compared to those surveyed in Accra-Ghana, where the improved fuel consumption may be related to the vehicle age. Also, it is recognized that three-wheelers have relatively smaller engine capacities, which are associated with lower fuel consumption compared to regular vehicles used for minibus and taxi services. Concerning engine oil consumption, the unit in km/litres is more practical, where consumption levels are much better in Accra-Ghana than those in Dar es Salaam-Tanzania. By mode, minibus engine oil consumption is much higher in both cities than taxis in Accra-Ghana or three-wheelers in Dar es Salaam-Tanzania.

In terms of kilometers per road crash (or accident), there are more kilometers travelled before a road crash occurs in Dar es Salaam-Tanzania than in Accra-Ghana. By mode, minibuses are more prone to road crashes, about five times more than taxis in Accra-Ghana. Whereas in Dar es Salaam-Tanzania three-wheelers are about 1.5 times more prone to road crashes than minibuses. The number of kilometers per mechanical breakdown is higher in Dar es Salaam-Tanzania than Accra-Ghana. Based on mode, minibuses travel slightly longer distances (37.5km) before experiencing a mechanical breakdown than taxis in Accra-Ghana. For Dar es Salaam-Tanzania, minibuses travel far longer distances, about three times more, before experiencing a mechanical breakdown than three-wheelers. There are more kilometers per tyre carcase in Accra-Ghana than in Dar es Salaam-Tanzania. For minibus, the kilometers travelled before tyre carcase is slightly higher in Dar es Salaam-Tanzania. It is noteworthy that taxis in Accra-Ghana have the highest kilometers per tyre carcase, with three-wheelers in Dar es Salaam-Tanzania associated with the least kilometers. Regarding the average age of the fleet, there are newer vehicles in Dar es Salaam-Tanzania overall, but that is primarily due to the relatively newer three-wheelers. That is, there are newer minibuses and taxis in Accra-Ghana compared to the minibus fleet in Dar es Salaam-Tanzania. The maintenance expenditure by vehicle was measured by day and by kilometer; the kilometer measure is more practical for comparison. Again, the actual expenditure costs are subject to the local currency and economy of each country. In Accra-Ghana, the maintenance expenditure by the vehicle per kilometer is almost the same for both minibuses and taxis. In contrast, there are disparities in Dar es Salaam-Tanzania with minibus being about 1.6 times more than the estimates for three-wheelers.

3.3.3 Characteristics of Personnel KPIs

The estimated values for the personnel KPIs for paratransit modes in both cities are presented in Table 9. The number of personnel per vehicle is similar across cities where two persons operate minibuses, whereas taxis and three-wheelers are operated by one person. The expenditure per kilometer on salaries and wages for drivers is subject to the local currency and economy of each country. However, their variations by mode are noteworthy with similar expenditures for minibus and taxis in Accra-Ghana. In Dar es Salaam-Tanzania, the expenditure for three-wheeler drivers is about three times that for minibus drivers. This wage disparity is quite high, and it will be insightful to determine the factors influencing this relationship. The kilometers per driver per day is relatively higher in Dar es Salaam-Tanzania across all modes compared to those in Accra-Ghana. Overall, drivers in Dar es Salaam-Tanzania operate about two times the kilometers operated by those in Accra-Ghana. This is partly in agreement with the sizes of the study areas considered in each city. By mode, minibus drivers operate about 1.3 times the number of kilometers operated by taxi drivers in Accra-Ghana. In Dar es Salaam-Tanzania, the minibus drivers operate about three times the number of kilometers operated by three-wheeler drivers. Concerning the kilometers per man hour, the KPMH in Dar es Salaam-Tanzania is about two times the estimates in Accra-Ghana. Based on the modes, the kilometers per man hour for a minibus is about 1.3 times those for taxis in Accra-Ghana. In Dar es Salaam-Tanzania, the kilometers per man-hour for a minibus is close to three times that of a three-wheeler. Based on the personnel KPIs alone, a three-wheeler operation is quite profitable from an operator perspective compared to a minibus in Dar es Salaam-Tanzania.

Table 9. Personnel key performance indicators and their estimated values for paratransit modes in Accra-Ghana and Dar es Salaam-Tanzania

KPI	Accra-Ghana			Dar es Salaam-Tanzania		
	Combined	Minibus	Taxi	Combined	Minibus	Three-Wheeler
Number of personnel per vehicle	1.4	1.5	1.0	1.6	2.0	1.2
Expenditure per kilometer on salaries and wages – Driver	5.2GHS/km (0.46USD/km)	4.9GHS/km (0.43USD/km)	5.0GHS/km (0.44USD/km)	154.8TZS/km (0.06USD/km)	112.0TZS/km (0.04USD/km)	313.4TZS/km (0.13USD/km)
Expenditure per kilometer on salaries and wages – Conductor	0.6GHS/km (0.05USD/km)	0.6GHS/km (0.05USD/km)	N/A	92.6TZS/km (0.04USD/km)	71.7TZS/km (0.03USD/km)	130.9TZS/km (0.05USD/km)
Kilometers per employee per period	53.2	54.8	59.1	102.3	116.9	66.9
Kilometers per driver per day	76.67	81.9	60.0	166.6	223.3	79.8
Kilometers per man hour (KPMH) (km/hr)	6.22	6.08	4.81	12.3	16.2	6.0

4. Findings and Implications

The study characterized the characteristics relating to vehicles, their operation and personnel for paratransit modes in both cities. The paratransit vehicle-make found in Accra-Ghana is mainly Mercedes Benz and Toyota, whereas those in Dar es Salaam-Tanzania are primarily Toyota, Nissan, and Bajaji motorcycles. Diesel was found to be the most popular vehicle propulsion followed by petrol in both cities. The dominant paratransit modes were found to be minibus and taxis in Accra-Ghana, and minibus and three-wheelers in the case of Dar es Salaam-Tanzania, with minibus being the leading mode in both cities. The seating capacity of paratransit vehicles is comparable in both cities, where the average is about 15 in Accra-Ghana, and about 16 in the case of Dar es Salaam-Tanzania. The high proportion of diesel usage by commercial vehicles in SSA cities has been found in studies by Ajayi et al. (2023), and Maduekwe et al. (2020).

Private ownership of paratransit vehicles is the largest category in both cities, with a notable one-third ownership by drivers in Accra-Ghana compared to 6% ownership in Dar es Salaam-Tanzania. Drivers are relatively younger with an average of about 37 years in Dar es Salaam-Tanzania compared to 47 years in Accra-Ghana. Driver employment is relatively more stable in Accra-Ghana with a higher proportion of 79% in full-time employment compared to 22% in Dar es Salaam-Tanzania. Driver formal training is distinctively high, about 97%, in Dar es Salaam-Tanzania compared to about 21% in Accra-Ghana. The overall length of paratransit routes based on travel distances is longer in Dar es Salaam-Tanzania, about two times that of those found in Accra-Ghana. Minibus routes were found to attract relatively lower travel fares in comparison to taxi routes in Accra-Ghana and three-wheeler routes in Dar es Salaam-Tanzania.

Vehicle utilization is consistently higher in Dar es Salaam-Tanzania compared to Accra-Ghana, based on several KPIs, including KPVPD, PPVPD, utilization by kilometer, and percentage of scheduled kilometers operated. Enhanced vehicle utilization is directly reflected in overall higher fare revenue generated daily in Dar es Salaam-Tanzania 75.1USD compared to 46.3USD in Accra-Ghana. This indicates that vehicles are used efficiently and effectively in Dar es Salaam-Tanzania, whereas vehicles in Accra-Ghana need improvement in fleet management factors such as unreliable schedules, fluctuating demand, poor coordination, and vehicle size restrictions. This information on vehicle utilization is crucial to help transport authorities to identify areas of improvement towards optimizing their operations to minimize operation costs and increase productivity. The percentage of dead kilometers is excessively high in Accra-Ghana, about four times that of those in Dar es Salaam-Tanzania. Dead kilometers directly result in loss of revenue, increased fuel consumption, operational costs, pollution, and wear and tear on vehicles. Dead kilometer trips need to be reduced considerably, especially in Accra-Ghana, by reducing empty trips, improving the scheduling of vehicles, and allocating vehicles closer to terminals, maintenance shops and washing bays. The findings based on revenue by route indicate that minibus is more cost-effective to operate in both cities than taxis in Accra-Ghana and three-wheelers in Dar es Salaam-Tanzania. This finding, in combination with passengers per vehicle per day, further illustrates that it is more economically and environmentally efficient to operate minibuses than the other modes in both cities.

Fuel consumption by paratransit vehicles was found to be relatively better in Dar es Salaam-Tanzania with a consumption rate of about 5.1km/litres compared to 3.7km/litres in Accra-Ghana. The difference in fuel consumption is partly explained by the relatively newer vehicles in Dar es Salaam-Tanzania compared to those in Accra-Ghana. This disparity means that fuel consumption rates can be improved, especially in the case of Accra-Ghana by considering factors such as vehicle maintenance, engine efficiency, vehicle speed, driving habits, stop-and-go driving, tire pressure, route planning, etc. Similar low energy efficiency levels were found in Anambra State of Nigeria for both petrol- and diesel-propulsion engines (Okafor et al., 2014). Relatedly, expenditure per kilometer on all expenses shows that expenditure on fuel is the indicator with the largest impact in both cities. Comparatively, the overall expenditure is relatively higher 0.41USD/km in Accra-Ghana than 0.28USD/km in Dar es Salaam-Tanzania. Thus, operational interventions that can lead to improved fuel consumption will directly result in financial and environmental benefits of paratransit operations. In terms of safety-related KPIs such as kilometers per accident, kilometers per mechanical breakdown, and kilometers per tyre carcase, there are relatively favourable conditions in Dar es Salaam-Tanzania compared to Accra-Ghana. The disparities between modes and across cities illustrate that improvements can be made and that operational interventions are needed where they can make a considerable impact on safe and efficient paratransit operations. For personnel-related KPIs, there are comparable working conditions in both cities, but there exist distinguishing disparities in wages across modes in Dar es Salaam-Tanzania.

5. Conclusions

Overall, this study has established the cost structure for paratransit modes in the two study cities, making available vital data and knowledge for decision-making. Our findings are particularly salient for conceptual development and inform relevant transport policy decisions and appraisal of public transport services towards enhancing their efficiency, formalization and integration. The quantification of the various KPIs unearthed some perceptions that are common but not exactly quantified. For example, the proliferation of three-wheelers is underpinned by its high profit margin, where its wages are about three times those of minibus operators in Dar es Salaam-Tanzania. Relatedly, the findings show that the operation of high-capacity vehicles is economically and environmentally beneficial. This represents a crucial indicator to convince operators to adopt high-capacity vehicles. Given that the paratransit system in SSA is characterized by several private actors, providing practical evidence that can lead to a boost in their revenue stream is crucial.

In addition, the disparities in the estimated KPIs emphasize the need for action by local governments and transport authorities. The high level of formal driver training is exemplary in the case of Dar es Salaam-Tanzania and should be replicated by local authorities in other SSA countries. Also, interventions by local authorities can lead to improvements in the overall vehicle and operational performance. For example, operational procedures relating to fleet management, improved scheduling and coordination, and vehicle size restrictions can lead to practical impacts in vehicle utilization levels. Example interventions such as GPS-based real-time tracking, dynamic scheduling, driver performance monitoring, passenger feedback integration, unified ticketing systems, and centralized control centers can be established to coordinate paratransit operations in real-time. That is, the estimated KPIs provide a diagnostic and a performance framework to evaluate the operational state of the paratransit system as well as identify specific actions that can lead to improvement in targeted KPIs.

These findings have implications for the study cities as well as other SSA cities. For example, fare-setting in the context of some elements of operational cost can be used to promote certain traffic-related environmental goals. For example, current fares and operational cost elements are favourable to three-wheelers compared to minibuses in Dar es Salaam-Tanzania. Also, high-capacity vehicles being economically and environmentally beneficial means that local authorities can incentivize their usage to maximize these goals. A good knowledge of operational costs of paratransit is critical in formulating fare-setting policies, and in expanding paratransit services. The findings are critical to public transport reorganization efforts, especially those involving BRT and the formalization of the paratransit system. That is, knowledge of operational costs is crucial in SSA cities planning to run or those already running paratransit services alongside BRT to ensure equitable competition. Given that fare-setting is a politically sensitive matter and that most governments are often resistant to fare increases, it is widely recognized that a legitimate public authority can be mandated to apply fare-setting procedures to de-politicize the fare issue.

This should go along with a clear re-organization of paratransit routes and consistent operating procedures, together with their registration and licensing to authorized operators.

Regarding the KPIs identified, strategies should target enhancing vehicle utilization and performance, operating procedures, and maintenance and safety. Also, action is needed to build capacity for paratransit operators and local transport authorities in better linking the operating cost elements to fare revenue. That is, local governments should be equipped to plan, administer, and manage the operation of paratransit routes in consultation with driver/operator/owner unions. Given the lack of established fare structures, knowledge of operating cost elements will help to develop and implement equitable fare policies for paratransit services. Crucially, the fare setting at the local level should consider sociodemographic information so that population groups and communities that are already economically, socially, or environmentally vulnerable should not be further disadvantaged. This will require local and national investments together with increased research and development activities for paratransit in both cities. Specifically, local and national governments in Ghana, Tanzania, and SSA countries with similar challenges should consider these findings toward formulating/enhancing their fare-setting policies.

There remain additional questions for future studies. It is acknowledged that the estimated KPIs are based on user-reported surveys that are particularly associated with respondents' ability to recollect past events, thus increasing the uncertainty levels in the estimated cost elements. In combination with the user-reported survey, a future study should sample paratransit operators to incorporate proper accounting of their expenses and a GPS-assisted travel monitor to capture the dynamics of their daily operations. These sample measurements could be used to validate as well as scale up the user-reported data to larger service areas. In addition, this study did not account for road conditions, which is a vital element in estimating the operation costs of public transport services. Accordingly, future studies should incorporate information on road conditions, its implications on the various cost elements and travel fares charged by operators. Further, other paratransit modes aside from minibus, taxis, and tricycles should be examined in a future study. Related information on traffic volume and travel speed for the various paratransit modes can be impactful in further studies to better characterize the operational characteristics of each travel route. To better link the KPIs to environmental and climate goals, data on vehicular emission levels will be crucial to establishing the pollution levels for each paratransit mode. Essentially, a comprehensive characterization and estimation of operational cost elements for paratransit services is fundamental to improving access, making the service affordable, enhancing the livelihood of operators, ensuring its sustainability, and reducing its negative impacts on the environment.

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Gift Dumedah: Writing – original draft, review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. Hannibal Bwire: Writing – review & editing, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. Alex Johnson: Writing – review & editing, Resources, Investigation, Formal analysis, Data curation. Albert Mwauzi: Writing – review & editing, Software, Resources, Investigation, Data curation.

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