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Minibus taxis in Kampala's paratransit system: Operations, economics and efficiency

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ABSTRACT

Most cities in sub-Saharan Africa rely for their public transport on paratransit in the form of fourteen- to twenty-seater privately owned and mostly old minibus taxis. The system is often seen as disorganized, unregulated and inefficient. To assess the accuracy of this picture, we analyzed the operations and economics of Kampala's minibus taxi system and its efficiency from the passengers' and the drivers' perspectives, using 'floating car data'. We found that the picture is largely accurate. Our findings suggest the need for moderate transformation: adequate enforcement of regulations, reorganization of ownership, renewal of fleets, and integration of ICT systems to facilitate scheduling, booking and fare collection. This will help to make the system safer, cleaner and more efficient for Kampalan commuters and more stable, secure and profitable for the minibus taxi drivers and the mini industries that depend on them.

1. Introduction

Across developing cities of sub-Saharan Africa, transport authorities are struggling to fulfil the mobility needs of rapidly growing populations, especially the urban poor. The transport systems that are supposed to connect commuters to jobs, services and markets have limited capacity and are loosely regulated and inefficient (Behrens et al., 2015; Agbiboa, 2018). Since the 1090s these typically quasi-demand-responsive services – referred to in the scholarly literature as "paratransit" or "informal transport" – have filled the gap left by the collapse of the colonial-era state-owned transport companies (Cervero and Golub, 2007; Kumar et al., 2008; Kumar, 2011). There were few barriers to market entry as a result of the World Bank structural adjustment policies of the 1990s and weak policies for regulating and enforcing licensing. The paratransit industry, consisting mostly of fourteen- to twenty-seater minibus taxis, therefore expanded to dominate public transport in many cities of sub-Saharan Africa (Booysen et al., 2013). In Uganda, two bus companies – the Uganda Transport Company (UTC) and the Peoples Transport Company (PTC) – provided public transport services in the 1970s and 1980s. However, after a litany of problems comprehensively documented by Kumar (2011), the companies collapsed in the early 1990s, paving the way for the organic evolution of privately-run paratransit with atomized ownership and dispersed financial capital.

Uganda's informal minibus taxi industry is a vital and lucrative component of the urban economy. It directly employs more than 100,000 people in Kampala (Uganda's capital city), and it provides many indirect jobs through the motor vehicle repair and servicing industry (Pablo, 2015; Goodfellow, 2017). In 2015, Kampala had 1.5 million residents and 16,000 minibus taxis that transported 82.6% of the commuters across its five divisions (i.e., Central, Kawempe, Makindye, Nakawa and Lubaga) (Vermeiren et al., 2015; KCCA, 2016; Aggrey, 2017). The remaining 17.4% of commuter travel was shared among private cars, busses and motorcycle taxis (boda bodas). Though many minibus taxis are not officially registered, Kampala's minibus taxi fleet is estimated to be growing at a rate of 5.4% annually (Pablo, 2015; Aggrey, 2017; Jean et al., 2018).

Although the minibus taxi ownership structure is fundamentally opaque, reports point to wealthy politicians owning fleets of minibus taxis, several private citizens owning one or two, and groups of individuals pooling funds to co-own one (Stewart-Wilson et al., 2017). The capital outlay of about $15,000 for a single second-hand minibus from Japan substantially contributes to the atomized ownership of minibus taxis in Kampala (Dorothy, 2018). The $15,000 start-up capital is out of reach for many Ugandans since Uganda's GDP per capita is only $642 (Dorothy, 2018). The minibus taxi business has a potential annual cash flow of $10,000 per minibus taxi and a profit of $35,000 over five years accrued to the owner (Aggrey, 2017; Dorothy, 2018). However,

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the operations of minibus taxis are opaque to the commuters and new drivers joining the industry; the economics of fares paid by the commuters and the daily cash flow to drivers and owners are not well documented; and the efficiency of paratransit in terms of passenger travel time has not been well studied.

This paper has three objectives. First, to study the operations of minibus taxis in Kampala's paratransit system, from basics like regulation, management and routes, to the industry's unique and peculiar practices. Second, to study and evaluate the economics of minibus taxis in terms of passenger fares, drivers' daily cash flow, profits, and estimate the drivers' profitability index (PI) of the minibus taxi business. Third, to assess the efficiency of the paratransit system from the passengers' and drivers' perspectives, and how it affects the overall minibus taxi operations and the subsequent operational economics. To estimate the system efficiency, we introduce the concept of "hold-back" time (t_h), which means the accumulated time a taxi driver waits at stops along a route waiting for and loading passengers. The hold-back time can be likened to the dwell time in scheduled public transport. However, hold-back time is unique to minibus taxis in Kampala and sub-Saharan Africa because of their unscheduled nature and it varies depending on the occupancy status of the taxi and the anticipated demand along the route.

2. Paratransit regulation and management in Kampala

Regulation in public transport universally covers three dimensions: quality regulation to ensure vehicle safety; quantity regulation to set targets for and limit the number of vehicles operating in the system; and fare regulation. The principal objectives of transport regulation are to ensure that, (1) services are operated in accordance with government policy, (2) demand for public transport is satisfied as far as possible, (3) standards of quality and safety are maintained, and (4) fares are controlled to affordable levels (Richard, 2005).

Efforts were made to regulate Kampala's paratransit system through statutory laws and regulations en acted by the Uganda Parliament and loosely enforced by the Kampala Capital City Authority (KCCA) – the local governing body of Kampala City. The laws included, the Traffic and Road Safety Act of 1998, the Kampala Capital City Act of 2010 and the subsequent amendments in 2012 (Uganda Parliament, 1998, 2011, 2012). The laws were strongly resisted by paratransit operators, backed by influential politically connected owners (Goodfellow, 2010). These laws provided for the formation of a transport licensing board and taxi owners' and drivers' associations to manage minibus taxi affairs and enable collective bargaining between taxi owners, drivers and the city authorities. The regulations and the means of enforcing them were not clear and thus left considerable room for discretion. For example, they left room for self-regulation through self-organized associations like the Uganda Taxi Operators and Drivers Association (UTODA) and the Kampala Operational Taxi Stages Association (KOTSA). Self-regulation of the quality of service, number of vehicles and fares charged by drivers generally worsened the quality of service provided by paratransit in Kampala. It also led to excessive competition between drivers seeking to maximize their profits, and left commuters with no choice but to travel in often overloaded and unroadworthy vehicles that seldom adhered to traffic rules. Goodfellow (2017) argues that the laxity in regulation enforcement and the subsequent chaos in the paratransit industry are not coincidental: the situation serves the economic and political purposes of the political elites who use the minibus taxi industry for political mobilization.

2.1. Minibus taxi management

Management controversy, exploitation, inefficiency and political interference are rife in Kampala's minibus taxi industry (Goodfellow, 2010; Goodfellow, 2012; Goodfellow, 2017; Phillips and Mesharch, 2018). In the early 1990s the first attempt to manage the informal taxi industry through the monopolistic Uganda Taxi Operators and Drivers Association (UTODA) resulted in a deadlock that Goodfellow (2017) refers to as the "double capture". In the double capture, political elites infiltrated the taxi industry and subsequently, UTODA wielded enormous influence over the city authorities. UTODA engaged in behind-the-scenes multi-institutional informal bargaining, played one arm of the state against the other, and made it very difficult to implement transport policy in Kampala (Goodfellow, 2010). The result of this laissez-faire manner of running the transport industry was exploitation of drivers and an inefficient transport service. Today the bad practices of UTODA still haunt the minibus taxi industry: the regulations are not fully implemented; the drivers and other sector employees do not fully benefit from the industry; and commuters have to suffer an inefficient service riddled with delays and high and inconsistent fares, and lacking standardized routes and schedules information (Ndibatya et al., 2016; Goodfellow, 2017).

3. Methods and data

This section presents our economic and efficiency metrics, data collection process, and data processing methods. The efficiency of a public transport system can be analyzed using both subjective measures, such as user opinions and satisfaction surveys, and objective measures, such as numeric values for attributes like load factor (percentage occupancy), travel time and total passenger-kilometers covered (Sampaio et al., 2008; Eboli and Mazzulla, 2011, 2012; Gorkem et al., 2014; Marcius et al., 2015). To study the operations of Kampala's paratransit system, both qualitative and quantitative data was collected between January and March 2016. The collected data was associated with pre-selected paratransit travel attributes: taxi ranks, stops, routes and route-related attributes such as fare, hold-back time, commuter waiting time and minibus taxi occupancy. The conditions in Kampala's minibus taxi system have not changed substantially since 2016. Therefore, the data collected and the results discussed in the subsequent sections are still relevant.

3.1. Metrics

We used economic metrics (minibus taxi fares (β), taxi occupancy ($\mathcal{O}$) and drivers' profitability index (PI)) and efficiency metrics (passenger waiting time (t_w), taxi hold-back time (t_h), operating speed (v_o) and commercial speed (v_c)) to study the operational economics and to estimate the efficiency of the minibus taxi transportation system in Kampala's paratransit. We define the metrics used for this study in Table 1. The hold-back time (see Table 1) has a knock-on effect on the trip duration for passengers passively completing their journey in the taxi. This concept is similar to a bus waiting at a stop mid-journey due to being too early according to its schedule. But, in the minibus taxi case, the taxi stops for an unspecified time because the driver considers the vehicle occupancy to be too low to make the trip profitable.

3.2. Data collection methods

We adopted a participatory observation data collection method in which fieldworkers acted as passengers. They used GPS-enabled devices to record minibus taxi movements on pre-selected routes. GPS data is widely used by researchers to study movements because it provides precise spatiotemporal characteristics of travel (Usyukov, 2017; Jonker and Venter, 2019). While on board and en route to the selected destinations, the fieldworkers also engaged in open-ended questioning of drivers to obtain qualitative information such as minibus taxi industry practices, driver revenue and expenses.

To preserve the data integrity, to detect and prevent errors (such as sampling errors) in the collected data, and to ensure the scientific validity of the results, we used two quality assurance and control strategies described by Whitney et al. (1998). First, the error prevention

Table 1
Description of economic and efficiency metrics.

Metric	Description
Minibus taxi fare (β)	The amount of money paid by a minibus taxi passenger for a complete one-way trip on selected a route. Note: Full trip fare was paid even for trips abandoned midway.
Occupancy ($\mathscr{O}$)	The number of passengers on board a minibus taxi as a percentage of the total taxi capacity. Note: only fourteen-seater minibus taxis were studied.
Profitability Index (*PI*)	The profitability index represents the relationship between the minibus taxi driver's revenue and expenses for day under study. Given one minibus taxi for one day, the driver's profitability index is computed using the equation $PI = \frac{\sum_{i=1}^{n} E_i}{R}$, where E_i is the expense incurred on a single item and R is the total daily revenue. R is computed as a function of (i) trip-based passenger fare (β), (ii) the average occupancy per trip ($\mathscr{O}$), (iii) the total number of trips per day (γ).
Waiting time (t_w)	The total time a passenger waits for a taxi at a stop or taxi rank.
Hold-back time (t_h)	The accumulated time a taxi stays at stops along a route waiting for (or in anticipation of) passengers. It includes the time spent at the stop of origin loading the minibus taxi before embarking on the trip.
Operating speed (v_o)	The average speed at which a minibus taxi could travel from origin to destination without stopping en route. When computing the operating speed, the hold-back time was excluded.
Commercial speed (v_c)	The overall average speed of the minibus taxis during the trip, including the time spent at the stops (hold-back time). $v_c = \frac{d}{T}$, where, d is the total trip distance, and T is the total time taken to complete a trip.

strategies included talking to key people in the paratransit industry to get a general understanding of minibus taxi operations before designing the data collection instruments and recruiting data collection assistants (volunteers) who were familiar with the paratransit system. We trained the volunteers on the use of GPS devices and the data collection mobile application before starting the data collection process. Second, the error detection strategies used during and after this process involved a daily early morning meeting with the volunteers to update and ensure data consistency, exit interviews with each volunteer to record further critical observations, and redoing (or validating) routes that had erroneous data.

3.2.1. Sampling methods and data

We used stratified sampling to select 155 routes from the 307 routes distributed across the five divisions of Kampala as follows: Central-99, Kawempe-10, Makindye-12, Nakawa-10 and Lubaga-24 (refer to the "*Routes count*" column in Table 4 and Fig. 4c(*vii*) for the detailed distibutions of sampled and studied routes). Four data collection volunteers participated in the data collection exercise. The volunteers used a standard data collection instrument to collect data about the routes, i.e., route name, route fare, stops, hold-back time, waiting time and occupancy. Additionally, the volunteers randomly engaged in informal chats with 54 minibus taxi drivers and collected extra data about the taxi industry practices, drivers' revenue and expenditure. We also talked to the leadership of KOTSA and KCCA to get data about minibus taxi ranks, routes, the general operations and regulations of minibus taxis in Kampala.

3.2.2. Participatory observation

We recruited and trained the volunteers and deployed them to collect geospatial data using a customized mobile application (GoMetro Pro) that was pre-installed on their smartphones running on an Android operating system (GoMetro, 2016). They traveled around the five divisions of Kampala to locate the gazetted and ungazetted taxi ranks and document the GPS coordinates and major routes originating from the taxi ranks. At some taxi ranks the routes and fares were written on small placards and carried from one minibus taxi to another in order of departure sequence (see the yellow placard in Fig. 1b); at others, the volunteers asked drivers to provide information about the routes. The volunteers rode in taxis from the taxi ranks to the destinations on preselected routes and recorded aspects of interest to our research such as stop location and hold-back time. Shortly before setting off, they recorded data about the taxi fare, waiting time and the number of passengers in the taxi. During transit, they recorded data about the location of stops and the hold-back time at each stop. The GoMetro Pro mobile application automatically recorded the minibus taxi's GPS locations every 30 s, and these were later processed into the route's GPS profile. The volunteers also observed the drivers' behavior during the journey, such as the hand signals used for communication between drivers and passengers on the road.

3.3. Data processing and analysis

We used a language-neutral Protobuf protocol developed by Google to serialize the collected data for transfer to custom-developed Python libraries to be cleaned, transformed and loaded into other Python scripts for further analysis (Blyth et al., 2019). During the transformation process, we developed and implemented several algorithms in Python programming language, such as a map-matching algorithm to remove multi-path errors in the data. However, in this paper we report only the results from these algorithms.

Preliminary data analysis was done using the Quantum Geographic Information System application to map the geospatial layout of minibus taxi routes, taxi ranks and stops, relative to the administrative regions (divisions) and sub-regions (parishes) of Kampala, as shown in Fig. 2. We developed other customized Python libraries to analyze further the relationships between routes, route lengths, fares per route, passenger waiting time and minibus taxi hold-back time. In Section 4, we present the results from the field study and data analysis for minibus taxi operations, economics and efficiency.

4. Results

We present the results in three subsections below, i.e., minibus taxi operations, minibus taxi economics, and minibus taxi efficiency.

4.1. Minibus taxi operations

Kampala's minibus taxi operations are quasi-demand responsive, being mostly based on, or in response to, passenger demand. The routes, stops and schedules are not static but evolve according to passenger demand and drivers' prior knowledge or anticipation of demand.

4.1.1. Minibus taxi ranks and stops

Kampala has seven officially gazetted minibus taxi ranks (locally known as "taxi parks"), and 307 routes (locally known as "stages") originate from the taxi ranks to destinations across Kampala city and the neighboring districts. The taxi ranks include: Old, New, Kisenyi,

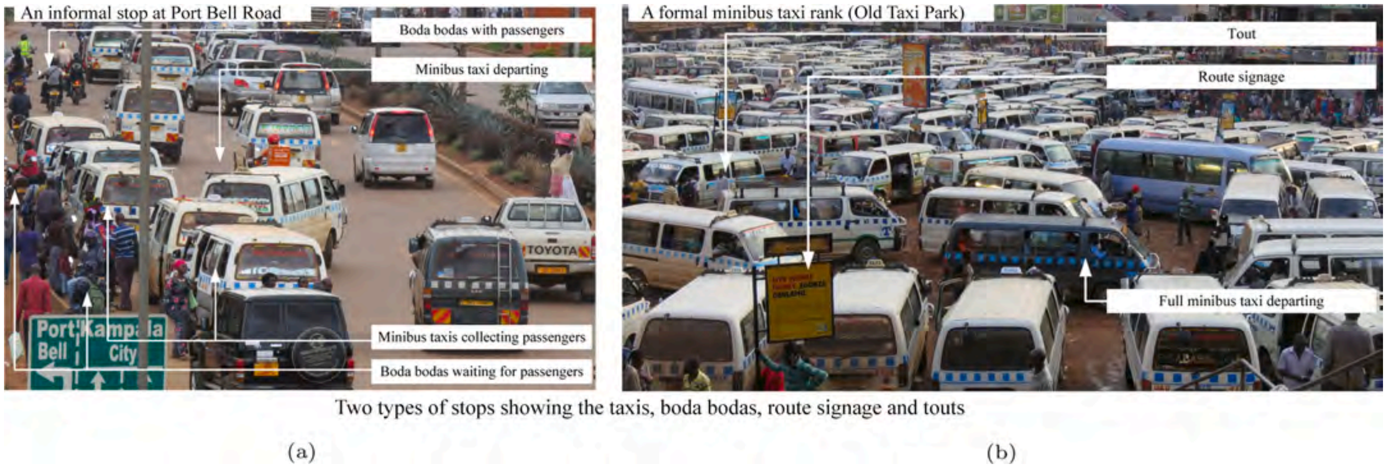

Fig. 1. Two types of stops showing the taxis, boda bodas, route signage and touts. (a) An informal stop at Port Bell Road; b) A formal minibus taxi rank (Old Taxi Park)

Namayiba, Usafi, Namirembe and Natete Taxi Park. Of the 307 routes, KCCA manages 122 and KOTSA manages 185 routes. Fig. 1b shows a typical minibus taxi rank in Kampala (the Old Taxi Park). Table 2 summarizes the minibus taxi ranks, stops, and routes originating from the five divisions of Kampala (Central, Kawempe, Makindye, Nakawa and Lubaga – see Fig. 2c). The routes in Table 2 indicate the routes whose origins we documented during the study. They are categorized according to the frequency of minibus taxi departures, i.e., high (every 20 min), medium (every 40 min) and low (every 60 min). The taxi ranks and stops in Table 2 are categorized according to the frequency of passenger pickups, drop-offs or departures in the case of taxi ranks. If the pickups/drop-offs were frequent at a stop (every 5 to 30 min), we regarded it as a "major stop", and one with fewer (every 30 to 60 min) as a "minor or informal stop". All routes are supposed to originate from the taxi ranks. However, from interacting with minibus taxi drivers, we established that – in response to demand and for passenger convenience – several illegal origins are scattered around the city at ungazetted informal stops, such as: Clock Tower, Mini Price, Namirembe Road, City Square, Nasser Road, Mutaasa Kafeero, Mega Standard, and many others. Each route attached to a taxi rank is managed by a committee comprising a chairman, vice-chairman, secretary, treasurer and welfare officer, all selected from drivers of taxis attached to the route. The committee resolves disputes, registers new drivers joining the route and manages the welfare needs of the members, such as loans and contributions in case of the death of any of its members. We did not find any formally documented details about the routes and the stops. However, the drivers we interviewed described the routes according to the significant towns they go through. Each route from the taxi rank operates on a first-in, first-out (FIFO) queuing system based on a ticket number booked in advance. The driver with the lowest ticket number loads passengers first. Two people operate each minibus taxi: a driver and a conductor. The conductor is responsible for touting passengers, negotiating and collecting the taxi fares.

We did not find documentation indicating the presence of formally gazetted minibus taxis stops along the roadsides in Kampala. However, we observed that there were several stops along the major roads. We learned – from minibus taxi drivers and other officials – that the roadside stops are organically established (informally by drivers) according to passenger demand, often as a result of increased economic, leisure and other passenger travel attracting activities. When the

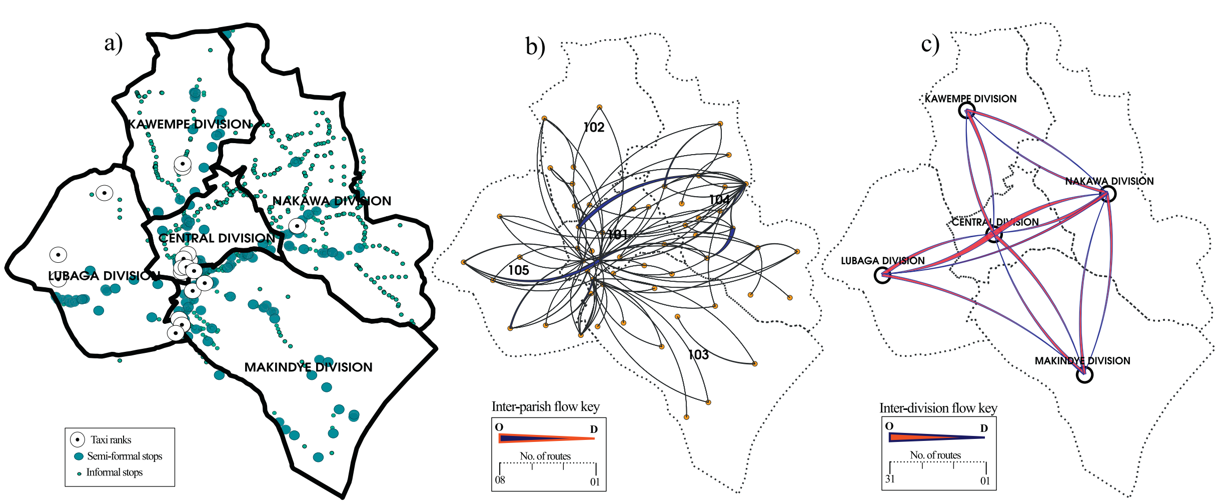

Fig. 2. a) Spatial distribution of taxi ranks and stops; b) Inter-parish routes flows; c) Inter-division routes flows.

Table 2
Number of minibus taxi ranks, stops and routes (categorized according to the frequency of taxi departures) originating from the five divisions of Kampala.

		Taxi ranks		Stops		Routes & frequency of taxi departures			
Code	Division	Major	Minor	Major	Informal	High	Medium	Low	Totals
101	Central	3	6	53	194	55	17	50	122
102	Kawempe	0	2	20	91	6	4	2	12
103	Makindye	0	4	41	102	4	5	6	15
104	Nakawa	0	1	19	241	3	3	6	12
105	Lubaga	0	2	19	16	14	12	4	30
	Totals	3	15	152	644	82	41	68	
		18		796		191			

demand at the location diminishes, the stop ceases to exist. Thus we categorized the stops as either formal or informal depending on the frequency of pickups and drop-offs at the stop (see Table 2). We observed with keen interest the presence of waiting areas for motorcycle taxis (known as "boda bodas") at most minibus taxi stops (major and minor), as can be seen in Fig. 1a. We could not verify independently whether the boda bodas attracted the minibus taxi stops or the stops attracted the boda bodas. Every major minibus taxi stop has two to four self-appointed wardens who often tout for passengers on behalf of the minibus taxi drivers. They are given a commission for each pickup. The commission is negotiated according to the number of passengers picked up from the stop: it ranges from \$0.11 to \$0.3 per minibus taxi.

Three basic characteristics of a minibus taxi paratransit system can clearly be seen in Fig. 1a. The first is the informality of the stop: there is no signage to say it is a stop, but drivers stop there because of their previous knowledge of passenger demand at that location. The second is the presence of a pseudo-modal exchange center between two modes of transport: motorcycle taxis and minibus taxis. We saw boda bodas dropping off and picking up passengers from the location. The third is the dominant presence of minibus taxis on the roads during peak hours (07:00–9:00 and 17:00–19:30). Only three ordinary vehicles can be seen in Fig. 1a, as opposed to at least 12 minibus taxis on the same road segment. However, we observed that most of the minibus taxis were only half full. This gives an idea of the low load factor (taxi occupancy) which is an indication of the minibus taxi system inefficiency. We later confirmed (from our results in Table 4 and Fig. 4b(v) that the average occupancy for minibus taxis in our sample was 69%.

4.1.2. Mid-trip change or abandonment of network routes

The minibus taxi route network consists of the major and minor nodes (gazetted and ungazetted taxi ranks) that are the most common origins and destinations for Kampala commuters. The nodes are interlinked with a series of stops (intermediate nodes), some known and gazetted, others ad hoc and organically evolving into major stops if passenger demand grows. Fig. 2a shows the distribution of taxi ranks and major and minor stops and 2b and 2c show the aggregated number of routes originating from parishes and divisions respectively (the circles represent parish and division centers respectively). Minibus taxi movements through the route network follow a near-straight course in some areas and a winding course in others, as shown in Fig. 3a. Several factors are responsible for such behavior: passenger demand (drivers wander off the main route looking for passengers); the presence of traffic police on the main route; the state of the roads; requests by passengers in the taxi; weather conditions; and sometimes the premature termination of the trip in pursuit of a new route considered to be more profitable. However, we observed that most of the diversions were made in search of passengers. Fig. 3a shows the winding characteristics of taxi movements on selected routes. We observed that in zones Z_1, Z_2 and Z_3 drivers diverted off the main route in search of passengers. In zone Z_4 the driver abandoned the trip before getting to the destination originally communicated to the passengers and abruptly ordered all of them to disembark. He then diverted to a new route, went south a little way searching for passengers and then headed to zone Z_3, where he resumed the search.

4.1.3. Industry practices

Minibus taxi drivers have developed a host of strategies to improve profits from trips and avoid getting caught breaking the traffic rules. They believe these strategies to be moderately effective if correctly interpreted and applied.

i) ***Hand and headlamp signaling***

Minibus taxi drivers in a paratransit system frequently signal each other using hand signs and headlamp flash signals for the taxis coming from the opposite direction. Some of Kampala's hand signs are similar to those documented in Johannesburg by Susan Eve Woolf (2014),

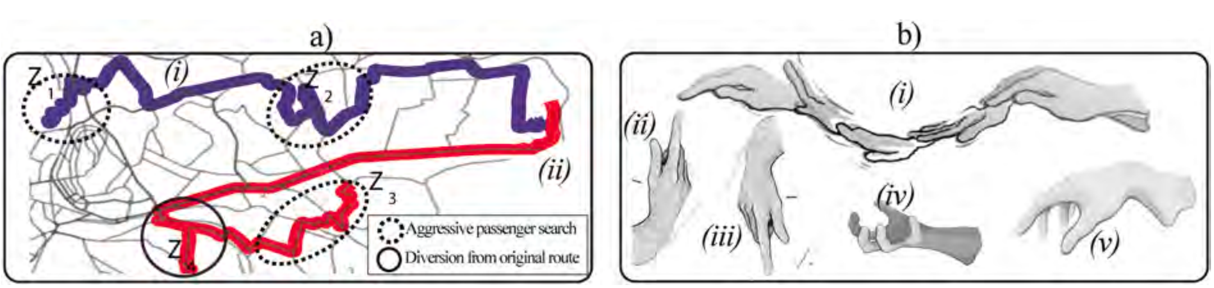

Fig. 3. a) Movement characteristics and route abandonment; b) Gestures used by drivers (Woolf, 2014).

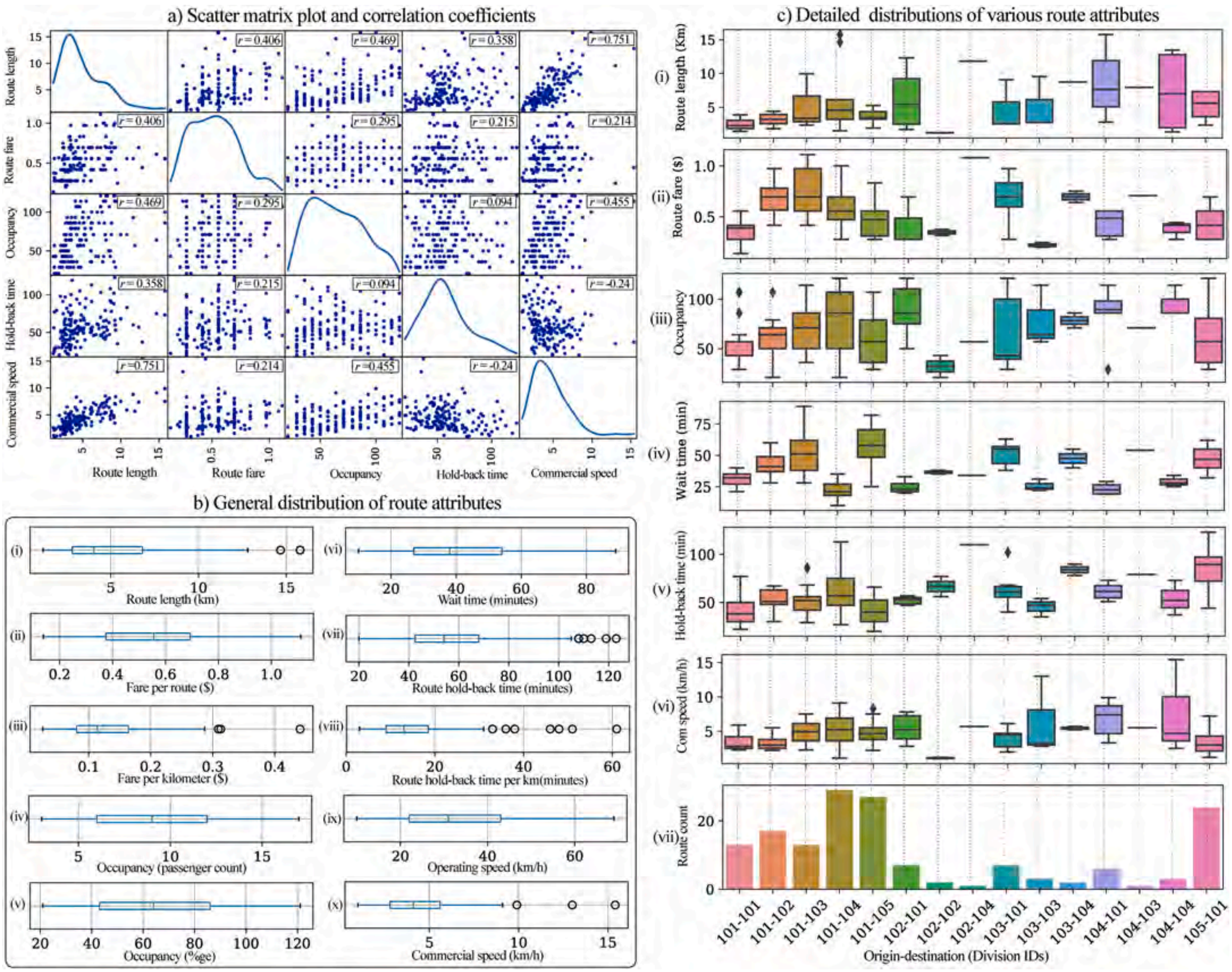

Fig. 4. Operational attributes of division-level origin–destination routes. a) Scatter matrix plot and corresponding correlation coefficients for different routes' attributes; b) General statistical distribution of operational route attributes ($n = 155$ routes); c) (i - vi) Detailed independent distributions of route attributes; c) (vii) Barplot showing origin-destination route counts.

apart from some local differences in meaning. Taxi hand signaling is a useful language developed out of a desperate need for transport among multi-cultural and multi-lingual city travelers (Susan Eve Woolf, 2014). Each hand sign conveys a message, such as a warning, a clue to passenger demand or an indication of the taxi's destination. Fig. 3b shows five of these. Signal (i) is usually for driver-to-driver communication and is associated with a hilly terrain ahead (usually within about three kilometers). It means that after the indicated number of hills there is a high probability of passenger demand. If preceded by a double headlight flash signal, it warns of the presence of traffic officers or mobile speed trap camera ahead, alerting the other driver to reduce speed or drop off any excess passengers. Signal (ii) is for communication both driver-to-driver (indicating the presence of traffic police or a speed camera usually about 4 km ahead) and driver-to-passenger (indicating to waiting passengers that the taxi is headed to destinations far out of Kampala). Signal (iii) is used for communication both driver-to-driver (indicating the presence of traffic police or a speed camera about 1 km ahead) and driver-to-passenger (indicating that the taxi is about to reach its final destination, usually less than 2 km away). Signal (iv) is a driver-to-driver signal indicating the presence of many passengers waiting, usually within a distance of 1 km. Signal (v) is a driver-to-passenger signal indicating that the taxi is about to take a detour off the main route, usually to the informal settlements.

ii) ***Passenger touting strategies***

Passenger touting is mainly done by taxis circulating within the town rather than heading for distant destinations, especially those that originate from the informal roadside stops within the city. Taxis usually start the trip with few or no passengers in anticipation of collecting some en route, a strategy referred to locally as "*okuvuga ekkubo*" (random passenger search). To ensure a profitable trip, various complementary sub-strategies are used. One such is called "*okubala gap*" (strategic demand estimation), where the driver observes the taxis coming from both directions to either receive a signal of passenger demand ahead or estimate the presence of demand ahead on the basis of the number of competing taxis heading in the same direction. Another is a sub-strategy called "*okukyeebakamu*" (random back-off) where, depending on estimated or received negative feedback from the *okubala gap* sub-strategy, the driver interrupts the trip and waits at a strategic stop for a random period to allow for commuter demand replenishment before continuing with the trip.

4.2. Minibus taxi economics

We looked at the economics of the minibus taxi operations from both the passengers' and the drivers' perspectives. Passengers are concerned with the fares they must pay; drivers are concerned with their overall cash flow and profit margins to keep their taxi business afloat. Fig. 4a shows a positive correlation between hold-back time and route fare ($r = 0.299$) and between waiting time and route fare ($r = 0.256$), and a negative correlation between waiting time and route length ($r = -0.265$). Fig. 4c shows the distributions of each attribute between and within divisions.

4.2.1. Passenger fares

We related our minibus taxi fare data to the length of the routes (total distance traveled from origin to destination). Table 4 shows the average route lengths, average fare per one-way trip, and approximate fare per kilometer for the inter-divisional routes in Kampala. Fig. 4b(*i-iii*) show the general distributions of route lengths, route fares and fare per kilometer, and Fig. 4c(*i-ii*) show the distributions of route lengths and route fares categorized according to the origins and destinations. The distances range from 1.2 to 11.8 km.

The average cost of travel by minibus taxi at the time of our study (January–March 2016) was $0.55 (UGX 1980) and the average fare per kilometer was $0.12 (UGX 432). Routes within Makindye (103 − 103) were the least expensive at $0.22 (UGX 799); routes from Kawempe to Nakawa (102–104) were the most expensive at $1.08 (UGX 3884) while routes from Central to Lubaga (101–105) were moderately priced at $0.46 (UGX 1656). The taxi fare per unit of distance traveled (fare per km) represents the unit cost of travel by minibus taxi, which ranged from $0.06 (UGX 216) for trips within Makindye to $0.28 (UGX 1008) for those within Kawempe, as shown in Table 4. There is a positive correlation ($r = 0.406$) between route length and route fare as shown in the scatter matrix in Fig. 4a. Fig. 4b(*ii-iii*) show the general distribution of route fares and fare per unit distance (fare per km) respectively, while Fig. 4c(*ii*) shows the division-level distributions of minibus taxi route fairs categorized according to division origin and destination pairs.

4.2.2. Drivers' profitability index (PI)

As noted earlier, Kampala taxis are privately owned by sole and multiple proprietors. After acquiring a taxi, the owner usually puts it up for hire by drivers. Drivers and taxi owners often execute an agreement (sometimes unwritten) where the driver rents the taxis and remits to the owner a daily rental fee ranging from $26 to $30 in addition to paying for the daily running costs of the taxi such as fuel, washing, overnight security and a commission to the tout. The owner pays for the routine vehicle maintenance and a monthly fee ($32) to the city authorities for the right to operate in the city. Preliminary results from analyzing data about minibus taxi occupancy, route length and taxi fares (see Table 4), indicated that the minibus taxi drive's revenue is generally low. The average fare per kilometer is $0.12, and the average minibus taxi occupancy is 69% (10 passengers). It means that, for an average 5 km trip, a driver earns $6, which represents a 29% revenue loss due to low occupancy. Fig. 4b(*ii-v*) show the general distribution of route fare, fare per km and minibus taxi occupancy. There were some cases of overloading as shown in Fig. 4b(*v*). Where taxi occupancy exceeded 100%, there is a positive correlation ($r = 0.46$) between route fare and route length.

Based on the preliminary results about route fare, fare per km, and occupancy, we estimated the minibus taxi drivers' profitability index. Table 3 summarizes the estimated minibus taxi driver's daily expenses and revenue for an average 5 km route. The "Base" column shows the driver's revenue and profitability index on a normal fifteen-hour working day; the "Practice" column shows the driver's revenue when some strategies described in Section 4.1 are used; and the "Objective" column shows the revenue a taxi driver could ideally achieve, given an improvement of the system with all 14 passenger seats occupied and 15 trips per day – an objective expressed by the drivers who work for approximately 15 h a day.

4.3. Minibus taxi efficiency

For this study, we focused on passenger waiting time, hold-back time and travel time as measures of efficiency, and we assumed all other factors to be constant. The waiting time (time spent at a stop or taxi rank waiting for a minibus taxi) and hold-back time were recorded by the data collection assistants per route. The figures shown in Table 4 are of all-day averages for all the routes studied during the research period. The travel time, operating speed, and commercial speed presented in this section were computed from the timestamped routes profile GPS data collected using the GoMetro Pro mobile application.

Conventionally, travel time is a function of velocity and the geometry of direct and subsidiary routes (Sampaio et al., 2008). In a quasi-demand responsive paratransit system, however, travel time is greatly influenced by the passengers' waiting time and the drivers' hold-back time. We thus included these in our analysis. Table 4 shows the average waiting time, average hold-back time, average hold-back per km,

Table 3
Driver's daily cash flow and estimating the profitability index for a single rented minibus taxi.

Average driver's expenses per day		Average driver's revenue per day			
Item	Cost ($)	Item	Base	Practice	Objective
Taxi rent (E_1)	$27.80	Occupancy per trip ($\mathscr{O}$)	10	11	14
Fuel (E_2)	$16.70	Avg fare per passenger (β)	$0.45	$0.55	$0.45
Washing bay (E_3)	$2.80	Trip duration (in hours) (ρ)	1.5	1.7	1
Security (E_4)	$11.10	Trips per day (γ)	10	11	15
Touts commissions (E_5)	$1.10	Total revenue per trip ($\lambda = \mathscr{O} \times \beta$)	$4.50	$6.05	$6.30
Total expenses $E = \Sigma_{i=1}{}^{5}E_i$	*$59.40*	*Total dailly revenue* ($R = \lambda \times \gamma$)	*$45.00*	*$66.55*	*$94.5*
		Profitability index ($PI = \frac{R}{E}$)	0.76	1.12	1.59

Note: (i) Profitability index is computed as a ratio of total revenue to total expenses. (ii) A driver works for 15 h a day. (iii) The Objective column assumes filling every seat (14) for an objective expressed by the driver of 15 trips per day. (iv) Occupancy $\mathscr{O}$ is the average number of passengers in a taxi per trip.

Table 4
Average operational attributes for origin–destination (O-D).

			Economic metrics (averages)			Efficiency metrics (averages)				
O–D	Routes	Length	Fare	Fare per	$\mathcal{O}$	t_w	t_h	t_h per km	v_o	v_c
(div IDs)	count	(km)	($)	($/km)	(%)	(min)	(min)	(min)	(km/h)	(km/h)
101–101	13	2.5	0.37	0.15	52%	31	41	17	32	3.4
101–102	17	3.2	0.68	0.22	60%	44	53	17	27	3.2
101–103	13	5.2	0.76	0.17	71%	51	52	12	32	4.8
101–104	29	6.5	0.58	0.10	80%	22	63	12	35	5.3
101–105	27	3.7	0.47	0.14	59%	59	40	11	31	4.7
102–101	7	6.3	0.40	0.07	90%	25	52	11	36	5.4
102–102	2	1.2	0.35	0.28	32%	36	66	54	31	3.1
102–104	1	11.8	1.08	0.09	57%	34	110	9	51	5.7
103–101	7	4.7	0.69	0.16	67%	51	64	15	35	3.9
103–103	3	5	0.22	0.06	78%	26	45	14	46	6.3
103–104	2	8.7	0.70	0.08	78%	48	84	10	44	5.5
104–101	6	8.7	0.44	0.06	85%	23	62	9	43	6.8
104–103	1	8	0.71	0.09	71%	54	79	10	60	5.5
104–104	3	6.9	0.38	0.07	95%	29	54	12	45	7.5
105–101	24	5.3	0.46	0.10	63%	48	84	20	27	3.3
Mean μ		5.85	0.55	0.12	69%	39	63	16	38	4.96
STD σ		2.9	0.21	0.07	28%	17	22	9	15	2.2

	Summary statistics				
	Min	Max		Min	Max
Route length	(102 – 102) 1.20	(102–104) 11.8	*Wait time* (t_w)	(101–104) 22	(101–105) 59
Routes fare	(103–103) 0.22	(102–104) 1.08	*Hold-back* (t_h)	(101–105) 40	(102–104) 110
Route fare/km	(104–101) 0.057	(102–102) 0.281	*Hold-back/ km*	(102–104) 9	(102–102) 54
Occupancy ($\mathcal{O}$)	(102–102) 32%	(104–104) 95%	*Speed* (v_c)	(102–102) 3.1	(104–104) 7.5

Note: IDs for the divisions are Central 101, Kawempe 102, Makindye 103, Nakawa 104, Lubaga 105. t_w - Waiting time,t_h - Hold back time,v_o - Operating speed, v_c - Commercial speed, $\mathcal{O}$ - Percentage minibus taxi occupancy.

operating speed and commercial speed for various minibus taxi routes within and between Kampala's divisions. Accordingly, the waiting time in Kampala's paratransit system ranges from 22 min (Central to Nakawa) to 59 min (Central to Lubaga), with an overall average waiting time of 39 min. We found that minibus taxis from Central to Lubaga spent less time holding back and waiting for passengers than those from Kawempe to Nakawa – 40 min as compared with 110 min. The hold-back time per kilometer traveled ranged from 9 min (Kawempe to Nakawa) to 54 min (within Kawempe) with a median of 16 min.

We found that the general operating speed for minibus taxis in Kampala ranges between 10 km/h and 69 km/h with a mean and standard deviation of 38 km/h and 15 km/h respectively. In contrast, the commercial speed is low, ranging between 3 km/h and 15.4 km/h with a mean and standard deviation of 4.9 km/h and 2.2 km/h.

5. Discussion

We discuss our results according to our three major themes: operations, economics and efficiency.

5.1. Operations

Minibus taxi operations in Kampala are characterized by informality in all their aspects: regulations, regulation enforcement, management, stops and routes. The minibus taxi routes and stops are not clearly established and labeled. The routes between two stops or ranks are difficult to present in static maps because they are not fixed: they vary according to demand, traffic conditions, competition, and sometimes drivers' preference. Fig. A.1 shows an attempt by KCCA to develop a static public transit route map for Kampala in 2017. It consists of 190 stops and 110 minibus taxi routes. When compared with our results in Table 2, we found a difference of 606 stops and 81 routes that do not appear on the KCCA route map (in Fig. A.1). The most probable causes of the difference in routes and stops count are either that the routes and stops have evolved because of changing passenger demand at different locations or that they were considered insignificant by the KCCA mapping team. Our insert in Fig. A.1 shows a snapshot of paratransit routes plotted directly from the routes' profile GPS data we collected.

We observed desperate attempts by drivers to make the trips profitable through rudimentary strategies such as starting trips with no passengers (*okuvuga ekkubo*), strategic observation (*okubala gap*) and random back-off (*okukyeebakamu*), as discussed in Section 4.1.3(ii). These strategies are not as effective as claimed by drivers: they may be responsible for the fluctuating minibus taxi occupancy and subsequent low profitability index presented in Table 3. The minibus taxi drivers adopt such ineffective strategies due to lack of proper minibus taxi scheduling, booking and demand forecast systems.

Kampala's public transport sector affects the livelihood of millions every day, especially the urban poor. It is dangerous to leave it to private management by manipulative wealthy elites (often referred to as “transport mafia”). Kampala can learn from cities like Accra, Lagos and Cape Town, where paratransit regulation and reforms are gradually gaining acceptance among taxi operators. Accra and Lagos, for example, have combined regulation with financial support to overcome resistance to reforms. This arrangement includes an ownership re-organization scheme where informal minibus owners form cooperatives and jointly invest in higher capacity busses. Cape Town authorities have plans to provide incentives to paratransit operators on selected routes to complement scheduled trunk services (du Preez et al., 2019). Alternatively, Uganda could come up with a taxi recapitalization policy similar to the one implemented by the South African government (Schalkwyk and Sadie, 2011) but avoid the mistakes that were made by that government by involving the paratransit operators during all stages of policy formulation. It is worth noting that the city authorities in

Kampala are making strides towards engaging paratransit operators in transportation planning for the city (ODA, 2020).

The complementary role played by motorcycle taxis (locally known 'boda bodas') in Kampala's paratransit industry is interesting and deserves further research. Almost every major minibus taxi stop has a 'boda boda' stop nearby. Even informal minibus taxi stops (such as the one shown in Fig. 1a) always act as terminal positions for boda boda trips. The boda boda stops act as inter-mode exchange centers, and they serve the passengers' last kilometer of commute. In a paratransit system, boda bodas are a necessary evil because of their ability to manoeuvre and to penetrate the sprawling townships' deeper locations that are often unreachable using other vehicles. They become a menace only when allowed onto highways, causing traffic interruptions and accidents. If regulated to serve only the first and last kilometer of commute, their role in paratransit would be substantial and a net positive.

5.2. Economics

Kampala's paratransit system operates a risky but generally profitable business model (to the taxi owners). It is characterized by restricted access to capital, no subsidies from the government, and exploitation of drivers, especially those who do not own taxis. Entry level capital for individual drivers and owners is mainly through personal savings, and soft loans from friends and family members. Drivers depend on passenger payments to cover all the operational costs. Most of the drivers rent the vehicles from owners (who pay for repairs) at fees that vary according to the vehicle's condition. While the taxi owners' cash flow is almost guaranteed, drivers are exploited, and they often make losses as illustrated by a low profitability index in Table 3 ("Base" column). To make profits, drivers work for long hours (15 h and more per day) (see Table 3 "Practice" column). Vehicles are often shared by several drivers, leading to rapid degradation due to overuse, and sometimes overloading (see Fig. 4b(*v*)). Paradoxically, the rapid vehicle degradation in the paratransit system generates many informal, indirect and unstable jobs through the repair industry (Pablo, 2015).

5.3. Efficiency

We used two main operational attributes to measure the efficiency of minibus taxi transport in Kampala's paratransit system, i.e., the waiting and hold-back time. As summarized in Table 4 and illustrated in Figs. 4b(*vi-x*), and 4c(iv-vi), we found that travel by minibus taxi was inefficient and characterized by long passenger waiting times (22 to 59 min), long hold-back times (35 to 110 min) and low commercial speeds (3.1 to 15.4 km/h). The result is that a large portion of minibus taxi commuters' travel time consists not of actual travel but of sitting in a stationary vehicle waiting for more passengers to fill up the minibus taxi. From the driver's perspective, the high hold-back time leads to fewer trips per day and thus a substantial loss in revenue resulting in a low profitability index as illustrated in Table 3.

We identified three factors that could be the root causes of the minibus taxi system inefficiency in Kampala. First, the absence of market entry controls. The collapse of the UTC and PTC in the early 1990s and the subsequent adoption of the World Bank structural adjustment policies left the public transport industry open to the free market forces of demand and supply (Kumar, 2011). With little or no entry controls, the minibus taxi industry emerged and boomed with fragmented ownership of often old vehicle fleets (Cervero and Golub, 2007; Kumar, 2011). To date, there are insufficient entry controls into the minibus taxis business. This often leads to oversupply or undersupply of low-quality vehicles and thus system inefficiency.

Second, inadequate regulation and enforcement thereof. Minibus taxis operations in Kampala are largely self-regulated (Goodfellow, 2010, 2017). The taxi drivers often determine individually the route to take for a particular trip, the fares to charge from the commuters (leading to fare variations shown in Table 4), the number of passengers to load, and when to take the vehicle for servicing (Ndibatya et al., 2016; Goodfellow, 2017). Self-regulation often leads to overloading, overpricing, trip abandonment (illustrated in Fig. 3), driving unserviced vehicles and generally inadequate service provision. There is general laxity in regulation enforcement by KCCA and KOTISA, resulting in general system inefficiency.

Third, the lack of known minibus taxi scheduling and booking mechanisms. This leads to wide variations in taxi occupancy: sometimes taxis are overloaded while others are half loaded. Passengers and drivers depend on personal experience and sometimes on random guesses to determine supply and demand. Hence, the quality of service is poor, driver profits are low, and vehicle quality rapidly degrades, causing traffic jams and pollution. This has a knock-on effect on businesses: they lose efficiency because the waiting times and hold-back times prevent the workforce from getting to work on time.

6. Conclusion and recommendations

In this paper, we used economic metrics (i.e., taxi fares, occupancy, drivers' revenue and expenses) to estimate minibus taxi drivers' profitability index, and efficiency metrics (i.e., waiting time, hold-back time, and commercial speed) to estimate the efficiency of the minibus taxi transportation system in Kampala. We found that the driver profitability index is low – ranging between 0.76 and 1.12 – and the waiting and hold-back times are high – ranging between 22 and 59 min and 35 to 110 min respectively. This indicates an overall minibus taxi system inefficiency. The absence of market entry controls into the minibus taxi business, coupled with inadequate regulation enforcement, poor minibus taxi scheduling and non-existent booking mechanisms, render Kampala's minibus taxi system inefficient to both the drivers and commuters. Furthermore, we found that the operations of minibus taxis are riddled with informalities, from management, regulations, to informal stops and routes.

We recommend moderate minibus taxi system transformations and adequate enforcement of paratransit regulations (i.e., regulation of quality, quantity licensing and fares); reorganization of ownership from fragmented to institutionalized shareholding with priority given to the existing owners and shares capped to prevent the domination of the "transport mafia"; vehicle-renewal programs to replace old vehicles with new ones by giving drivers flexible and cheap access to capital; and investment in ICT systems to support scheduling, booking and fare collection. Furthermore, we recommend further research into the complementary role of motorcycle taxis (locally known as"boda bodas") in Kampala's paratransit industry; specifically, their influence on the establishment of informal minibus taxi stops and the subsequent suspected minibus taxi routes evolution.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Appendice A: Kampala public transport routes

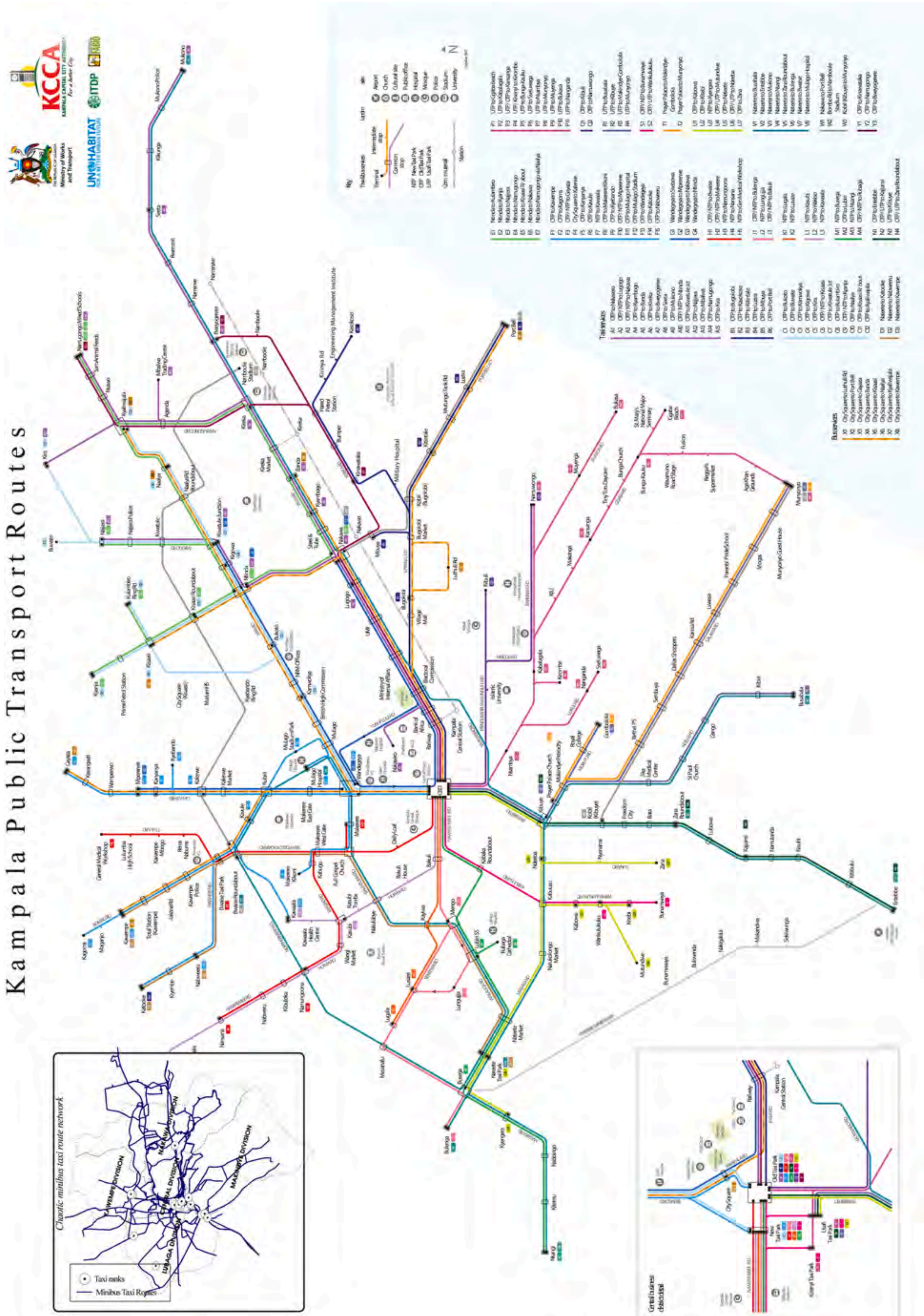

Fig. A.1. Kampala public transport routes (Source: KCCA - https://www.kcca.go.ug/media/docs/Kampala%20Public%20Transport%20Routes.pdf).

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